Evidence for partial melting in reflectance spectra of 433 Eros. L. A. McFadden[1] Noah Goldman[1], M. J. Gaffey[2], N. R. Izenberg[3],[1]U. Maryland (Astronomy Department, College Park, MD 20742-2421 mcfadden@astro.umd.edu), [2]U. North Dakota (Dept. Space Studies, Grand Forks, ND 58202 gaffey@space.edu). [3] JHU/APL, Laurel MD. noam.izenberg@jhuapl.edu.

Introduction: The NEAR Shoemaker spacecraft returned near-IR spectra of asteroid 433 Eros at spatial resolutions ranging from 2.5 to 100's km during its year-long orbital mission in 2000. Assuming modified Gaussian absorption bands represent the reflectance spectrum between 0.8-2.5 μm we fit the average of all geometrically corrected spectra acquired by the near-IR spectrometer (NIS) [1] with seven absorption bands. Interpretation of the absorption bands in terms of olivine and pyroxene minerals indicates that the surface of Eros contains olivine and two pyroxenes with compositions that are indicative of a partially melted assemblage. This partial melting must have occurred when the asteroid was part of a larger minor planet, prior to break up into its current elongated and irregular shape.

Modified Gaussian Method Analysis: Least-squares fitting of the average Eros spectrum was carried out with MGM algorithms [2] assuming that light interacts with mafic silicates according to crystal field theory [3] and that the bands have a modified Gaussian profile that is a result of bond lengths in the crystal structure of olivine and pyroxene. Expected absorption band parameters including band center, width and strength are given in a start-up file from which a reflectance spectrum is calculated and compared to the observed spectrum. The best fit is determined when residuals are small (in this case <0.009) and random with respect to wavelength. The resulting band parameters are validated by comparison with band parameters of single mineral calibration standards [3-6].

Results: The best fit of the average Eros spectrum is shown in Fig. 1 and Table 1. Absorption bands for a low-Ca pyroxene, a high-Ca pyroxene and olivine can be validated against spectra and MGM fits of laboratory minerals (e.g. Fig. 2) where the band centers fall within the range of those of single minerals of pyroxene and olivine respectively, each with a range of chemical compositions. The band widths and relative strengths of the fitted bands are also consistent with single mineral spectra.

Discussion: In ordinary chondrites, low-Ca orthopyroxene is the dominant pyroxene phase, but there is a small but spectrally significant high-Ca pyroxene (diopside/augite) component. The high-Ca component in these chondrites has a composition of ~Wo_{45} with ~Fs_{7} (H), ~$Fs_{8.5}$ (L) and ~Fs_{10} (LL). The

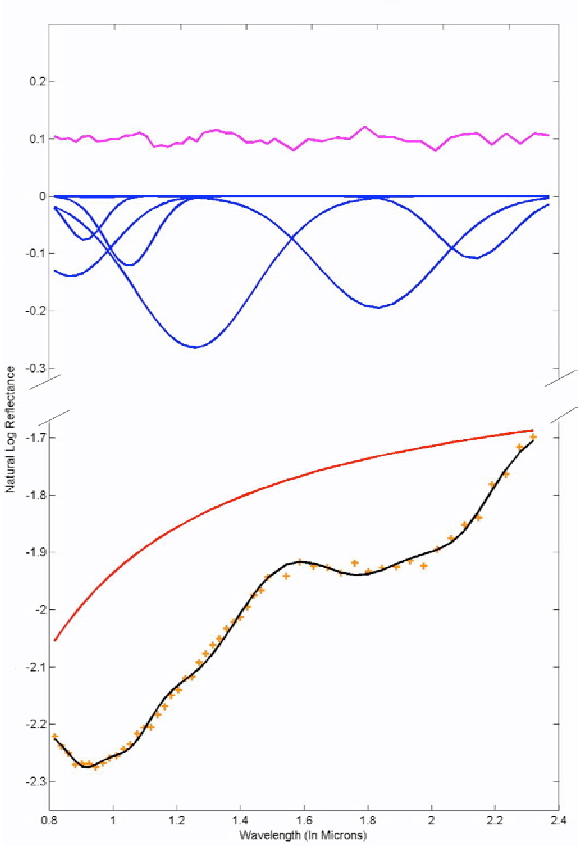

Fig. 1 MGM fit of average Eros spectrum. Top: residuals of the least-squares fit. Middle: Modified Gaussian bands of the best fit. Bottom: average spectrum with combined spectrum from 7 components in black, continuum is solid line in red.

Table 1:
Band centers for start-up file, Eros fit and partial melt

	Ordinary Chondrite Startup	Eros Fit	Partial Melt Predictions	Mineral Composition
low-Ca Pyx				
Band 1	0.910 μm	0.908 μm	~0.92 μm	$Fs_{9-45}Wo_{0-5}$
Band 2	1.89 μm	1.79 μm	~1.88 μm	$Fs_{6-32}Wo_{0-5}$
high-Ca Pyx				
Band 1	0.990 μm	0.948 μm	~1.02 μm	$Fs_{17-38}Wo_{17-51}$
Band 2	2.21 μm	2.09 μm	~2.28 μm	$Fs_{30-62}Wo_{14-36}$
Olivine				
Band 1	0.845 μm	0.865_m		Fo_{65}
Band 2	1.05 μm	1.04 μm		Fo_{65}
Band 3	1.24 μm	1.24 μm		Fo_{65}

Band I and II positions for such a pyroxene are approximately 1.02 μm and 2.28 μm. The low-calcium (orthopyroxene) component in ordinary chondrites has a composition of ~Fs_{17} (H), ~$Fs_{21.3}$ (L) and ~$Fs_{24.1}$ (LL) with ~$Wo_{1.5}$ for all types. The Band I and II positions for such a pyroxene are

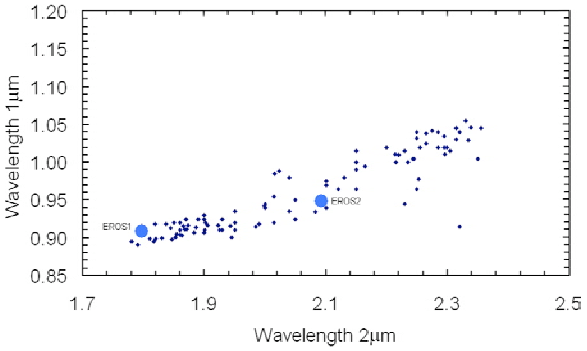

Fig. 2 1-Micron band vs. 2-Micron band of laboratory pyroxenes (triangles) and Eros pyroxene bands (circles). Band positions are consistent with standard pyroxene band positions.

approximately 0.92 μm and 1.88 μm. The fitted pyroxene bands for low-Ca pyroxene for Eros are at shorter wavelengths than for ordinary chondrites. We consider partial melting and its effects of pyroxene composition.

Partial Melting. The onset of partial melting produces a eutectic silicate liquid of basaltic composition. In the primitive achondrites, this liquid has not been extracted from the solid residue but instead moved a short distance from small concentrations that solidified in place. The eucrite meteorites have such a composition, and can be used as proxies for crystallized, trapped, partial melt. Eucrite pyroxenes appear to have originally been pigeonite which exsolved a high-calcium pyroxene phase from the host low-Ca pyroxene host. With 10% partial melting in the primitive achondrite-type assemblage the fitted spectrum should exhibit strong ~0.91 & ~1.86 μm and weaker (~10-20% as intense) ~0.91 & ~2.02 μm. The MGM fits are closer to the partial melting values than they are to ordinary chondrite or eucrite band positions. See Table 1.

Further Analysis. Two things need to be done to ensure this interpretation. The MGM fits presented here did not include the 0.750 μm reflectance from the NEAR MSI instrument. Fitting needs to be done with this point to explore effects on interpretation of the composition. Secondly, the pyroxene calibration needs to be conducted with more precisely known pyroxene chemistry. The range of compositional interpretation is large due to uncertainty in the chemistry of the minerals whose spectra were measured. Single crystal or synthetic spectra may need to be measured to improve the laboratory calibrations. MGM fitting of the laboratory spectra does not improve the calibration relationships. However, the band centers of Eros pyroxene and olivine is more iron rich than ordinary chondrite minerals.

References: [1] Izenberg, N. R.; et al. (2003) Meteoritics & Planet. Sci., 38, 1053-1077. [2] Burns R. G. 1993. Mineralogical Applications of Crystal Field Theory. 2nd edition. New York: Cambridge University Press. pp. 551. [3] Sunshine J. M., et al. (1990) *JGR* 95:6955-6966. [4] Sunshine J. M. and Pieters C. M. (1993). JGR 98:9075-9087. [5] Sunshine J. M. and Pieters C. M. 1998. JGR 103:13675-13688. [6].

Additional Information: This research was funded by NASA Discovery DAP, NAGW-0004