Asteroids, Comets, Meteors 1991, pp. 413–416
Lunar and Planetary Institute, Houston, 1992

S97-89
N93-19210

P. 4

Near Infrared Reflectance Spectra: Applications to Problems in Asteroid - Meteorite Relationships

Lucy A. McFadden & Alan B. Chamberlin
California Space Institute, University of California, San Diego, La Jolla, CA 92093

INTRODUCTION

An observing program designed to search for evidence of ordinary chondrite parent bodies near the 3:1 Kirkwood Gap was carried out in 1985 and 1986. Studies by Wisdom (1985), Wetherill (1985), and subsequent work by Milani et al. (1989) indicate that the 3:1 Kirkwood gap is the most probable source region for the majority of ordinary chondrite meteorites. Figure 1 shows the location (in eccentricity vs semimajor-axis space) of the observed asteroids as well as the chaotic zone of the 3:1 (Wisdom, 1983) and the 5:2 Kirkwood Gaps.

The diversity of the reflectance spectra among this small data set is surprising. Early work by Gaffey and McCord (1978) showed that the inner region of the main asteroid belt is dominated by high albedo objects with mafic silicate surfaces. One would expect to see mostly spectra with 1- and 2-μm absorption bands based on this earlier work. Only 5 (of 12) spectra have these expected features. The distribution of taxonomic types presented by Gradie and Tedesco (1982) is in most cases a useful simplification of the compositional structure of the asteroid belt. The range of spectral characteristics seen with higher resolution in the near-IR has not been previously reported and is not represented in the standard asteroid taxonomy. Near-IR spectra contain valuable mineralogical information which enhances knowledge of the composition and structure of asteroids.

OBSERVATIONS AND INSTRUMENTATION

Two observing runs were carried out at the Infrared Telescope Facility (IRTF), Mauna Kea, Hawaii, on 10-12 August 1985 UT and 2-4 December 1986 UT. A single, liquid-Helium cooled, InSb detector and two circular variable filters (CVFs) cooled to liquid-Nitrogen temperature were used. The filters cover the region from 0.8-μm to 2.6-μm. A 10" entrance aperture was used. The signal from the detector passed through a preamplifier and then a "lockin" amplifier. A voltage-to-frequency converter was used to convert the output of the lockin amplifier to a digital signal.

DATA REDUCTION

The background sky flux was subtracted from the asteroid flux. Extinction coefficients were calculated using a least squares fit to both the rising and setting fluxes of standard stars versus airmass. The fits were calculated separately for rising and setting measurements. With these coefficients, the flux of the standard star is scaled to that at the airmass of

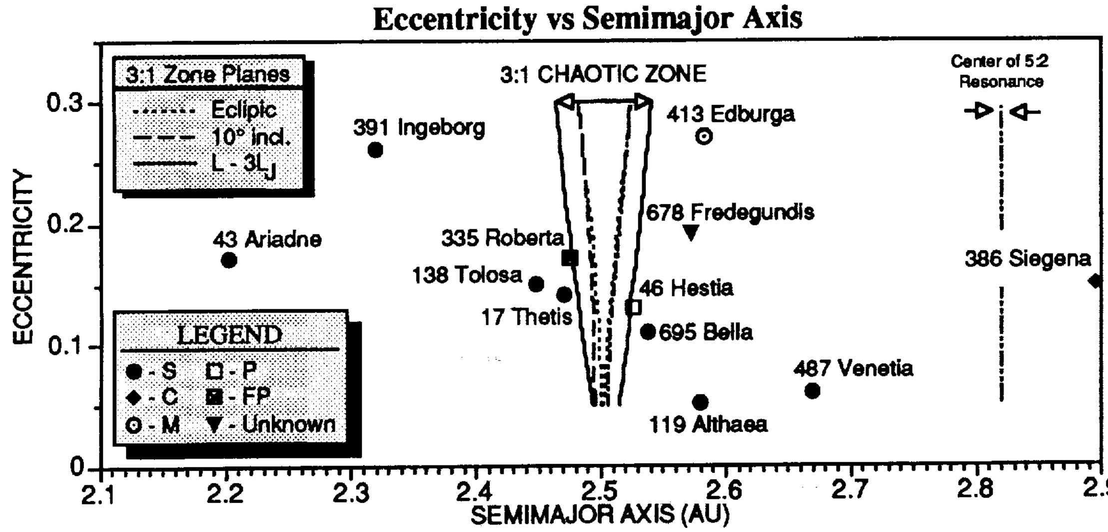

Figure 1. Eccentricity vs Semimajor Axis of the 12 Asteroids Observed.

the asteroid. The asteroid flux is divided by the extinction corrected standard star flux to eliminate instrumental noise. Each asteroid/standard star pair is averaged and converted to a relative flux by multiplying by the standard star/Sun ratio. This latter ratio is calibrated from many previously acquired data sets assuming the flux of the solar-type stars 16 Cygnus B and 13 Orionis is equivalent to that of the Sun.

Non-linear Error Correction

The IRTF lockin amplifiers experienced an abnormal non-linearity during the observations in December 1986. The effect of the lockin non-linearity was seen in the raw data (counts per second). A correction curve (20 discrete data points) was provided by the IRTF staff. The non-linear correction program used linear interpolation between the two closest correction curve data points to convert raw data to corrected raw data. In the case of a raw data point lying outside the range of discrete correction points, the two closest correction points (the closest end points) were used for the linear interpolation.

THE DATA

The calibrated spectra are placed into four groups with similar spectral features. Each group is discussed instead of each spectrum. In figures 2-5, an H4 ordinary chondrite spectrum is plotted as a solid line while the asteroid spectra are plotted as discrete points with error bars.

Group 1 - These asteroids have bands at 1- and 2-μm, and a UV absorption band (Figure 2). The spectral differences between these asteroids and the H4 ordinary chondrite imply chemical and mineralogical differences in pyroxene composition and olivine/pyroxene abundance shown by different positions and strengths of the 1- and 2-μm absorption bands. All 5 asteroids of this group are classified type S by Zellner et al. (1985). The absorption features are due to the presence of olivine and pyroxene on the asteroid surface.

Group 2 - We placed three asteroids, 413 Edburga, 678 Fredegundis, and 46 Hestia, in a group (Figure 3) because they lack 1- and 2-μm absorption bands and their reflectance increases with increasing wavelength. The different taxonomic types represented, M, S, and P are a reminder that the taxonomy is based on colors in a different spectral region. The

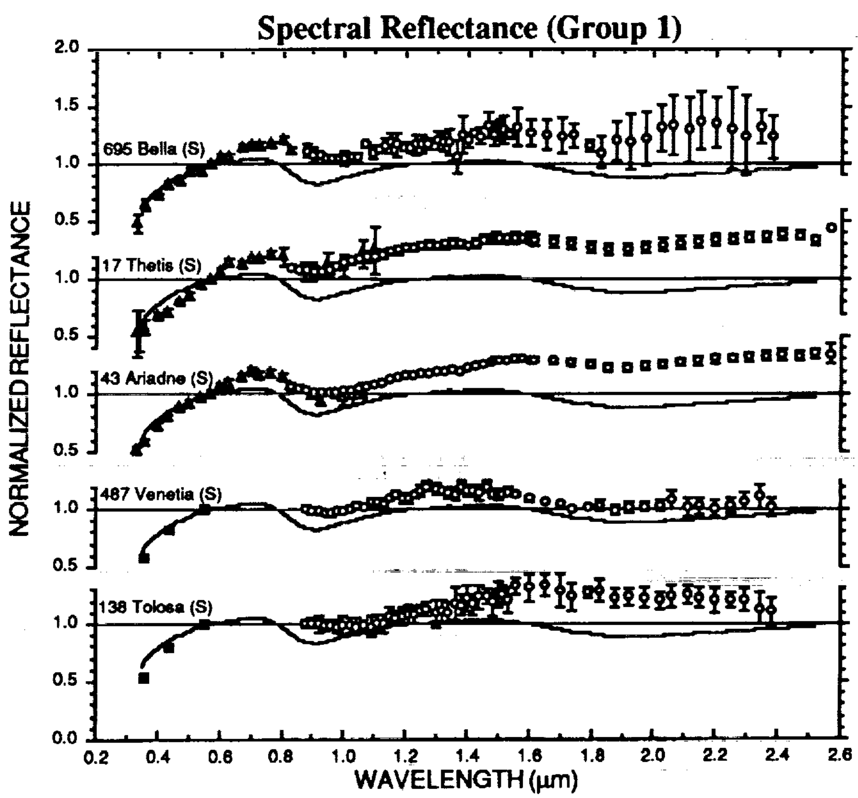

Figure 2. Spectral Reflectance of Group 1 Asteroids Compared to an H4 Ordinary Chondrite.

method of grouping used is for convenience and has no significance in relation to taxonomy, though it is interesting to consider whether inclusion of near-IR data would contibute to a classification scheme. The low signal to noise and the incomplete removal of telluric water bands in spectra of 413 and 678 increase the uncertainty of these data, though the absence of crystal field absorptions at 1- and 2-μm is established to within 10-20%.

Group 3 - The two spectra in this group (Figure 4), 386 Siegena and 335 Roberta, have UV absorption band edges and

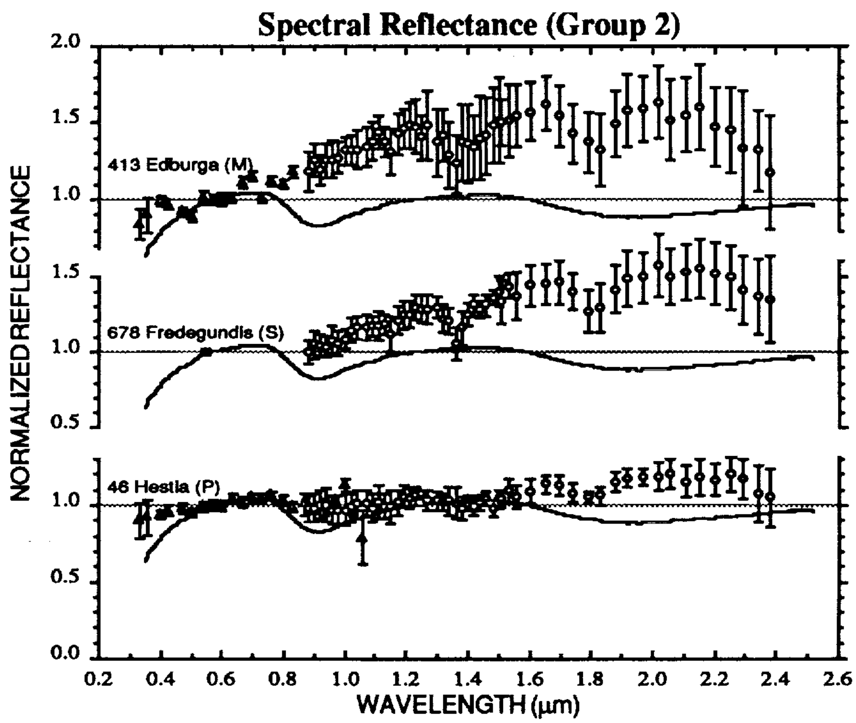

Figure 3. Spectral Reflectance of Group 2 Asteroids Compared to an H4 Ordinary Chondrite.

weak absorption bands in the 1-µm region. In the spectrum of 386 Siegena the UV absorption edge is strong and extends into the visible to 0.56-µm indicating a significant iron abundance. The presence of a weak 1-µm band is also consistent with an iron-rich surface. The flat reflectance in the near-IR combined with the assumed low albedo of a C-type asteroid indicates the presence of an opaque material which masks the 2-µm pyroxene band. The broad and weak feature seen in the spectrum of 335 Roberta is similar to that in 704 Interamnia observed by Bell et al. (1987). Terrestrial plagioclase minerals have broad, weak bands in this spectral region (Adams, 1975), though plagioclase-rich assemblages have not been previously reported.

Group 4 - The group 4 asteroids (Figure 5) have unusually strong 2-µm bands and include asteroids 119 Althaea and 391 Ingeborg. There are two explanations for these spectra. Either the tracking of these objects was off (though there is no mention of this in the data logbooks), or the mineralogy of these asteroids is unusual. The mineralogical interpretation of 119 Althaea implies a very iron and calcium-rich pyroxene. A terrestrial rock with this spectrum would be called a hedenbergite, it is a highly differentiated assemblage. The strong, broad band in the spectrum of 391 Ingeborg is similar to features seen in laboratory spectra of spinels (Adams, 1975). Because these features have not been seen in asteroids before, the spectra of these asteroids should be confirmed by repeated measurements. Recent, almost concurrent reports of additional asteroids with strong 2-µm features have been reported (Burbine et al. 1991).

DISCUSSION

Of the 12 spectra in our sample, only those in group 1 have the combination of features that are also found in spectra of ordinary chondrite meteorites yet there are differences among these spectra and the ordinary chondrites. The near-infrared reflectance of the asteroids is higher than the ordinary chondrites. What is the mineralogical and cosmochemical significance of these spectral differences? An explanation for the higher IR reflectance may be that there is more metallic

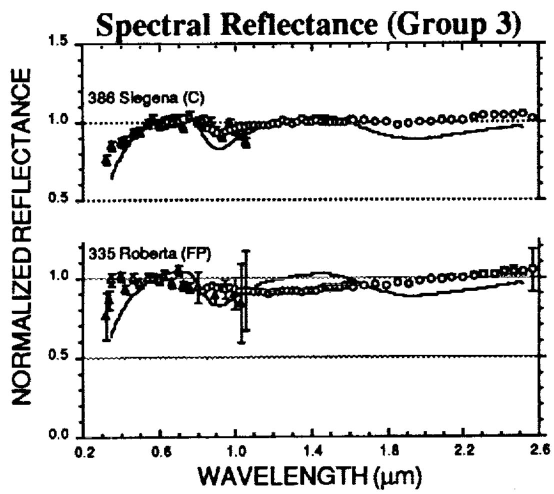

Figure 4. Spectral Reflectance of Group 3 Asteroids Compared to an H4 Ordinary Chondrite.

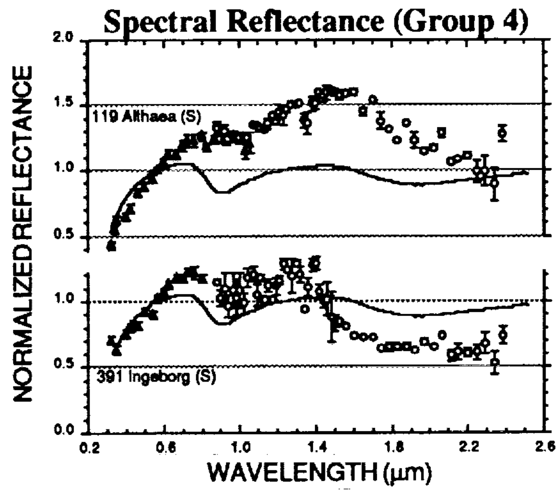

Figure 5. Spectral Reflectance of Group 4 Asteroids Compared to an H4 Ordinary Chondrite.

iron on the asteroid surface than in ordinary chondrites, in which case, the asteroids are not ordinary chondrite analogues. It has been hypothesized that the higher reflectance might be attributed to alteration caused by proton bombardment from the solar wind. Experiments are being conducted by the authors to test this hypothesis. In a subsequent publication we will measure the band position and depth of these spectra and compare them with those analyzed by Gaffey (1991) to quantitatively determine the chemical mineralogy and compare it with ordinary chondrites. We have found possibly three asteroids with mineralogical compositions not previously known among the asteroids. Their compositions may be similar to those of 387 Aquitania, 980 Anacostia (Burbine et al., 1991), and 704 Interamnia (Bell et al., 1987).

REFERENCES

Adams J. B. (1975) Interpretation of visible and near-infrared diffuse reflectance spectra of pyroxenes and other rock forming minerals. In Infrared and Raman Spectroscopy of Lunar and Terrestrial Minerals (J. C. Karr, ed.), pp. 91-116. Academic Press, New York.

Bell J. F., Hawke B. R., Owensby P. D. and Gaffey M. J. (1987) Atlas of asteroid infrared reflectance spectra (0.8-2.5 microns). unpublished.

Burbine T. H., Gaffey M. J. and Bell J. F. (1991) S Asteroids 387 Aquitania and 980 Anacostia: Possible Fragments of the Breakup of a Spinel-Rich Parent Body. B.A.A.S., 23, 1142.

Gaffey M. J. (1991) Variations in magmatic processes among igneous asteroids. Abstracts for The International Conference On Asteroids, Comets, Meteors 1991, Flagstaff, AZ, p. 71.

Gaffey M. J. and McCord T. B. (1978) Asteroid surface materials: Mineralogical characterizations from reflectance spectra. Space Sci. Rev., 21, 555-628.

Gradie J. and Tedesco E. (1982) Compositional structure of the asteroid belt. Science, 216, 1405-1407.

Milani A., Carpino M., Hahn G. and Nobili A. M. (1989) Dynamics of planet-crossing asteroids: Cases of orbital behavior Project SPACEGUARD. Icarus, 78, 212-269.

Wetherill G. W. (1985) Asteroidal source of ordinary chondrites. Meteoritics, 20, 1-22.

Wisdom J. (1983) Chaotic Behavior and the Origin of the 3/1 Kirkwood Gap. Icarus, 56, 51-74.

Wisdom J. (1985) Meteorites may follow a chaotic route to Earth. Nature, 315, 731-733.

Zellner B., Tholen D. J. and Tedesco E. F. (1985) The eight-color asteroid survey: Results for 589 minor planets. Icarus, 61, 355-416.