THE FAMILY OF ASTEROID (6) HEBE: INITIAL RESULTS. S. K. Fieber-Beyer[1,2] and M. J. Gaffey,[1,2] [1]Dept. of Space Studies, Box 9008, Univ. of North Dakota, Grand Forks, ND 58202. [2]Visiting astronomer at the IRTF under contract from the NASA, which is operated by the Univ. of Hawai'i Mauna Kea, HI 97620. sherry-fieb@hotmail.com

Introduction: Focusing on asteroids identified as strong meteorite sources based on dynamical criteria [1-3], led to the identification of asteroid (*6*) Hebe, located near the intersection of the 3:1 and ν_6 resonances, as the probable parent body of an abundant meteorite type. Based on spectral data, [4] identified Hebe as an H-type chondrite. [*Based on isotopic and chemical criteria, meteorite investigators have concluded that the ordinary chondrite groups (the abundant H, L, LL and the rarer HH, H/L & L/LL types) each derive from a single original parent body*.] The Portales Valley meteorite [5-7] and subsequent dynamical analysis by [8] strengthened this conclusion. Furthermore, the Pribram (H5) meteorite fall's pre-terrestrial orbital elements are consistent with delivery via the ν_6 secular resonance [9-10], the Annama (H5) meteorite's orbital elements are consistent with delivery via the 3:1 Kirkwood Gap [11], as well as the recent near-Earth asteroid identifications of H-chondrite assemblages that have been proposed as possible (*6*) Hebe fragments [12-16], indicating additional H-chondrites are delivered from this dynamical region.

For the past several years spectral investigation of additional asteroids adjacent to the 3:1 mean motion resonance has been conducted with the goal of identifying possible meteorite parent bodies [12, 16-21]. During this time, a small number of asteroids with semi-major axes near Hebe which have H-chondrite type spectra and mineralogies were identified. However, they are located on the opposite side of the 3:1 Kirkwood Gap than Hebe. These three asteroids were proposed to be a part of a small Hebe genetic family [12, 16]. Dynamics show after a collisional event produces fragments, fragments are influenced by secular resonances, mean-motion resonances, and Yarkovsky/YORP effects [22], which can spread them in both proper element space, inclination and/or frequency domain such that members may be neighbors in proper element space, but not frequency domain and vice versa [23-25]. [23] examined the Vesta, Eunomia, Eos, and Koronis families using frequency domains and found members on the periphery that most likely drifted due to Yarkovsky forces. Numerical simulations by [6] show Hebe fragments would have a high drift rate and that meteoroids can jump the resonance (e.g., Figs 14-16 in [6] explicitly show asteroids can jump inward or outward in semi-major axis to cross a resonance).

If this small group is part of a Hebe genetic family, then logic implies that there should be Hebe-derived objects nearer Hebe itself, which is the focus of the proposed research effort. If this hypothesis cannot be verified and there are no H-chondrite bodies on the short side of the gap, then the alternate scenario would suggest that the asteroids located on the far side of the gap condensed from the same nebular compositional reservoir inferring several H-chondrite parents, a conclusion which is at odds with the meteorite isotope data, which point to a single H-chondrite parent body [26]. The cosmic ray exposure ages of H-chondrites span from <1 Myr to ~80 Myr, but exhibit a distinct peak near 7 Myr, which includes nearly half of the H-chondrites, and an earlier smaller cluster at ~33 Myr. These clusters of ages are attributed to single events that ejected large volumes of material from the H-chondrite parent body [e.g., 27-29]. In addition to a plethora of meter scale meteoroids, these events may have ejected larger fragments producing a temporary family of multi-kilometer objects. The CRE peaks and the chemical and isotopic constraints that the H-chondrites (meteorite collections include more than 6,900 H-chondrite samples among the ~22,500 cataloged meteorites– British Museum Catalog of Meteorites 5th Ed.) come from a single parent body would seem to preclude any significant contributions from a second original parent body. In that case, any H-chondrite family would most probably derive from that same parent body.

The use of diagnostic spectral parameters can robustly identify H-type assemblages ("Yes") even in the presence of space weathering [e.g. 30]. Spectral effects of metamorphism do not mimic the spectral difference between different ordinary chondrite types, nor are the spectral changes associated with partial or complete differentiation consistent with the identification of H-chondrite assemblages.

Observations and Data Reduction: Near-infrared spectra of 37 asteroids were obtained throughout 2015-2017 at the NASA IRTF using the SpeX instrument [31] in the low-res spectrographic mode (0.68–2.54 μm). Asteroid and standard star observations were interspersed within the same airmass range to allow modeling of atmospheric extinction. Data reduction was done using previously outlined procedures [32,33].

Analysis: We have completed band analysis on 24/37 of the targets—the other 13 are currently in queue. Several of this particular subset of asteroids have absorption features located near 1- and 2- μm. We utilized the band centers and band area ratios (BAR), which are diagnostic of the abundance and composition of the mafic silicates [e.g.,32-41], to estimate the surficial compositions. We estimated the error using several polynomial fits which sampled different ranges of points within the Band I and II spectral intervals. The uncertainty was estimated from the difference between the min & max determined values. After initial measurement of the Band I and Band II centers, the pyroxene chemistry was determined using [32]. If the pyroxene chemistry was consistent with an HED assemblage, [40]'s equations were used to verify the pyroxene chemistry and if the pyroxene chemistry was consistent with an ordinary chondrite assemblage, [41]'s equations were applied as verification of the derived silicate mineralogy.

Results: 5/24 of the currently analyzed asteroids have answered "Yes" to having chemistries consistent with H-chondrites representing 21% of the bodies recently parametrically examined. In total, four asteroids are located on the short-side and four asteroids are located on the long-side of the 3:1 Kirkwood Gap (Fig 1)

What does this mean? We now have definitive proof that asteroids with H-chondrite mineralogies reside on both sides of the 3:1 Kirkwood Gap. This implies that (6) Hebe does, in fact, have an old-dispersed family. Our study provides spectral evidence for Bottke's hypothesis of resonance jumping. We still have 13 asteroids to analyze, and given these results, will likely add one or two more bodies to this newly identified genetic family.

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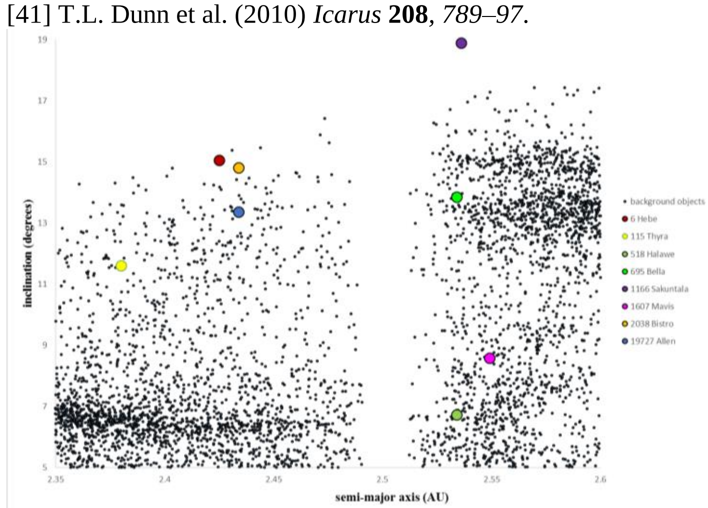

Figure 1: Asteroids identified as having surficial mineralogies consistent with the H-chondrites.

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