Surface Mineralogy of Mars-Crossing Asteroid 1747 Wright: Analogous to the H Chondrites

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Introduction

Asteroid dynamical work has suggested that differentiated asteroids, precursors of metallic (core) and olivine-rich (mantle) fragments may have formed in the terrestrial planet region and are now interlopers to the inner main-belt [1]. Furthermore, recent work has suggested that the Hungaria asteroids are the survivors of an extended and now largely extinct portion of the asteroid belt that existed between 1.7 and 2.1 AU early in solar system history [2] (Figure 1). The mineralogy of these relatively close objects hold important clues to the dynamical evolution of the inner-Solar System. In particular, a key aspect of asteroid mineralogy is the abundance and composition of olivine and pyroxene, which can reveal details regarding the degree (or lack) of igneous differentiation.

Pure olivine-rich A-types remain cryptic among the observable asteroids. However, a number of small (<~8 km) asteroids that reside *interior* to the main-belt (i.e., Hungaria Group, Mars-crossers, near-Earth asteroids) are thought to be rare olivine-rich A-type asteroids in one or more visible-light taxonomic surveys [3,4,5,6]. Therefore, it is vital to examine these objects not just in terms of their taxonomic types, but also in terms of their detailed mineralogy. Interestingly, eight presumed A-types *interior* to the main-belt have recently been shown to be classified as S-type asteroids after further spectral data was acquired into the near-infrared (NIR) [7,8]. These results are consistent with spectral studies [9,10] that indicate that two-thirds of all near-Earth asteroids (NEAs) belong to the S- or Q-complexes. These taxonomic types are spectrally analogous to ordinary chondrites [10].

Here we present the visible and near-infrared spectrum (VISNIR) of the Mars-crossing (MC) asteroid 1747 Wright (a = 1.709 AU), heretofore only recorded in visible wavelengths (Figure 3). The spectral type of this asteroid has been uncertain as taxonomic surveys have identified 1747 Wright as an A-type [3,6], Sl-type [5], or an Ld-type [6]. We hypothesize that 1747 Wright is relatively olivine-rich. We test this hypothesis by performing detailed spectral band parameter analyses (Tables 2 and 3).

Observations

- ✓ Spectra recorded using SpeX spectrograph [11] at the NASA Infrared Telescope Facility (IRTF), remote observations from UTK
- ✓ SpeX low-resolution prism mode to obtain 0.7-2.5 µm spectra
- ✓ Reduction performed with IDL-based Spextool provided by the IRTF
- ✓ S/N ≥400 for 1747; S/N ≥100 for 1509 and 3352

Table 1. – Observational circumstances for three asteroids *interior* to the main-belt.

Asteroid	Date (UT)	t_{int} (min)	V(mag)	Airmass	Phase	r (AU)	Standard Star	Spectral Type
1509 Esclangona	2009 09 28	24	15.3	1.175	22.5	1.927	SAO36472	G0
1747 Wright	2012 09 18	16	15.4	1.096	24.3	1.748	SAO72420	G0
3352 McAuliffe	2012 04 17	24	16.1	1.032	12.4	1.520	HD113959	G5

Asteroids *Interior* to the Main-belt - Hungarias

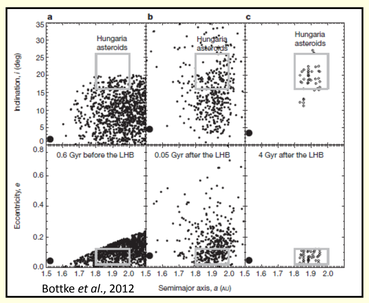

Figure 1. – Evolution of the now extinct E-belt of asteroids, survivors are the Hungaria asteroids, from [2].

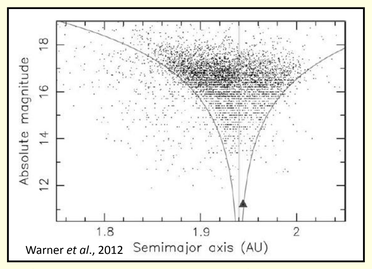

Figure 2. – Hungaria population asteroids (~5000) plotted in H vs. a space. Hungaria family parent 434 Hungaria (triangle) and family zone (gray curves) indicated, from [18].

Mars-Crosser 1747 Wright

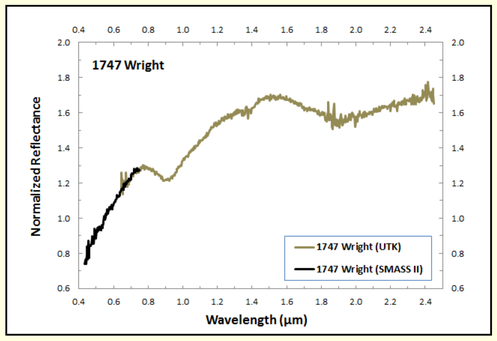

Figure 3. – VISNIR spectrum of 1747 Wright obtained with the SpeX instrument on the NASA IRTF in low-resolution prism mode. Reflectance values normalized to unity at 0.55 µm. Visible data (black) from SMASS II [5].

- Previously classified in visible-light spectral surveys as an A-type [3,6], Sl-type [5], or an Ld-type [6]
- We found 1747 Wright to be a Sw-type (Bus-DeMeo extended taxonomy)
- Presence of Band I near 0.90 µm and Band II near 1.9 µm strongly indicates the presence of pyroxene

Near-Earth Asteroid (NEA) 3352 McAuliffe

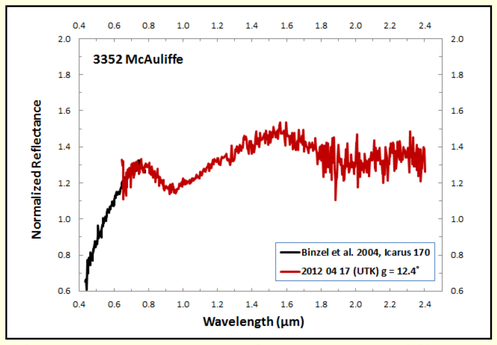

Figure 4. – VISNIR spectra of NEA 3352 McAuliffe obtained with the SpeX instrument on the NASA IRTF in low-resolution prism mode.

- We are interested in the mineralogy of asteroids *interior* to the main-belt (Hungaria, MCs, NEAs)
- Previously classified in visible-light surveys as an A-type [5], or a S- or Sq-type [6]
- We found 3352 McAuliffe to be a S-type (Bus-DeMeo extended taxonomy)

Spectral Band Parameter Analysis

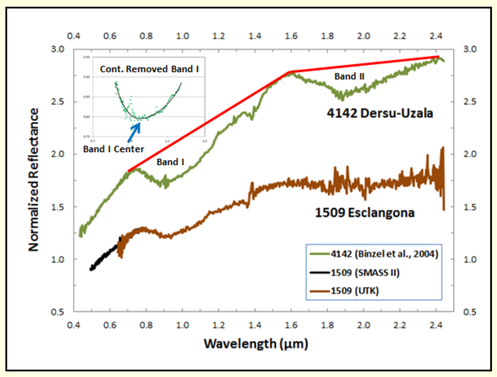

Figure 5. – VISNIR spectra of Hungaria *background* asteroids 1509 Esclangona and 4142 Dersu-Uzala, example continuum lines shown in red. Inset box shows continuum removed Band I (lower ½ band) with polynomial fit an Band I center for Dersu-Uzala. Spectra offset for clarity. Dersu-Uzala data from Binzel *et al.* (2004).

- Band Parameters measured after dividing by a straight line continuum (Figure 5)
- Band I and II Centers and Depths
- Band Area Ratio (BAR)
- Uncertainty for 1747 derived by measuring band centers and depths 10x with different order polynomial fits (2nd through 5th order) and different band ranges (e.g. – full band, lower 1/2 band, lower 1/3 band)

Table 2. – Measured spectral band parameters for four objects located *interior* to the main-belt (Δ = temperature corrected).

Asteroid	T (K)	BI (µm)	BI_{dep} (%)	BII (µm)	ΔBII (µm)	BII_{dep} (%)	ΔBII_{dep} (%)	BAR	ΔBAR
1509 Esclangona	193	0.937	11.55	2.045	2.066	3.46	1.85	0.389	0.303
1747 Wright	204	0.924 ±0.007	11.11 ±1.10	1.914 ±0.014	1.933 ±0.014	7.13 ±1.07	5.70 ±1.07	1.16 ±0.21	1.08 ±0.21
3352 McAuliffe	220	0.942	13.15	1.939	1.955	6.68	5.49	0.508	0.443
4142 Dersu-Uzala	202	0.957	20.45	1.949	1.969	10.36	8.89	0.591	0.512

➢ Typical errors for Band I center (BI ± 0.01), Band I depth (BI_{dep} ± 0.3), Band II center & ΔBII center (BII ± 0.03), Band II depth & ΔBII depth (BII_{dep} ± 0.5), Band Area Ratio (BAR) & ΔBAR (BAR ± 0.04)
➢ Asteroid temperatures calculated as in Burbine *et al.* (2009)

Mineral Abundance and Composition

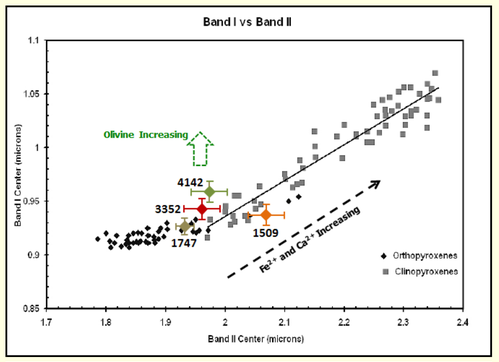

Figure 6. – 1747 Wright and three more asteroids *interior* to the main-belt indicated on the band-band plot from [15]. 1747 Wright plots within the field of orthopyroxene (**black diamonds**), while 1509 Esclangona appears to be more clinopyroxene (**gray squares**) rich.

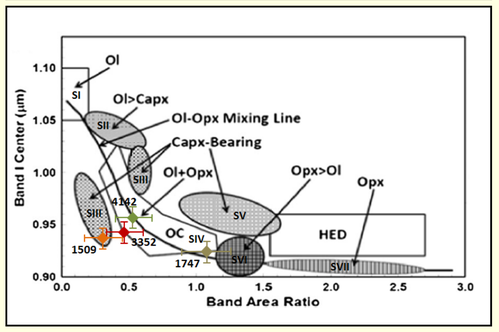

Figure 7. – Mars-crosser 1747 Wright and three more asteroids *interior* to the main-belt shown on the S-subtypes plot from [16], 1509 Esclangona (possibly 1747 Wright & 3352 McAuliffe) plot outside of the SIV field of ordinary chondrites. Ol-Opx mixing line is indicated.

Ordinary Chondrite Analogs

Figure 8. – Four asteroids located *interior* to the main-belt plotted as Fa mol% vs. ol/(ol+px) ratio, compositional fields from [14], error bars shown

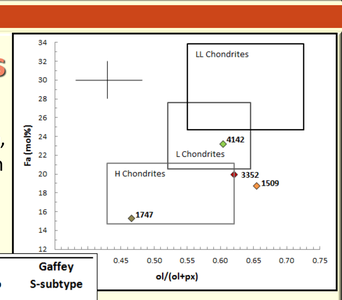

Table 3. – Mineralogy and taxonomy for four asteroids located *interior* to the main-belt.

Asteroid	ol/ (ol+px)	Δol/ (ol+px)	Fo	Fa	Fs	Taxonomy Bus-DeMeo	Gaffey S-subtype
1509 Esclangona	0.63	0.65	81	19	16	Sw	SIII
1747 Wright	0.45 ±0.05	0.47 ±0.05	85 ±2	15 ±2	14 ±1.4	Sw	SIV or SVI
3352 McAuliffe	0.61	0.62	80	20	17	S	SIV
4142 Dersu-Uzala	0.59	0.60	77	23	20	Srw	SIV

Current and Future Work

- ✓ NIR spectral survey of poorly-observed (heretofore only 14 objects) Hungaria asteroids
- ✓ To date, acquisition of NIR spectra of 24 Hungarias (Table 4)
- ✓ Separate the mineralogical characteristics of Hungaria *family* and *background* populations
- ✓ Proposals submitted to record NIR spectra of ≥40 more small (<~8 km) Hungarias, focus on *background* objects
- ✓ Constrain the degree of igneous differentiation experienced by these asteroids

Table 4. – Hungaria asteroids observed thus far, asteroids listed in order of decreasing H.

Asteroid	a (AU)	i (deg)	H	Population
3635 Kruetz*	1.795	19.223	14.8	background
9069 Hovland	1.913	19.573	14.4	background
2449 Kenos*	1.909	24.978	14.3	background
55854 (1996 VS1)	1.931	23.295	14.2	family
5577 Priestly*	1.844	22.276	14.1	background
2047 Smetana	1.872	25.278	13.9	background
6447 Terrycole	1.952	19.772	13.6	family
4142 Dersu-Uzala*	1.912	26.495	13.6	background
19164 (1991 AU1)	1.856	22.318	13.5	background
4736 Johnwood	1.957	21.966	13.5	family
7187 Isobe	1.938	21.785	13.4	family
7086 Bopp	1.909	25.617	13.4	background
6310 Jankonke	1.914	23.594	13.4	background
4674 Pauling*	1.859	19.444	13.3	background
5806 Archieroy	1.963	20.817	13.2	background
1750 Eckert	1.926	19.087	13.2	family
26471(2000 AS152)	1.918	19.694	13.0	background
1453 Fennia	1.897	23.672	12.8	background
2131 Mayall	1.887	33.996	12.7	background
5641 McCleese*	1.819	22.200	12.7	background
1727 Mette	1.854	22.897	12.7	background
1509 Esclangona	1.866	22.324	12.6	background
1019 Strackea	1.912	26.973	12.6	background
6249 Jennifer*	1.915	28.106	12.4	background

* Data obtained from MIT-UH-IRTF

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