A SURVEY OF BASALTIC ASTEROIDS IN THE MAIN BELT. N. A. Moskovitz[1], M. Willman[1], S. J. Lawrence[2], R. Jedicke[1], D. Nesvorny[3] and E. J. Gaidos[2]. [1]Insitute for Astronomy, Univ. of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, nmosko@ifa.hawaii.edu, willman@ifa.hawaii.edu, jedicke@ifa.hawaii.edu [2]Department of Geology and Geophysics, Univ. of Hawaii, POST Building, Honolulu, HI 96822, slawrenc@hawaii.edu, gaidos@hawaii.edu [3]Department of Space Studies, Southwest Research Institute, 1050 Walnut Street, Suite 400, Boulder, CO 80302, davidn@boulder.swri.edu

Introduction: Basaltic materials on the surface on an asteroid are indicators of past partial melting, a phenomenon that occurs due to the complicated interplay of heating (e.g. short-lived radioactive isotope decay, gravitational energy released during accretion, chemical reactions) and cooling processes (e.g. thermal radiation, fluid convection) within the interior of rocky bodies. Thus far astronomical observations have been unsuccessful at providing a coherent picture of how these processes affect the observed diversity amongst Main Belt asteroids, specifically with regards to metal-silicate differentiation. This program has been designed to discover new basaltic asteroids, thus aiming to provide an observational constraint on the distribution of asteroidal differentiation throughout the Main Belt and a reconciliation of the discrepancy between the number of differentiated parent bodies represented by iron meteorites, approximately 60 [1], and the 3 known occurrences of Main Belt differentiation [2][3][4].

Selecting Basaltic Asteroid Candidates: To maximize the potential for discovery of unique instances of Main Belt differentiation, candidate basaltic asteroids are chosen based on two selection criteria: (1) they have photometric colors similar to the Vestoid family of basaltic asteroids and (2) are dynamically distinct from this family. Eight different SDSS Moving Object Catalog [5] *ugriz* color combinations and two principle component colors [6] are used to define regions in color-color space occupied by the Vestoids. Basaltic candidates are then chosen as those that lie within these regions. An analogous process is applied to exclude candidates that lie within the region of orbital element phase space occupied by the Vestoids. Figures 1 graphically depict the dynamical selection of the target asteroids.

Observations: To unambiguously determine whether our targets have basaltic surfaces, low-resolution spectroscopy of candidate asteroids is performed using the Echellette Spectrograph and Imager (ESI) on Keck II [7] and the Supernova Integral Field Spectrograph (SNIFS) on the University of Hawaii, 2.2 meter telescope [8]. The broad wavelength coverage of these instruments is well suited to resolving both the 0.9 micron olivine/pyroxene absorption feature and the 0.5 – 0.7 micron spectral slope that are signatures of a basaltic surface. To date, 35 targets have been observed as part of this campaign. Reduction of these data is still underway, though the initial results suggest that greater than ½ of our targets have V-type spectra. However many of these are most likely unclassified Vestoids that lie at the dynamical periphery of this family.

Of the V-type objects that have been revealed by this survey, three have proven to be particularly interesting. Two of these, asteroids 38070 (1999 GG2) and 9553 Colas, have proper orbital elements of a' < 2.2 AU, e' < 0.15 and i' < 3.4 degrees (Fig 1). The differences in orbital elements between these objects and the Vesta family are difficult to explain by the Yarkovsky effect, resonance scattering or other dynamical effects. To have ejected either of these from Vesta to their current orbits would have required an unlikely ejection speed of several km/s [9]. It seems that these objects are not fragments linked to the Vesta family; instead they may have originated from other differentiated parent bodies. In October of last year asteroid 38070 was bright enough to allow an infrared follow-up observation with SPEX on NASA's Infrared Telescope Facility [10]. The SPEX and ESI spectra of asteroid 38070 are plotted in Figure 2.

A third object of interest was observed with ESI in October of 2006. The spectrum of this asteroid is shown in Figure 3. Unfortunately this object will be too faint for infrared follow-up observation until late in 2007. Nevertheless, the optical spectrum reveals a truly unusual object. Longwards of 0.75 μm this spectrum displays the basaltic signature of an olivine/pyroxene absorption band. However the deep absorption feature centered at 0.62 μm is not observed in any V-type asteroids. Furthermore, the dynamical properties of this object place it in the outer Main Belt (a'=2.8 AU), which if confirmed to be V-type would make it the third V-type discovered exterior to the 3:1 mean motion resonance at 2.5 AU.

The Composition of Asteroid 38070: The spectrum of asteroid 38070 displays the well-defined 1 μm and 2 μm absorption features associated with the HED meteorites and the HED parent body [2][11][12]. Figure 2 shows a comparison between asteroid 38070 and a RELAB spectrum of the Y74450 meteorite, a polymict eucrite [13]. There is remarkably good agreement between the Y74450 laboratory spectrum and the observed spectrum of asteroid 38070. This strongly indicates that the surface materials on this asteroid are comprised of similar, eucrite-like components (i.e. pyroxene and plagioclase).

Distribution of Basaltic Asteroids: One of the primary goals behind the discovery of new basaltic asteroids is to map their spatial distribution. Currently it is not known whether these objects formed in-situ throughout the Main Belt or instead were formed in the inner Solar System (where solid-body accretion times were faster and thus partial melting and differentiation were more likely) and later scattered radially outwards into stable Main Belt orbits [14]. Resolution of this problem may be found by observationally determining the distribution of basaltic asteroids throughout the Main Belt.

The criteria that are used in the selection of basaltic candidates yields a distribution of objects across a range of semi-major axis. Correcting this distribution for the completeness of the SDSS as a function of semi-major axis and multiplying by the fraction of observed candidates that are found to be basaltic produces an unbiased distribution of basaltic asteroids throughout the Main Belt. This distribution can then be compared with theory [14] to address whether partial melting and differentiation occurred within the Main Belt. This will have important consequences for the constraint of planetesimal accretion times in this region of the Solar System; if accretion proceeded slowly in the Main Belt then short-lived radioactive isotopes would not provide an adequate heat source to drive silicate melting and subsequent differentiation.

References: [1] Chabot N. L. and Haack H. (2006) in *Meteorites and the Early Solar System II*, eds. D. S. Lauretta and H. Y. McSween Jr. [2] McCord T. B. et al. (1970) *Science*, 168, 1445. [3] Lazzaro D. et al. (2000) *Science*, 288, 2033. [4] Hammergren, M. et al. (2006), submitted to *Icarus*, astro-ph/0609420. [5] Ivezic Z. et al. (2002) in *Survey and Other Telescope Teechnologies and Discoveries*, eds. J. A. Tyson and S. Wolff. Proceedings of SPIE Vol. 4836. [6] Nesvorny D. et al. (2005) *Icarus*, 173, 132. [7] Sheinis A. I. et al. (2002) *PASP*, 114, 851. [8] Lantz, B. et al. (2004) in *Optical Design and Engineering*, eds. L. Mazuray, P.J. Rogers and R. Wartmann. Proceeding of SPIE Vol. 5249. [9] Carruba et al. (2006) submitted to *A&A*, astro-ph/0506656. [10] Rayner, J.T. et al. (2003) *PASP*, 115, 362. [11] Gaffey M. J. (1976) *JGR 81*, 905-920. [12] Burbine, T. H. et al. (2001) MAPS, 761-781. [13] Delaney J. S. et al. (1983) Proc. 8th NIPR, 206-233. [14] Bottke, W.F. et al. (2006) *Nature*, 439, 821.

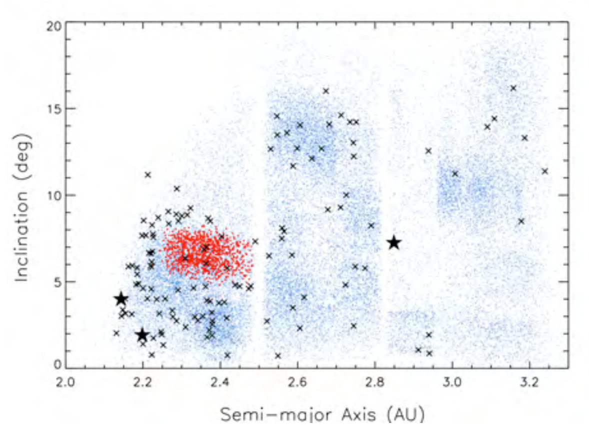

Figure 1 Dynamical selection of basaltic asteroids. Small dots are SDSS objects, large dots the Vestoids and X's mark basaltic candidates. The three stars indicate newly discovered V-types that are likely dissociated from the Vestoids.

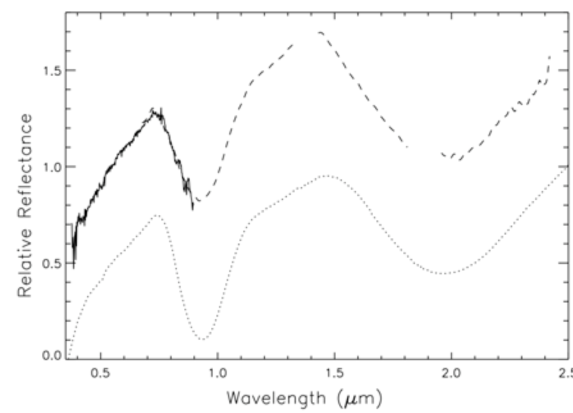

Figure 2 Reflectance spectrum of asteroid 38070. ESI data is plotted as the solid line and SPEX as the dashed. The dotted curve, which has been offset for clarity, is a laboratory spectrum collected from a 25-45 μm size fraction of the polymict eucrite Y74450 (RELAB spectrum **MB-TXH-071-B)**.

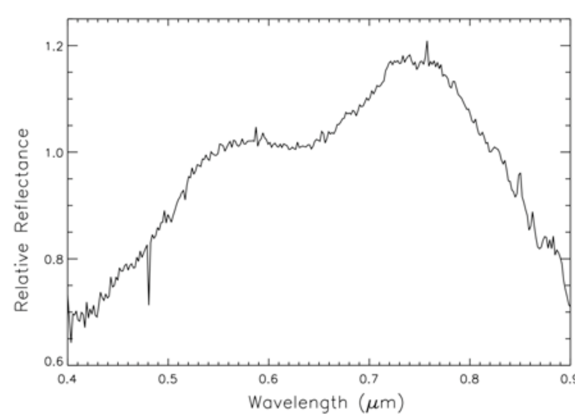

Figure 3 ESI spectrum of a potential V-type asteroid. This spectrum shows the blue-edge of the 1 μm basaltic absorption feature and an unusual 0.6 μm absorption feature.