Compositional Investigation of (5404) Uemura: The Largest Fast-Rotating Monolith. V. Reddy[1,6,7], E. A. Cloutis[2], M. J. Gaffey[1,7], A. Galád[3,4], P. Pravec[4], A. W. Harris[5], A. Nathues[6, 7], J. A. Sanchez[6]; [1]Department of Space Studies, University of North Dakota, Grand Forks, ND 58203, email:Vishnu.kanupuru@und.nodak.edu; [2]Department of Geography, University of Winnipeg, Canada; [3]Modra Observatory, Comenius University, Slovakia; [4]Astronomical Institute, Ondřejov, Czech Republic; [5]Space Science Institute, La Canada, California; [6]Max-Planck Institute for Solar System Research, Germany; [7]Visiting Astronomer at the Infrared Telescope Facility, which is operated by the University of Hawai'i under contract from the National Aeronautics and Space Administration, Mauna Kea, Hawai'i 96720.

Introduction: The rotational state of an asteroid provides insights into its internal structure and helps physical characterization. This information helps distinguish between monoliths, rubble piles, and shattered but coherent objects. The analysis of the spin rate distribution of asteroids reveals several relationships between sizes and spin state. The most striking parameter was the spin barrier limit where asteroids larger than 1 km did not spin faster than 2.1 h [1, 2]. More rapid rotators were observed in the NEA population but these objects were typically <0.20 km in diameter. This suggested that super fast small rotators are monoliths with non-zero tensile strength and the larger asteroids (>0.20 km) are predominantly cohesionless structures held together by gravity (rubble piles).

In 2008, the main belt asteroid (5404) Uemura was observed as part of a photometric survey for asynchronous binary asteroids [3]. Observations over several months revealed that (5404) Uemura is the fastest rotating large main belt asteroid (>1 km) with a synodic rotation period P = 1.72436±0.00004 h and amplitude of 0.10 mag. This would suggest that the object has a high bulk density (>4.0 $g.cm^{-3}$) similar to metal-rich objects. In an effort to verify this, we conducted compositional study of Uemura. Here we present results of that effort.

Observation/Data Reduction: Asteroid Uemura was observed between 06:36-07:56 on 20 October, 2009 UT, using the SpeX instrument (low resolution prism mode) at the NASA IRTF, Mauna Kea, Hawai'i. Data reduction and analysis methods used in this study are explained in depth in [3] and [4]. The asteroid was observed on three other observing runs, however, the weather conditions were less than ideal for obtaining high quality spectra necessary for mineralogical characterization.

Results and Analysis: Figure 1 shows an average of 30 (120 second) individual near-infrared (0.7-2.48 µm) spectra of (5404) Uemura obtained on 20 October, 2009. The asteroid showed no rotational spectral variation based on band parameters (band centers and band area ratio) of average spectra of opposite rotational phases. The average spectrum shows two weak bands, Band I with a band center at 0.92±0.01 µm, band depth 2±1% and Band II with a band center at 1.83±0.03 µm, band depth 2.5±1%. These absorption features were also seen in lower SNR spectra from the three other observing runs affected by poor weather.

Due to the inherent weakness of the absorption features and incomplete correction of the 1.9 µm telluric band, the estimated band area ratio (BAR) of Uemura (5.4±1.8) has large errors. It is important to note that even with these large uncertainties this BAR value falls within the pure orthopyroxene field. The spectrum has an overall red slope (16.42% per µm).

The presence of absorption features at 0.92 µm and 1.83 µm is indicative of the mineral pyroxene. Based on the band centers, the dominant pyroxene phase on the surface of (5404) Uemura is low-Ca pyroxene. The absorption features are however severely suppressed and are weaker due to a variety of reasons.

The presence of opaques (e.g. metal) suppresses absorption features [5] and reddens the spectral slope (increasing reflectance with increasing wavelength). Cloutis (pers. comm.) noted reddening of slope in pyroxene + metal mixtures with more than 70% metal. Metal also tends to increase the albedo (moderate albedo ~10-20%). Other opaques (e.g. carbon) suppress spectral features and decrease albedo [6, 7]. A low abundance of the absorbing species (e.g., Fe^{2+}) in a moderate albedo mineral can also cause weak features.

Based on band parameters and the red spectral slope, we conclude that the surface of (5404) Uemura is most probably dominated by low-Ca pyroxene and NiFe metal. Uemura band centers are higher than what would be expected from a low-Fe pyroxene (0.90-0.91 µm) which has been detected on some M-taxonomic type asteroids (e.g., 8). In order to quantify the amount of metal, we compared the band depth and slope of Uemura absorption features to spectra of laboratory mixtures of metal plus low-Ca pyroxene.

Pyroxene band centers are not affected by the presence of metal and remained essentially constant within the error bars irrespective of the metal content. The lab spectra were obtained by Cloutis at the University of Winnipeg's HOSER Lab using ASD FieldSpec Pro HR spectrometer [9].

The spectral slope of the metal plus low-Ca pyroxene mixture reddens when the metal content >70% in the mixture. With increasing metal content the slope of the spectrum reddens at a rate of 2%/µm for every 10% increase in metal and the band depth decreases at the rate of 4% and 2% for every 10% increase in metal content for Band I and II respectively. Based on Uemura's slope (16.42%/µm) and band depth (~2%) we estimate the metal content on the surface to be ≥90%.

Meteorite Analog: The identification of possible meteorite analogs for (5404) Uemura was done based on the mineralogy and morphological similarities with laboratory meteorite spectra. Based on our analysis, the mineralogy of Uemura is dominated by metal (most probably Fe) and silicate (low-Ca pyroxene). Stony iron meteorites like pallasites (core+mantle mixtures of differentiated asteroids) and mesosiderites (core+crust mixtures) are the most common metal plus silicate dominated meteorites in the terrestrial collection. While most pallasites are dominated by metal and olivine, a small subgroup called pyroxene pallasites contain small quantities (<3 vol. %) of low-Ca pyroxene [10]. Spectrally, olivine would be the dominant silicate even on pyroxene pallasites as it is present in much higher vol. % (~13-55 vol. %) when compared to low-Ca pyroxene (0.7-3 vol. %) [10].

Mesosiderites are brecciated mixtures of metal related to IIIAB irons and silicates similar to the HED meteorites from Vesta. The silicates in mesosiderites are predominantly low-Fe orthopyroxene similar to diogenites along with minor olivine. The wt % of silicates ranges from 28-80% with the rest being metal and minor troilite [11]. Thus mineralogically, the most plausible meteorite analog for Uemura are mesosiderites.

In an effort to further constrain this, we measured the spectral band parameters of eight mesosiderites from Relab [12], and Burbine (pers. comm) and 12 diogenites and 12 eucrites from RELAB [12]. The band centers of these meteorites were plotted on the Band II vs. Band I plot [13] as presented in Figure 2. Uemura plots on the low-Ca pyroxene side between mesosiderites and diogenites strengthening the case for a mesosiderite meteorite analog. Despite large uncertainties in BAR, the asteroid plots to the left of the basaltic achondrite zone on Gaffey S-asteroid subtypes plot [14] confirming a basaltic origin for the silicate component. Based on several independent lines of evidence, we suggest that the most plausible meteorite analog for (5404) Uemura is mesosiderites. It is important to note that mesosiderites are a diverse group of meteorites with a range of compositions.

[15] interpreted the spectrum of M-type main belt asteroid (369) Aeria to be similar to mesosiderites and band centers of Aeria absorption features are consistent with Uemura's. The spectrum of Uemura is consistent with a metal-rich M-asteroid similar to Aeria.

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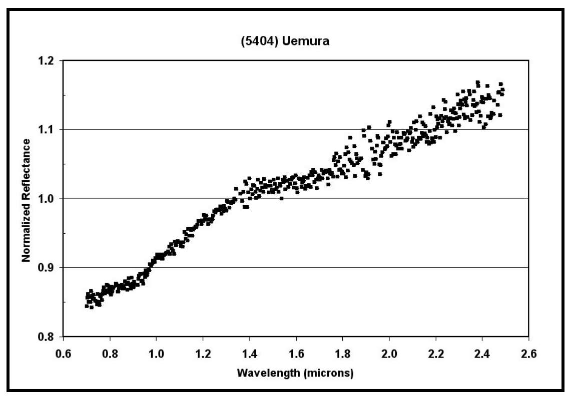

Figure 1. An average of 30 spectra of (5404) Uemura.

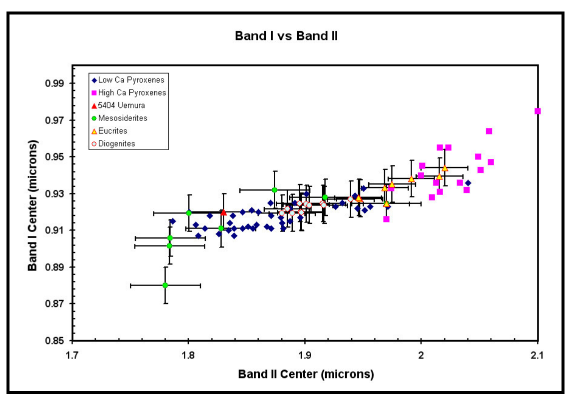

Figure 2. Band I and II centers of Uemura (red) compared to band centers of mesosiderites (green), eucrites (open circle), diogenites (yellow), low-Ca (blue) and high-Ca pyroxenes (purple).