Near-infrared Spectroscopy of 3:1 Kirkwood Gap Asteroids 908 Buda and 1772 Gagarin. S. K. Fieber-Beyer[1,2,3] and M. J. Gaffey[1,3]. [1]Dept. of Space Studies, Box 9008, Univ. of North Dakota, Grand Forks, ND 58202. [2]Dept. of Earth System Science & Policy, Box 9007, Univ. of North Dakota, Grand Forks, ND 58202. [3]Visiting astronomer at the IRTF under contract from the NASA, which is operated by the Univ. of Hawai'i Mauna Kea, HI 97620. sherryfieb@hotmail.com gaffey@space.edu

Introduction: The Kirkwood gaps are severely depleted zones in the asteroid belt located at proper motion resonances with Jupiter. Objects near the 3:1 Kirkwood Gap at 2.5 AU have their eccentricities pumped up and are removed from the resonance by collisions with other asteroids, by collisions or gravitational encounters with Jupiter or other planets, or by collisions with the Sun. Theoretical models indicate the majority of asteroidal material delivered to the inner solar system, particularly to the Earth, originates from the 3:1 mean motion and the ν_6 secular resonances [1-4].

Asteroids and collisionally-ejected fragments with semi-major axes in the range of 2.47-2.53 AU undergo chaotic orbital evolution on timescales as short as 10^6 years [5]. Changes in eccentricity, inclination, and semi-major axis due to gravitational perturbations, collisions, and the Yarkovsky effect can deliver nearby meter-to-kilometers-scale objects into the chaotic zone of the 3:1 resonance [6-11]. 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 near-Earth asteroids [10-13].

Currently, probable parent bodies have been identified for only four [14-16] of the 135 distinguishable meteorite classes [17]. These three parent bodies: 4 Vesta, 3103 Eger, and 6 Hebe account for ~40% of terrestrial meteorite falls. Thus, the sources of ~60% of the meteorite flux and ~97% of the meteorite classes still need to be accounted for. Asteroids within the "feeding zone" of the 3:1 resonance are obvious candidates for such parent bodies.

Near-infrared data (0.8-2.5 µm) for most asteroids adjacent to the 3:1 resonance have not been published. The NIR spectral coverage is needed for detailed characterizations of their surface minerals. This research explores possible links between two asteroids located near the 3:1 resonance (908 Buda and 1772 Gagarin) and the meteorite types in the terrestrial collections.

Observations/Data Reduction: Near-infrared spectra of 908 Buda and 1772 Gagarin were obtained in May 26, 2009 at the NASA IRTF using the SpeX instrument in the low-resolution spectrographic mode. Asteroid and local standard star observations were interspersed to allow optimal modeling of atmospheric extinction. Data reduction was done using procedures outlined by [18-19]. Figure 1 illustrates the solar corrected near-infrared spectra of 908 Buda (top) and 1772 Gagarin (bottom) a value of 0.3 reflectance was added to 908 to offset the spectra. The water band correction is poorer than normal for both spectra.

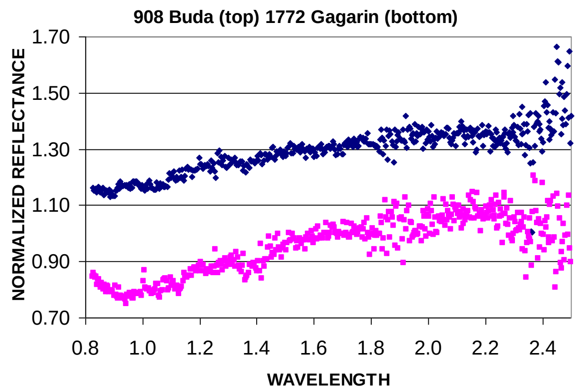

Figure 1

Analysis/Interpretations: The spectra of 908 Buda and 1772 Gagarin both show absorption features located at ~1 µm. A straight-line continuum was fitted through the reflectance peaks bracketing the absorption feature and the band center was determined by fitting an n-order polynomial to the resulting continuum-removed feature.

For 908 Buda, the Band I center was very weak and calculated to be 1.04 ± 0.03 µm. An ~2 µm absorption feature is absent. The near-infrared spectrum was merged with the SMASS [20] visible spectrum (Fig. 2) to obtain wavelength coverage extending from 0.4-2.5 µm.

Two interpretations appear most plausible for 908 Buda. First, the IRAS albedo [21] of 0.1576 as well as the nature of the spectrum itself suggests an M-taxonomic type, which is in disagreement with the L-taxonomic type suggested by [20]. The weak 1.04 ± 0.03 µm Band I Center and moderate albedo suggest a surface composed mostly of metal with minor olivine. This interpretation would suggest 908 Buda is a portion of a crust mantle boundary of a differentiated object. A possible meteorite analog for 908 Buda may be a pallasite type meteorite or an olivine-bearing iron meteorite. The second interpretation involves an object which did not undergo differentiation, but experienced partial melting and removal of the basaltic melt, but where the temperatures were not high enough to allow the metal and olivine to efficiently segregate.

For 1772 Gagarin, the Band I center was calculated at 0.98 ± 0.02 µm. An absorption feature in the

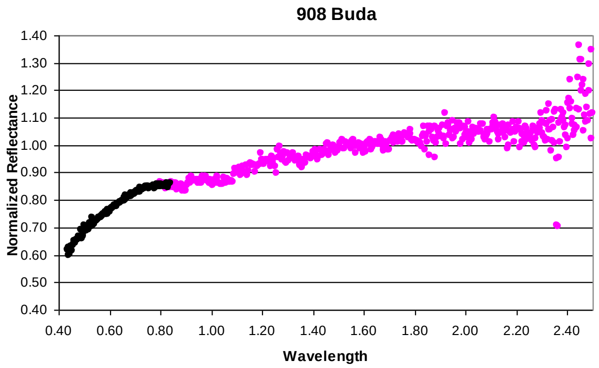

Figure 2

~2 µm region is absent. The near-infrared spectrum was merged with the SMASS [20] visible spectrum (Fig. 3) to obtain wavelength coverage extending from 0.4-2.5 µm.

Asteroid 1772 Gagarin's spectrum is similar to, but yet different from the carbonaceous chondrite (CM2) meteorite Cold Bokkevelt. When plotted with the spectrum of Cold Bokkevelt [22] one will notice the apparent 1.4 µm absorption feature in both the asteroid and meteorite spectra (Fig. 3). The 1.4 µm feature in 1772 is an artifact due to poor atmospheric correction and the 1.4 µm feature in Cold Bokkevelt is probably due to terrestrial contamination. The CM2 meteorites exhibit a diverse set of features between 0.6 and 1.2 µm. Both spectra exhibit the same overall slope in the NIR and both exhibit a feature around ~0.9 µm, however the bands are offset from one another, as 1772 Gagarin's feature is located at longer wavelengths. An absorption feature can be noted in the ~0.6 µm region in both spectra, however the slopes associated with the feature are drastically different and the feature itself is offset between the two spectra. The most likely interpretation for 1772 Gagarin suggests a meteorite type with a phyllosilicate assemblage similar to that found in the carbonaceous chondrites. The caveat to this interpretations rests on albedo (an albedo is not available for 1772), if this interpretation is to hold then the albedo must be low (i.e. <10%).

Conclusions: Asteroid 908 Buda has two competing interpretations. One suggests complete differentiation with 908 being a portion of the crust-mantle boundary possibly yielding pallasites to near-Earth space. The second suggests a heated body that did not attain temperatures high enough to undergo complete differentiation, but experienced partial melting.

1772 Gagarin's spectral properties fall within the spectral range of CI1 / CM2 carbonaceous chondrite meteorites and suggests the surface has a phyllosilicate assemblage similar to that of a CM2 meteorite.

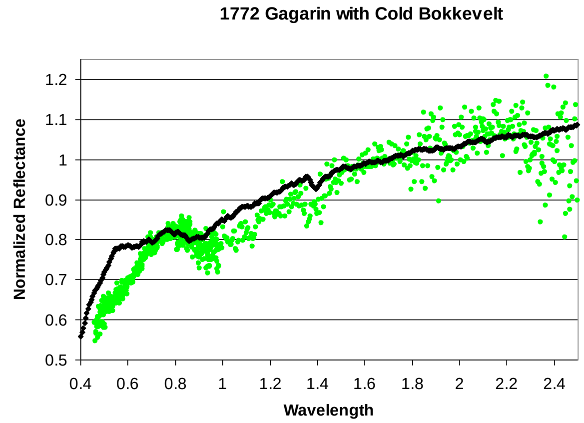

Figure 3

Dynamical models have indicated meteoritic material is being transferred from the 3:1 Kirkwood Gap to Earth crossing orbits. These meteorites give us insight into the processes that took place during the late nebular/early solar system stages and by constraining the mineralogical composition of 3:1 resonance asteroids we can put a better spatial context on the conditions that were taking place. Establishing asteroid-meteorite links is important to understanding nebular processing and/or solar system formation. 908 and 1772 are two of many asteroids near the resonance under investigation.

References: [1] P. Farinella et al. (1993) *Icarus* 101, 174-187. [2] A. Morbidelli et al. (1995) *Icarus* 114, 33-50. [3] A. Morbidelli et al. (1995) *Icarus* 115, 60-65. [4] J.H. Ji et al. (2007) *Chin. J. Astron. Astrophys* **7**, 148-154. [5] J. Wisdom (1985) *Icarus* 63, 272-289. [6] W.F. Bottke et al. (2000) *Icarus* 145, 301-331. [7] W.F. Bottke et al. (2006) *Ann. Rev. Earth Planet. Sci.* 34, 157-191. [8] P. Farinella et al. (1999) *Science* 283, 1507-1510. [9] R. Greenberg et al. (1983) *Icarus* 55, 455-481. [10] W.F. Bottke et al. (2005) *Icarus* 179, 63-94. [11] B.J. Gladman et al. (1997) *Science* 277, 197-201. [12] D.L. Rabinowitz (1997) *Icarus* 127, 33-54. [13] P. Farinella et al. (1994) *Nature* 371, 315-317. [14] T.B. McCord et al. (1970) *Science* 168, 1445-1447. [15] M.J. Gaffey et al. (1992) *Icarus* 100, 95-109. [16] M.J. Gaffey et al. (1998) *MAPS.* 33, 1281-1295. [17] K. Keil (2000) *Planet. Space Sci.* 48, 887-903. [18] M.J. Gaffey et al. (2002) *Asteroids III* Univ. of Arizona Press, pp. 183-204. [19] P.S. Hardersen et al. (2005) *Icarus* 175, 141-158. [20] Bus S. J. and R. P. Binzel (2002) *Icarus* **158**, 106-145. [21] Tedesco, E.F. et al. (2002) *The Astronomical Journal*, 123, 1056-1085. [22] M.J. Gaffey (1976) *J.G.R.* 81, 905-920.

Acknowledgements: This work was supported by NASA HQ under the NESSF Grant NNX08AW0414 (S.K.F.) and NASA PGG Program Grant NNX07AP73G (M.J.G).