COMPOSITIONAL AND DYNAMICAL STUDIES OF ASTEROIDS LOCATED IN/NEAR THE 3:1 KIRKWOOD GAP: 495 EULALIA - A FIRST STEP.
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Introduction: The Kirkwood gaps are severely depleted zones in the asteroid belt located at proper motion resonances with Jupiter (semi-major axes where the orbital period is a small integer fraction of Jupiter's orbital period). Objects in the 3:1 Kirkwood gap at 2.50 AU have their eccentricities pumped up and are removed from the resonance by collisions with other asteroids, by gravitational encounters with Jupiter or the terrestrial planets, or by collision with the Sun. Theoretical models indicate the majority of asteroidal material delivered to the inner solar system, particularly Earth, originates from the 3:1 mean motion resonance and the ν_6 secular resonance [1-8].

Asteroids and collisionally-ejected fragments with semi-major axes in the 2.47-2.53 AU range undergo chaotic orbital evolution on timescales as short as 10^6 years [9]. Changes in eccentricity, inclination, and semi-major axis due to gravitational perturbations, collisions, and the Yarkovsky effect deliver nearby meter-to-kilometers-scale objects into the chaotic zone of the 3:1 resonance [7-12]. These objects are rapidly (10^6–10^7years) transferred to Earth- and Mars-crossing orbits making the 3:1 resonance a major potential source for meteorites and NEA's [13-15]. [3] developed a model that predicted which specific asteroids would efficiently deliver material into the 3:1 Kirkwood Gap, and estimated the percentage of fragments delivered into planet crossing orbits. For purposes of this and future studies, asteroids that have been predicted to have at least 20% of their fragments transferred into such orbits were selected as observing candidates.

Currently, four of the 135 distinguishable meteorite parent bodies [16] have been specifically identified [17-19]. These four parent bodies account for ~40% of terrestrial meteorite falls. This leaves ~60% still to be accounted for. Asteroids within the "feeding zone" of the 3:1 resonance are obvious candidates for such parent bodies. Previous spectral investigations of a small set of asteroids near the 3:1 resonance were limited to VNIR (~0.3 – 0.95 μm) spectra as part of a search for the parent bodies of the ordinary chondrites [20-24]. Such limited wavelength coverage does not permit the detailed mineralogical analysis required to rigorously test possible meteorite affinities. Additionally, ambiguities introduced by space weathering severely undermine the validity of any putative asteroid-meteorite links derived from curve matching, requiring the use of interpretive methodologies insensitive to space weathering [25]. Future research will search for any linkage between bodies adjacent to the 3:1 resonance and the meteorite types in the terrestrial collections. The goal is to better understand the parent bodies of the various types of meteorites in the Earth collection. In addition, by combining the cosmic ray exposure ages of meteorites linked to specific asteroids, additional constraints can be placed on the mean dynamical lifetime of objects from the 3:1 resonance in space before impacting the Earth.

Methodology: 495 Eulalia is located within the chaotic zone of the 3:1 Kirkwood gap (2.487 AU), has a SIMPS diameter of 38.85±1.4 km, and an IRAS albedo of 0.0571±0.004 [26], and is a member of the C taxonomic class [27]. Observations of 495 Eulalia were remotely obtained on the night of June 11, 2007 UT using the NASA Infrared Telescope Facility located on Mauna Kea, Hawai'i. The spectra were obtained using SpeX in the low resolution spectrographic mode. A total of ten spectra were obtained, of these, six were used in the analysis. Spectra were discarded due to persistence, star contamination, and excessive noise.

Asteroid and local standard star spectra were interspersed within the same air mass range to give optimal modeling of atmospheric extinction. 495 Eulalia's spectral observations were 120 seconds long, standard star HD 166544 spectral observations were four seconds long, and solar analog SAO 120107 spectral observations were three seconds long. Extraction of spectra, determination of wavelength calibration, and data reduction were done using procedures outlined by [28-30]. Each asteroid flux curve was divided by the starpack that most effectively removed the atmospheric water vapor features to produce a final spectrum. Individual spectra were averaged together to produce a nightly average spectrum. The ratio of the (asteroid/standard star) / (solar analog/standard star) was not used in the final anlysis as the introduction of the solar analog introduced inconsistent slope variability. The issue is currently under investigation.

Analysis: Eulalia's spectrum is devoid of any mineralogically diagnostic absorption features and reveals a slight negative slope. 495 Eulalia was plotted with Vilas's [31] visible data to obtain wavelength coverage extending from 0.4 μm mto 2.5 μm (Figure 1). Even though the spectrum is "featureless", it does indirectly convey compositional information through the albedo and slope. Using [32] and looking at the "featureless" classes of meteorites, the negative slope argues against irons and enstatite chondrites. However, it is unlikely that any pure phase would fit 495 Eulalia's spectrum. So a possibility could be organics, and along with organics, there should be many other phases in dark asteroid regoliths, some of them, especially fine-grained magnetite and fine-grained sulfides (very abundant in carbonaceous chondrites) that may suppress the slopes. The albedo of 0.0571±0.004 is a strong indication that 495 Eulalia is not a remnant iron core. Further research of the meteorite classes uncovered a plausible meteorite link. The spectrum of $CV3_{OXB}$ Grosnaja [33] shares similar attributes with 495 Eulalia such as a "featureless" spectrum, slightly negative slope, and an albedo of 0.055 (Figure 2).

[3] has predicted Eulalia to deliver 48.7% of her fragments into the resonance, and with delivery timescale of 10^6-10^7 years calculated by [9], the likelihood of reaching Earth is high. Furthermore, the cosmic ray exposure ages of the $CV3_{OXB}$ carbonaceous chondrite Grosnaja (1.7 Ma) further support that 495 Eulalia is a plausible parent body for this meteorite.

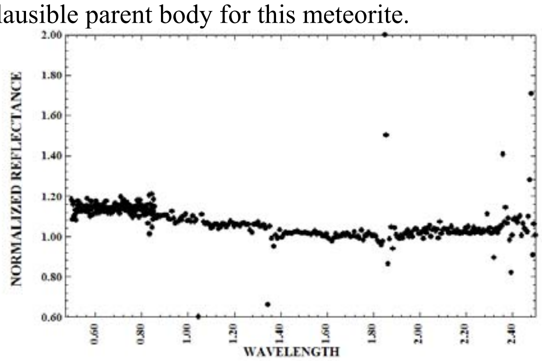

Figure 1: VNIR spectrum of 495 Eulalia.

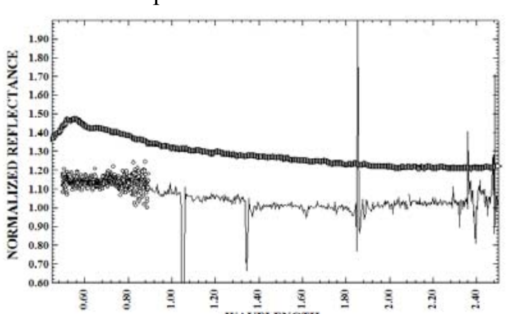

Figure 2: Normalized spectrum of 495 Eulalia (offset) plotted with normalized spectrum of CV3 Grosnaja.

Conclusions: 495 Eulalia's spectral properties are consistent with spectral properties of $CV3_{OXB}$ Grosnaja, and the 1.7 Ma meteorite's CRE age make it a plausible parent body for this meteorite. Dynamical models have indicated meteoritic material is being transferred from the 3:1 Kirkwood Gap to Earth crossing orbits, so it's time we begin to study this region in the mainbelt. Meteorites give us insight into the processes that took place during the late nebular/early solar sytem stages and by constraining the mineralogical composition of 3:1 resonance asteroids we can better put a spatial context on the conditions that were taking place. Establishing asteroid-meteorite links is important to understanding nebular processing/solar system formation. 495 Eulalia is just the first of several asteroids in the 3:1 resonance to be studied.

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Acknowledgements: This research was funded by NASA Planetary Geology and Geophysics Grant NNG04GJ86G [MJG].