COMPOSITIONAL INVESTIGATION OF BINARY NEAR-EARTH ASTEROID 66063 (1998 RO_1): A POTENTIALLY UNDIFFERENTIATED ASSEMBLAGE.

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Introduction: It is now thought that approximately 16% of all asteroids among the near-Earth population may be binary objects. Several independent lines of evidence, such as the presence of doublet craters on the Earth and Moon [1, 2], complex lightcurves of near-Earth objects exhibiting mutual events [3], and radar images of near-Earth asteroids revealing distinct primary and secondary objects, have supported this conclusion [4].

To date at least 23 near-Earth objects have been discovered as binary systems with expectations that many more have yet to be identified or recognized. Little is known about the physical characteristics of binary objects except that they seem to have fairly rapid rotation rates, generally have primaries in the ~1 km diameter range with smaller secondaries on the order of a few hundred meters, and apart from a few exceptions, are in synchronous orbits [4, 5].

Previously only two of these binary near-Earth asteroids (1998 ST_{27} and 2003 YT_1) have been characterized in terms of detailed mineralogical investigations [6, 7]. Such investigations are required to fully understand the formation mechanisms of these binary objects and their possible source regions. In addition, detailed knowledge of these objects may play an important role for planning future spacecraft missions and for the development of impact mitigation strategies. The work presented here represents a continued effort to characterize this particular sub-group of the near-Earth asteroid population.

66063 (1998 RO_1): This object was discovered by LINEAR on September 14, 1998 [8, 9]. Its orbital parameters indicate that it is a member of the Aten class of near-Earth asteroids. This class of near-Earth objects has semi-major axes less than 1 AU and orbits which cross Earth's during their aphelion passage. 66063 (1998 RO_1) was initially discovered to be a binary object through lightcurve studies in September, 2002 and then subsequently confirmed via radar imagery in September, 2003 [10]. The lightcurve and radar studies indicate that the primary object has a rotation period of approximately 2.5 hours and is roughly 800-m in diameter [10, 11]. The secondary may be on the order of more that half the size of the primary diameter, which would suggest that this is one of the larger secondaries observed in a binary near-Earth asteroid [10]. The orbital period of the secondary is roughly 14.5 hours and seems to be in synchronous rotation about the primary [11].

Observations: Given that this object has a semi-major axis of 0.991, its orbital period (360 days) is close to that of Earth's, and so it has been in favourable viewing geometries during each September of the last few years. In September 2004, an observing campaign was initiated to collect near-IR spectroscopic data on this object. 66063 (1998 RO_1) was observed for two nights (Sept. 17 and 19, 2004 UT) with the SpeX near-infrared spectrograph at the NASA Infrared Telescope Facility (IRTF) located atop Mauna Kea, Hawai'i [12]. A total of 80 spectra were obtained over the course of the observing run. The weather was photometric and the asteroid was observed at low airmass throughout each of the two nights. The object's V-mag ranged from 15.3 to 15.6, which coupled with the weather conditions, allowed for high signal-to-noise spectra to be obtained.

Data Analysis and Interpretation: After data collection, the asteroid and associated standard star spectra were extracted into one-dimensional arrays using IRAF, and then further processed to the final spectra with the SpecPR program [13]. Data of 66063 (1998 RO_1) for the night of Sept. 19, 2004 UT were averaged together and the final spectrum for this night is shown in Fig. 1. This spectrum represents a total of 24 individual spectra. The remaining spectra from this object obtained on Sept. 17, 2004 UT are in the process of being analyzed.

Analysis of the average spectrum in Fig. 1 involves obtaining band parameters (centres and areas) for each of the features that are present. The spectrum of this binary asteroid has two features, Band I centred near the one micron region, and Band II, centred near the two micron region. Such a combination of features is indicative of an object with an olivine and pyroxene composition. Taxonomically this object would be classified as a member of the S-type asteroid population [14]. A more precise description of the positions of these bands is as follows: Band I centre at 0.95 ± 0.002 µm and Band II centre at 1.92 ± 0.002 µm. The band areas are ratioed as Band II area/Band I area to give a Band Area Ratio (BAR) value of 0.49 ± 0.01.

Plotting the two Band centres on a band-band plot reveals that the point for the asteroid lies above the calibration curve for orthopyroxenes and clinopyroxenes shown in Fig. 2 [15, 16]. This fact combined with the BAR value of 0.49 ± 0.01 suggests that there must be a significant olivine component present. In addition, the asymmetry of the Band I feature also suggests that this asteroid has a significant amount of olivine present on its surface (Fig. 1). The calculated opx/(ol+opx) percentage from the obtained BAR value is roughly 0.25 ± 0.01 using the equation given by Gaffey et al. (2002) [17]. If the displacement of the Band I position is solely due to olivine, then the Band I center position due to the pyroxene contribution is approximately 0.92 ± 0.01 µm. Using the equations developed by Gaffey et al. (2002), the pyroxene chemistry is estimated to be $Wo_{4\text{-}6}Fs_{31\text{-}32}$ [17].

Plotting the Band I position and BAR of this asteroid on a Cloutis diagram indicates that it lies within the S(IV) field and may have an affinity to the ordinary chondrite meteorites [18]. The chondritic subtype that most closely matches this asteroid's absorption feature parameters would be the L-chondrites, suggesting that the parent body of this asteroid experienced little heating. However, the calculated orthopyroxene chemistry has an Fs component that is too high for ordinary chondrites. L-chondrites have $Fs_{19\text{-}22}$ and LL-chondrites have $Fs_{22\text{-}25}$ [19], so perhaps there is a spectrally significant high-Ca pyroxene component present on the surface of this object as indicated by the longer than expected Band II position for ordinary chondrites as discussed in Gaffey et al. (2002) [17]. 66063 (1998 RO_1) has a Band II center located at 1.92 µm, but the expected L-chondrite Band II position is 1.88 µm. Typically the Band II positions for L-chondrites are longer than expected due to the presence of a high-Ca pyroxene (augite/diopside) component in the matrix of these meteorites [19].

The Band I position and BAR for 66063 (1998 RO_1) seem to be consistent with an undifferentiated assemblage similar to an L-chondrite, but the orthopyroxene (Fs) composition derived assuming a single pyroxene is above the L-chondrite range. The simplest and favoured interpretation is that this binary near-Earth asteroid represents a L-chondrite-like assemblage, but the data does not preclude that the object could have been generated as a result of a low-partial melt and therefore may be more similar to a primitive achondrite. An improved calibration appropriate for a "two-pyroxene" assemblage would be necessary to distinguish between the two options.

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Fig 1: Ave. spectrum of 66063 (1998 RO_1) for Sept. 19, 2004 UT.

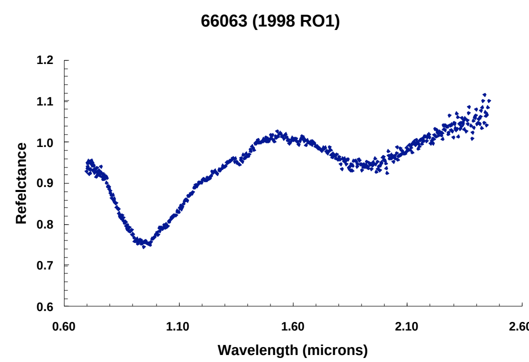

Fig 2: Pyroxene Band I vs. Band II plot