Geophysical Research Abstracts
Vol. 14, EGU2012-8914, 2012
EGU General Assembly 2012

Analysis of ground-based and VIRTIS-M/ROSETTA reflectance spectra of asteroid 2687 Šteins: A comparison

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The asteroid 2687 Šteins was encountered by Rosetta in 2008. Prior to the fly-by, ground-based observations of Šteins were performed [1, 2, 3, 4, 5, 6]. We present a summary of ground-based VIS and NIR reflectance spectra of Šteins and compare them with VIRTIS-M-spectra obtained during the fly-by. On the basis of these spectral data we discuss the relationship to meteorite materials, and the classification of Šteins.

The ground-based spectra cover a wavelength range from 0.4-2.5 μm. All spectra show a clear absorption feature at $\sim$0.5 μm and a steep spectral slope between $\sim$0.6-0.8 μm. At wavelengths >1 μm the spectra show a neutral to slightly reddish trend. The absorption band at $\sim$0.5 μm is commonly linked to the feature at that wavelength in the oldhamite spectrum [7]. The oldhamite spectrum shows another weaker feature at 0.96 μm. This weaker feature at $\sim$0.96 μm is visible in two of the ground-based spectra. Spectral slopes of most Earth-based spectra are comparable within arrow bars. The uniform spectral characteristics indicate a homogenous surface of Šteins.

The VIRTIS-M-spectra of Šteins cover the wavelength range from 0.25-1 μm (VIS) and 1-5 μm (IR). The spectra show an overall flat behavior with a steep red slope at wavelengths <1 μm. The absorption feature located at $\sim$0.5 μm is clearly visible. At wavelengths >3.5 μm thermal emission contributes significantly to the detected radiation. The thermal properties derived from VIRTIS-M long wavelength measurements suggest a thin regolith layer and a low porosity. The shape of the asteroid is consistent with the hypothesis that Šteins is a rubble-pile.

Ground-based and fly-by spectra of Šteins are in good agreement with each other considering the overall spectral characteristics and the occurrence of the absorption feature at 0.5 μm. Prior to the Rosetta fly-by Šteins has been classified (by e.g. [1, 5]) as an E[II]-type asteroid (after [8, 9], also Xe after [10]). VIRTIS data suggest that Šteins can be classified as an igneous E-type asteroid, being a member of the E[II]-subclass. E-type asteroids are linked to aubrites, which are nearly monomineralic enstatite achondrites [11]. This interpretation is supported by comparative laboratory reflectance measurements. Although aubrites give the best agreement with Šteins spectra, several spectral features cannot be assigned unambiguously. Ti-rich minerals or space weathering implanted products were alternatively proposed to reproduce the observed spectral characteristics [1, 12]. Currently no meteorite in our present collection fits the Šteins spectra, indicating that Šteins is probably not the parent body of these meteorites. Because Šteins is a reduced anhydrous body, it can be argued that it formed in the inner planetary system and was scattered to the main belt. This opens interesting parallels between the E-type population and the formation of Mercury.

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