REFLECTANCE SPECTRA OF METAL-TROILITE MIXTURES: IMPLICATIONS FOR M-/X-TYPE ASTEROID EXPLORATION. S. D. Dibb[1], J. F. Bell, III[1], L.A.J. Garvie[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 (sdibb@asu.edu)

Introduction: Measurements of density, thermal inertia, and visible to near-infrared (VNIR) and radar reflectivity indicate that M-/X-type asteroids contain a significant fraction of metal [*e.g.,* 1-4]. Possible meteoritic analogs for these bodies include iron and metal-rich meteorites (*e.g.*, mesosiderites and CH/CB chondrites). Troilite (FeS) is the most abundant accessory mineral in many iron meteorites and is a significant component of other metal-rich meteorite classes, such as mesosiderites and some chondrites [5]. Thus, it is reasonable to infer that metal-rich asteroids may also contain abundant troilite.

VNIR reflectance spectra of iron meteorites and troilite have been measured [*e.g.,* 6,7]. However, published spectra of mixtures of iron meteorite metal and troilite have been limited to a single reported 90/10 wt.% mixture [7]. In order to better constrain the possible metal to troilite ratio from asteroids, a dataset is needed that covers a wide ratio of these two components. Here we present reflectance spectra of mixtures of troilite and iron meteorite powder at 20 wt. % intervals. These data can be compared with published spectra of asteroids and can be used to support interpretation of spectral data returned from future missions.

Samples and methods: Two samples were studied: metal from the Gibeon (IVA) iron meteorite, and troilite from the Toluca (IAB) iron meteorite. Gibeon has a typical Fe-Ni ratio (7.93 wt.% Ni), and we chose a freshly cut piece without visible weathering [8]. The troilite is from a ~5 cm nodule that was free of the surrounding metal. A powder was produced from the metal and the troilite using diamond-coated files.

A few microdiamonds were plucked by the iron during the filing. These microdiamonds were separated from the filings by magnetically lifting the iron meteorite powder from the cuttings multiple times until none could be observed in the leavings. None were subsequently observed in the troilite sample under a microscope, which is expected as troilite is brittle. The filings were dry-sieved and the <75 µm fraction was collected. This grain size fraction was chosen to reflect estimates for grain sizes on the surface of the largest M/X-type asteroid, (16) Psyche [*e.g.,* 2,9]. Metal to troilite mixtures were made at 20 wt.% intervals of each component by vigorous shaking/swirling in air-tight vials. All powders were stored in air-tight vials.

Reflectance spectra from 350 to 2500 nm were acquired with an ASD FieldSpec 4 Hi-Res spectrophotometer. All spectra were measured relative to a Spectralon white reference standard at a phase angle of 30° (i/e = 38°/8°). Spectra were collected within 2 hours of the beginning of the powder grinding process.

Powder X-ray diffraction (XRD) was used to determine the bulk mineralogy of the Gibeon and troilite samples. The powder patterns were acquired for the samples using a Rigaku MiniFlex 600. This diffractometer is operated with Cu $K\alpha$ radiation and is equipped with a post-diffraction graphite monochromator and automatic divergence slit system.

Results: The powder XRD pattern from Gibeon is dominated by reflections for kamacite and a few sharp reflections for tetrataenite. The XRD pattern from the Toluca troilite is dominated by reflections from troilite, with weak reflections for graphite and daubréelite ($FeCr_2S_4$), and minor schreibersite ($(Fe,Ni)_3P$) and cohenite ($(Fe,Ni,Co)_3C$.

Reflectance spectra of the metal and troilite mixtures are shown in Figure 1. Our endmember spectra are consistent with published spectra of these materials [*e.g.,* 6,7]. We find that an increasing abundance of metal increases the overall reflectance and near-infrared slope (measured between 760 and 1500 nm), while an increasing abundance of troilite decreases the overall reflectance but increases the visible wavelength slope (measured between 450 and 700 nm). There appears to be development of an absorption feature centered at ~410 nm with increasing troilite abundance, but its center and shape cannot be confirmed without more data at UV wavelengths. Minor features in the reflectance spectra at ~2150 nm are from imperfect correction of the white reference standard and are not due to mineralogy of the samples.

Table 1. Spectral properties of metal/troilite mixtures. Visible slopes are calculated between 450-700 nm and near-infrared (NIR) slopes are calculated between 760-1500 nm.

Metal/FeS (wt. %)	Refl. @ 550 nm (%)	Vis. Slope (%/100 nm)	NIR slope (%/100 nm)
0/100	5.94	0.68	0.146
20/80	6.97	0.68	0.148
40/60	7.81	0.65	0.175
60/40	9.54	0.62	0.217
80/20	11.74	0.48	0.332
100/0	15.74	0.20	0.592

Discussion: Our measurement of a change in slope between visible and NIR wavelengths for pure iron meteorite powder is consistent with [7]. This slope change is attributed to variations in the index of refraction and absorption coefficients at visible wavelengths [7]. It is unlikely that our iron meteorite powder experienced significant atmospheric alteration/oxidation due to the total lack of a ~0.9 um absorption common in iron oxides/hydroxides like hematite or goethite [7, 10]. Past studies attribute the subtle slope change at visible wavelengths in the troilite spectra to microscopic deviation from ideal FeS to pyrrhotite ($Fe_{1-x}S$), which may smooth an otherwise strong absorption edge common in semiconductors like metal sulfides [7,11,12].

The relatively featureless nature of the metal-troilite mixture spectra presented here are similar to spectra of M-/X-type asteroids. A spectrum of (16) Psyche, the largest M-type asteroid, is shown in Figure 1 scaled to its IRAS albedo at 550 nm [13,14]. Asteroid (16) Psyche's density (3,400-4,100 kg/m^3) is consistent with that of a metal-troilite mixture with some porosity [15]. The asteroid's radar, thermal, and spectral properties also suggest a significant non-metal component [15].

At least three missions are under development for M-/X-type asteroid exploration: the Psyche mission, to asteroid (16) Psyche, the Lucy mission targeting (among others) P-type (an X-subtype) asteroids (15094) Polymele and (617) Patroclus, and the Hera mission to the X-type binary system of (65803) Didymos. All missions are expected to carry VNIR instruments that could be sensitive to the results and interpretations being derived from meteoritical mineral laboratory studies like those described here.

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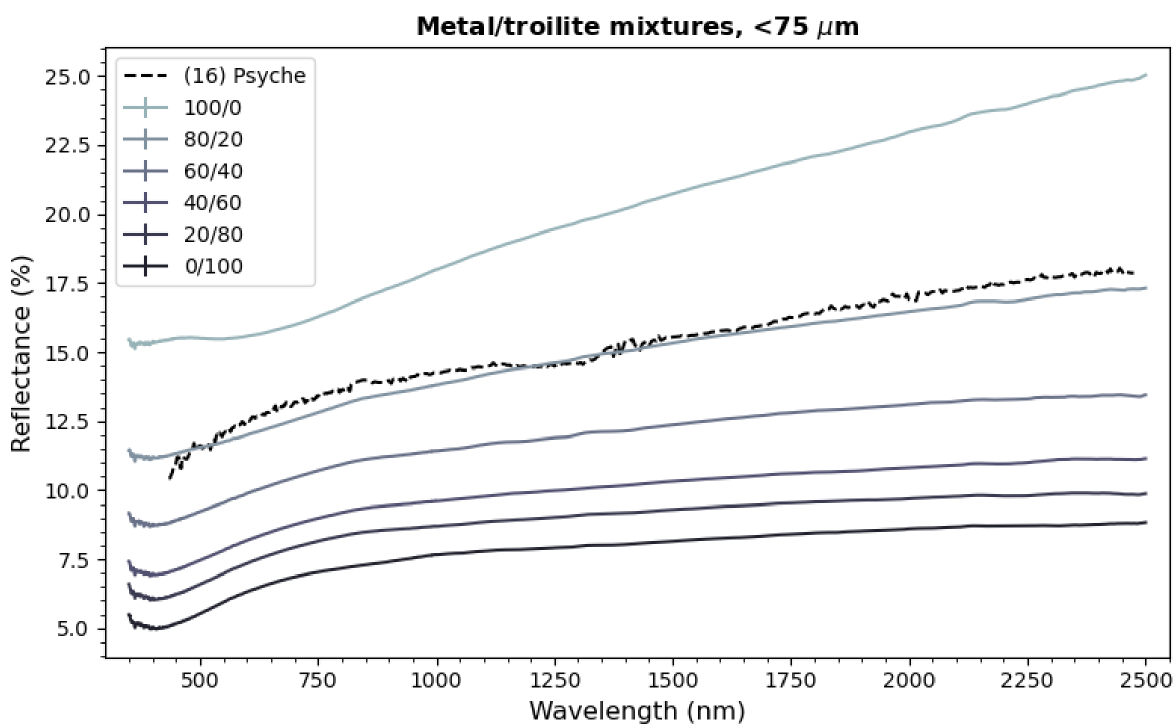

Figure 1. Reflectance spectra of metal/troilite mixtures (solid lines). Ratios of metal/troilite (in wt. %) decrease from the top down. A spectrum of M-type asteroid (16) Psyche is shown as a dashed line [13,14].