Heterogeneity of Ryugu samples due to space weathering effects: near-infrared spectroscopy and fitting analysis

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Introduction

Hayabusa2 brought back about 5.4 g of Ryugu samples (chamber A: surface samples, chamber C: excavated samples) from the C-type asteroid Ryugu in 2020, and the initial description of the returned samples is ongoing at the Curation Center of the Institute of Space and Astronautical Science (ISAS), JAXA [1][2]. In the initial description, measurements with a near-infrared hyperspectral microscope MicrOmega and spectral analysis are ongoing, and we have developed a fitting analysis method for the asymmetric absorption bands [3].

MicrOmega is a near-infrared hyperspectral microscope developed by the Institut d'Astrophysique Spatiale (IAS) in France, characterized by its ability to acquire spectral data over an area of approximately 5 mm square with a resolution of 22.5 µm/pix at 0.99-3.65 µm [4]. The measurement results to date have indicated a relatively deep absorption band at 2.7 µm which is thought to originate from the OH group and a slope around 2.0 µm, as common features of most of the Ryugu samples [2].

Methods

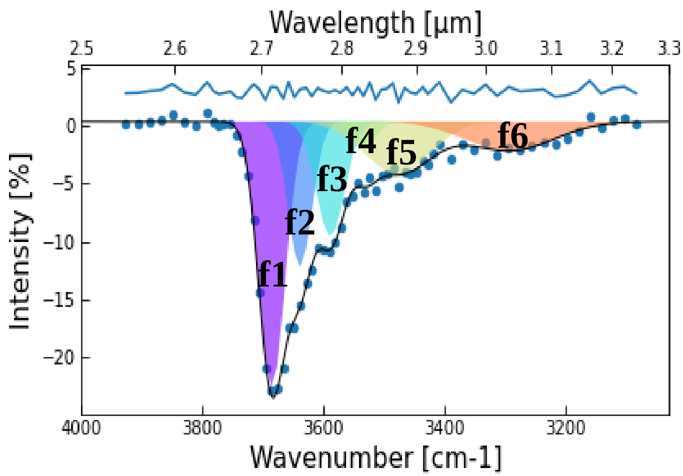
In our previous work [3], we developed a fitting analysis method with four Gaussian functions to achieve a more physically accurate analysis for the characteristic 2.7 µm asymmetric absorption band of Ryugu samples. In this study, we applied a fitting analysis with six Gaussian functions after applying baseline estimation and smoothing where necessary [5]. We also applied a fitting analysis with linear functions to the slope around 2.0 µm, which is a characteristic of Ryugu samples, to determine the magnitude of the slope [6].

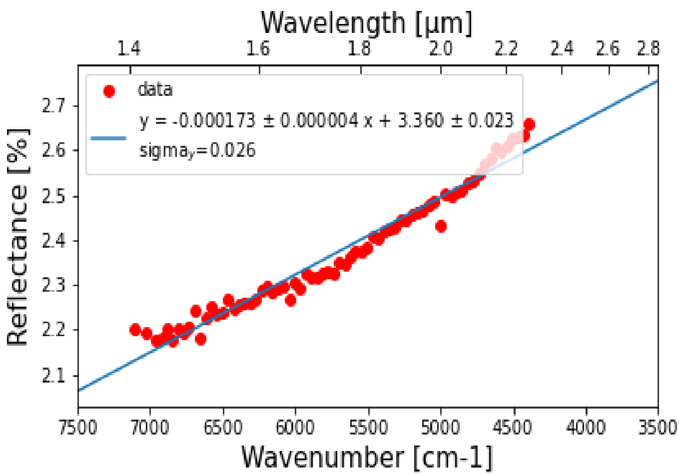
The spectroscopic data were used in the MicrOmega-Curation DARTS Server (chamber A: 95 spectra, chamber C: 62 spectra).

Results

The results of the fitting analysis are shown in Figure 1 (left) with each Gaussian function, composite waveform, and residuals for the asymmetric absorption band of Ryugu sample A0007 at 2.7 µm. Each of the six Gaussian functions is named f1 to f6 from the short wavelength side, where their peak wavelengths are f1: 2.713 µm, f2: 2.748 µm, f3: 2.786 µm, f4: 2.831 µm, f5: 2.874 µm, and f6: 3.036 µm, respectively.

The results of the fitting analysis using linear functions are shown in Figure 1 (right) for the slope around 2.0 µm.





[Figure 1: Results of fitting analysis of spectral data measured by MicrOmega with Ryugu sample A0007 (left: fitting analysis by six Gaussian functions for the asymmetric absorption band at 2.7 µm, right: fitting analysis by linear functions for the slope around 2.0 µm)]

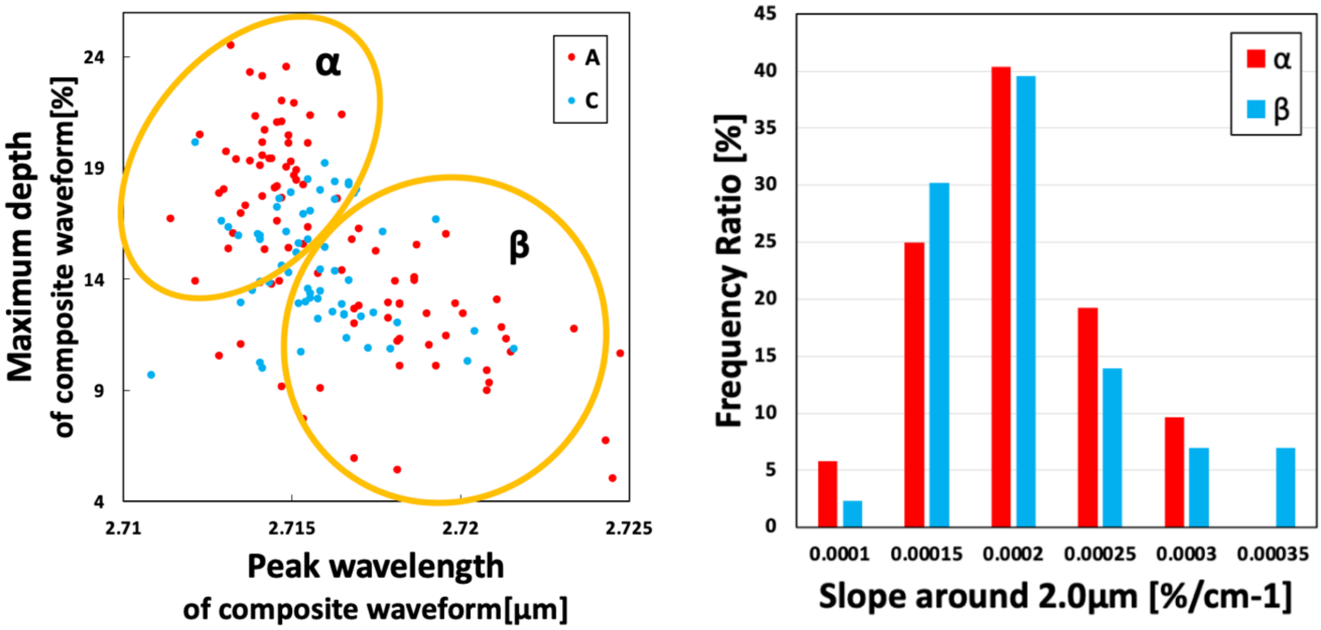
Discussion

The relationship between peak wavelength and depth of the 2.7 μm absorption band (Figure 2 left) shows that the chamber A sample is split into two groups: α, with a shorter peak wavelength and greater depth, and β, with a longer peak wavelength and smaller depth. In contrast, the chamber C sample does not exhibit a clear tendency for such division into two. This dichotomous distribution for the chamber A sample is also present for f1, f2, and f4. Therefore, f1, f2, and f4 are considered to be derived from the same functional OH group. On the other hand, f3, f5, and f6, which do not exhibit dichotomous distribution in the chamber A sample, may be derived from carbonate, carbonyl, and NH groups, respectively, based on the position of the peak wavelengths [2][4][8].

Based on the results of the slope analysis around 2.0 μm, β tends to have a larger absolute value of slope than α, despite within the standard error range, as shown in Figure 2 right (α: (1.79 ± 0.501) x 10^{-4} [%/cm^{-1}], β: (1.84 ± 0.576) x 10^{-4} [%/cm^{-1}], C: (1.81 ± 0.496) x 10^{-4} [%/cm^{-1}]). Since the slope of the spectrum is considered to reflect the effect of space weathering, β may be affected by greater space weathering than α [9].

Therefore, in the relationship between peak wavelength and depth in the 2.7 μm absorption band (Figure 2 left), the longer wavelength and smaller depth of the peak position for β compared to α may be due to the greater effect of bond scission related to the OH group caused by space weathering.

In summary, the Ryugu return samples that were measured by MicrOmega were classified into three major groups: α and β in chamber A, and C in chamber C. Also, each of them is considered to be affected by greater space weathering in the order of α < C < β, respectively.



[Figure 2: Left: Relationship between peak wavelength and depth of the composite waveform in the 2.7 μm absorption band, right: slope magnitude around 2.0 μm (chamber A sample: α and β only) versus Frequency ratio]

References

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