A Galileo Multi-Instrument Spectral Analysis of 951 Gaspra

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On October 29, 1991 the Jovian bound Galileo spacecraft encountered the asteroid 951 Gaspra. It was the first time any spacecraft encountered an asteroid. 951 Gaspra is a S-asteroid. The composition and evolutionary history of S-asteroids is somewhat of a controversy. S-asteroids are the most common asteroids known. Ordinary chondrites are the most common meteorites that are found on the Earth. Earth based telescopes obtained spectra that S-asteroids are composed of olivine, pyroxene, and reddish NiFe much like lodranites and mesosiderites. Ordinary chondrites are primarily composed of olivine, pyroxene, and NiFe. Hence many researchers subscribe to one of the following views: (1) S-asteroids may be composed of undifferentiated ordinary chondrite type material because meteorites and asteroids have common origins, and because S-asteroids and ordinary chondrites are respectively, the most abundant of each. (2) S-asteroids may be differentiated stony iron type material because S-asteroids are most spectrally similar to stony iron meteorites.

In order to further explore the composition of a S-asteroid the Galileo team collected images of 951 Gaspra through discrete visible wavelength filters (.41-.99 microns) with a solid state imaging camera (SSI) and in infrared wavelengths (.8-5.2 microns) via a near-infrared mapping spectrometer (NIMS). By combining these two data sets into a 3 dimensional array know as a spectral image cube, it is possible to analyze mineralogical composition and morphology simultaneously. At least two different spectral units are characterized in this data set. Figure 1 compares the spectra of "Typical Gaspra" with "Olivine Enriched Gaspra". There error bars of these spectra are equivalent or less than the symbols representing the data. Notice how the "Olivine Enriched Gaspra" has a more pronounced 1.05 micron feature than "Typical Gaspra". The "Olivine Enriched Gaspra" also has a significantly reduced 2 micron pyroxene absorption feature. The spectra plotted in figure 1 are representative spectra from "Typical Gaspra" and "Olivine Enriched Gaspra" and are not averages. The "Olivine Enriched Gaspra" corresponds with some of 951 Gaspra's craters.

A band area analysis developed by Cloutis et al.[1] was utilized in determining relative olivine/orthopyroxene abundances. Preliminary results indicate that the bulk composition of 951 Gaspra's surface has a relative olivine/orthopyroxene abundance ratio of 81% olivine/19% orthopyroxene (Note: the olivine/orthopyroxene abundance ratio does not indicate the relative abundance of 951 Gaspra's observed NiFe). A small fraction of the observed 951 Gaspra appears to have a relative olivine/orthopyroxene abundance ratio of 87% olivine/13% orthopyroxene. The uncertainty of these measurements is + or - 2%. Figure 2 compares these results with quantities derived by petrologic analysis of ordinary chondrites [2]. In order to verify that the spectral measurements of 951 Gaspra, an additional experiment was conducted. Spectra of ordinary chondrite meteorites were convolved to SSI/NIMS resolution and then measured utilizing the Cloutis et al.[1] band area techniques. The results were nearly identical to those portrayed in figure 2. This test validates the spectral analysis techniques that were applied to the 951 Gaspra data.

These observations are consistent with 951 Gaspra being a differentiated object. An undifferentiated asteroid is expected to be homogeneous in composition. 951 Gaspra possesses a heterogeneous composition. The spectra of 951 Gaspra have a redder spectral slope than ordinary chondrite spectra. It also contains materials which contain significantly higher abundances of olivine than ordinary chondrites. These are qualities consistent with the stony iron meteorites (like Pallasites).

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Figure 1: 951 Gaspra SSI/NIMS Spectra

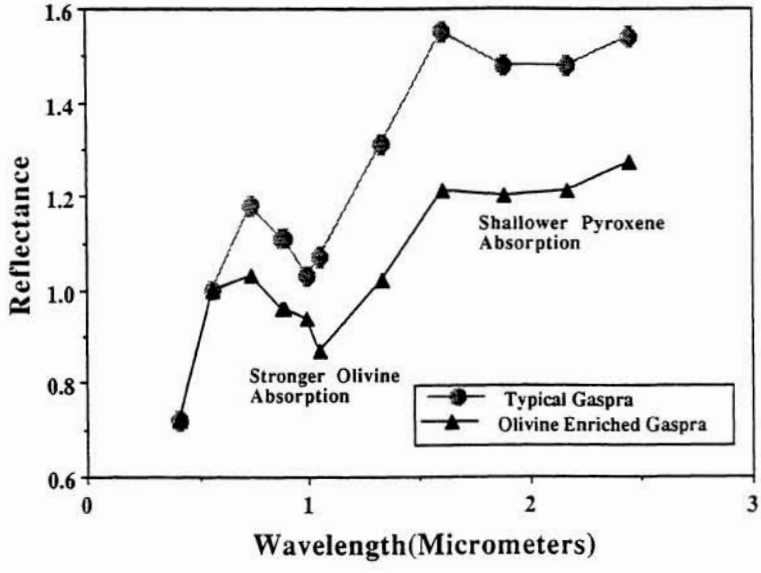
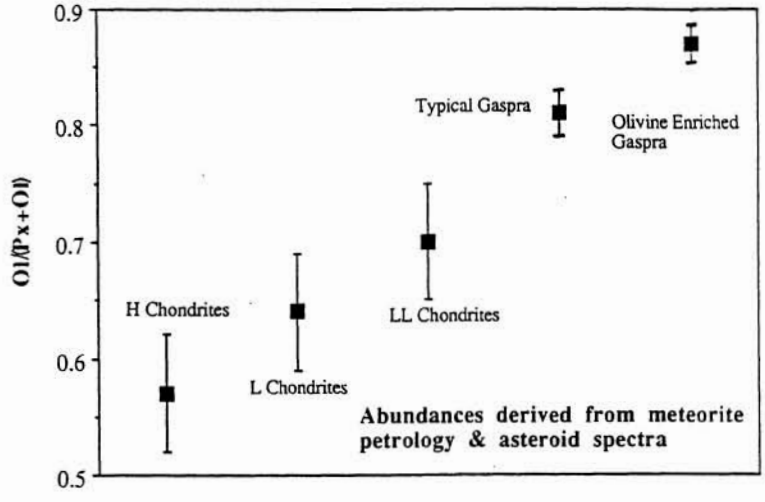


Figure 2: Olivine/(Olivine+Pyroxene)



[1]Cloutis, E., M.J. Gaffey, T.L. Jackowski, and K.L. Reed (1986) Calibrations of phase abundance, composition, and particle size distribution for olivine-orthopyroxene mixtures from reflectance spectra. JGR 94:11641-11653. [2]McSween, H.Y., M.E. Bennett, and Eugene Jarosewich (1991) The mineralogy of ordinary chondrites and implications for asteroid spectrophotometry. Icarus 90:107-116.