Detection of high-calcium pyroxene in the near-infrared spectra of asteroids

S. J. Bus[1], J. M. Sunshine, T. J. McCoy, T. H. Burbine, C. M. Corrigan, and R. P. Binzel

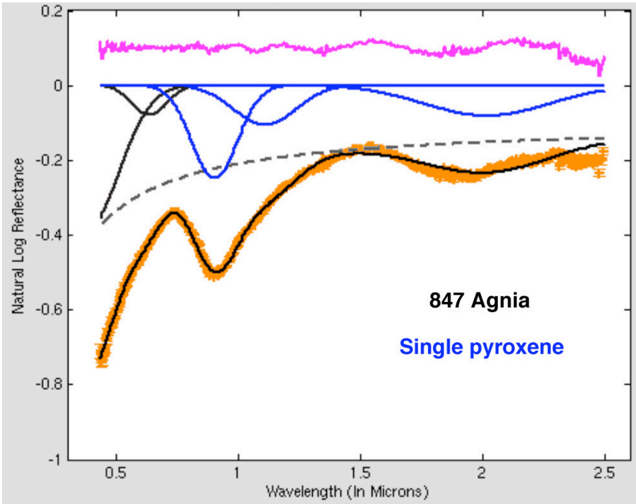
[1]Institute for Astronomy, Univ. of Hawaii

Publication: J. M. Sunshine, S. J. Bus, T. J. McCoy, T. H. Burbine, C. M. Corrigan, and R. P. Binzel (2004). High-calcium pyroxene as an indicator of igneous differentiation in asteroids and meteorites. *Meteoritics and Planetary Science* **39**, 1343-1357.

We are carrying out a large-scale spectroscopic survey of silicate-rich asteroids using SpeX on the NASA IRTF. The goal of this work is to sample the full range of silicate mineralogies observable in the asteroid belt, and to look for trends in composition that could provide clues about the properties of the solar nebula and the early stages of planet formation.

The spectra of silicate-rich asteroids contain very diagnostic absorption bands centered near 1- and 2- μm that are associated with the minerals pyroxene and olivine. These same mineral phases are also major constituents of most meteorites. Used in its low-resolution "prism" mode, SpeX can provide high signal-to-noise spectra covering the wavelength interval from 0.8 to 2.5 μm for asteroids as faint as visual magnitude 16.5. When combined with visible-wavelength CCD spectra, **the SpeX observations are revealing spectral absorption features in asteroids at a level of detail never before possible.**

One of the first results from our survey has been our ability to directly resolve the presence of both high-calcium and low-calcium pyroxenes in asteroid spectra. Using the Modified Gaussian Modeling (MGM) technique to deconvolve the individual absorption bands associated with each of these pyroxenes, we can measure the ratio of these two mineral phases to remotely trace igneous processes on asteroids.



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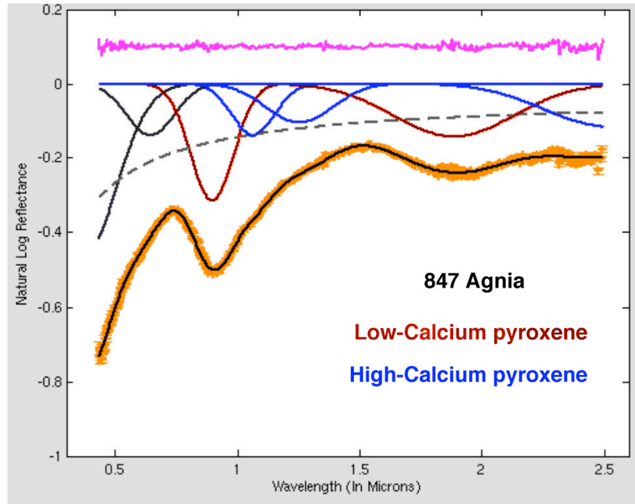

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A. Modified Gaussian Modeling (MGM) fit of the spectrum of 847 Agnia that assumes a single pyroxene. This plot shows the individual absorption bands (blue) associated with a single pyroxene, along with a fitted continuum (dashed line). This fit results in high residual errors (shown in pink) in the 2-μm region of the spectrum, and smaller but significant systematic errors in the 1-μm region.

B. MGM model of the spectrum of 847 Agnia that includes both low-calcium (red) and high-calcium (blue) pyroxene absorption bands. The improved fit, especially in the 2-μm region, provides strong evidence for the presence of both pyroxene phases on the surface of this asteroid.

Importance of this work

Many of the asteroids we have studied to date show evidence for both low- and high-calcium pyroxenes, but little or no olivine. Calcium is a fundamental tracer of temperature in geologic systems, and it's presence provides a means of estimating the amount of melting that these asteroids have experienced. The silicate mineralogy inferred for these asteroids requires that their parent bodies experienced igneous differentiation early in their histories, producing broadly basaltic (crustal) surface lithologies.

Prior to this work, only the asteroid 4 Vesta (along with the numerous small Vesta family asteroids), and 1489 Magnya were unambiguously characterized as having basaltic surfaces. As a result of this new work and the identification of high-calcium pyroxene on many other main-belt asteroids, we can expect the number of known differentiated asteroids to increase, consistent with the large number of differentiated parent bodies that are inferred from the isotopic studies of iron meteorites.