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Olivine Composition of the Mars Trojan 5261 Eureka: Spitzer IRS Data

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Abstract

The largest Mars trojan, 5261 Eureka, is one of two prototype "Sa" asteroids in the Bus-Demeo taxonomy [1]. Analysis of its visible/near-IR spectrum [2] led to the conclusion that it might represent either an angritic analog or an olivine-rich composition such as an R chondrite.
Spitzer IRS data (5–30 μm) have enabled us to resolve this ambiguity. The thermal-IR spectrum exhibits strong olivine reststrahlen features consistent with a composition of $\approx Fo_{60-70}$. Laboratory spectra of R chondrites, brachinites, and chassignites are dominated by similar features.

1. Vis/NIR Observations

In the vis/NIR, the spectra of angrites [3] are similar to those of olivine-dominated meteorites such as R chondrites, brachinites, and chassignites. Both feature a broad 1-micron absorption band and weak or absent 2-micron band. The angrite spectra provided a particularly close match to the near-IR spectra of 5261 Eureka [2] and thus, based on these data, an angritic mineralogy was reasonably considered to be a possibility for this asteroid. Angrites are basaltic achondrites dominated by Al-Ti diopside pyroxene ("fassaite"), anorthite, and olivine (<35%).

2. Spitzer IRS Observations

The thermal IR spectrum of 5261 Eureka was measured by the Spitzer IRS in December 2007. IRS spectra from the four low-resolution modules were extracted and spliced together using methods similar to those described in [4]. The asteroid standard thermal model [5; 6] was then fit to the data while allowing the maximum temperature and asteroid radius to float. The ratio of the IRS spectrum to this model is the emissivity spectrum shown in Fig. 1.

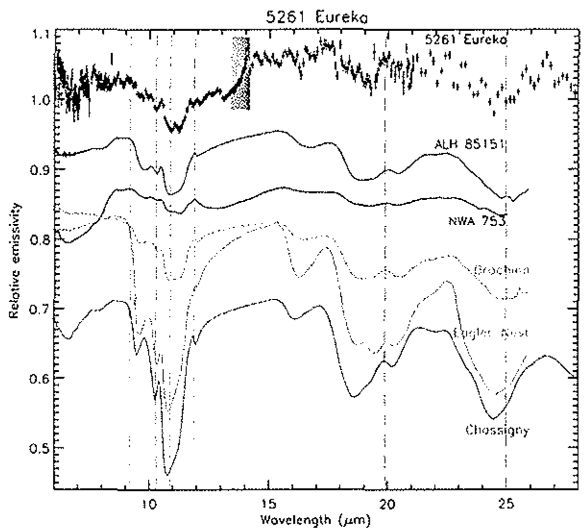

Figure 1. Spitzer IRS Spectrum of 5261 Eureka and candidate meteorite analogs. The shaded box from 13.65 to 14.15 microns indicates the region where the IRS data are unreliable due to an instrumental artifact. Vertical dashed lines are included for ease of comparison of the wavelengths of compositional features between spectra. All meteorite spectra are from RELAB and have been offset vertically. From the top: RELAB spectra of two R chondrites, two brachinites, and Chassigny. All have over 65% modal olivine with compositions ranging from Fo_{60} to Fo_{70}.

In the thermal IR, 5261 Eureka is a better match to olivine-rich meteorites such as R chondrites, brachinites, or chassignites (Fig. 1) than it is to the angrites (Fig. 2). Of the three angrite RELAB spectra, D'Orbigny's superficially provides the closest match to Eureka in the 9–12 μm region; but its deep <11-micron minimum falls at a shorter wavelength than the asteroid's due to its large modal abundance of anorthite (39%, e.g. [7; 8]). Angra dos Reis, which contains very little olivine, provides the poorest match.

3. Summary and Conclusions

We therefore infer that the thermal emission spectrum of 5261 Eureka is dominated by a more olivine-rich composition than that of any of the known angrites. Currently, the closest meteoritic analogs in the spectral library are R-chondrites (65–78% modal olivine with composition Fo_{60-63}, e.g. [9, 10] and references therein), brachinites (79–93% olivine, Fo_{68-70}, [11]), and Chassigny (90% modal olivine, Fo_{69}, [12]).

The wavelengths of both the 9–12 μm reststrahlen features and especially the ≈ 25 μm emissivity minimum vary systematically among olivine spectra as a function of Fo content [e.g. 13; 14]. Thus, the olivine composition of 5261 Eureka is unlikely to be far from $\approx Fo_{65}$, although more work is required to derive a robust uncertainty in this composition.

Olivine-dominated asteroids are relatively uncommon, with only six "A" and two "Sa" examples having been identified among the 371 asteroids classified in [1]. Further analysis will be required to determine whether components other than olivine can be identified in the IRS spectrum of 5261 Eureka and whether the composition can be determined well enough to establish whether this asteroid is more likely to be a primitive object (R chondrite analog), a product of a low degree of partial melting of a chondritic precursor (a leading hypothesis for the origin of brachinites, e.g. [15]) or a fragment of a mantle or magma chamber from a differentiated object.

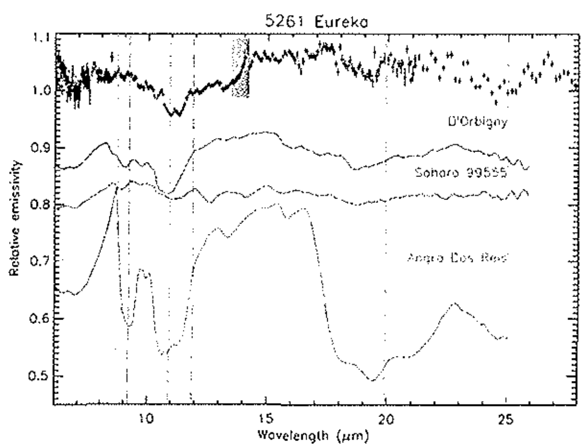

Figure 2. Spitzer IRS Spectrum of 5261 Eureka and RELAB spectra of angrites [3]. The olivine-rich meteorites (Fig. 1) provide a better spectral match to the reststrahlen features in the IRS data than do these basaltic meteorites.

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