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PHYSICAL CHARACTERIZATION OF CHELYABINSK-SIZED (~20 METER) NEAR-EARTH ASTEROIDS: IMPLICATIONS FOR IMPACT HAZARD, METEORITE SOURCE BODIES, AND HUMAN EXPLORATION

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Introduction —

Impacts due to small (~20 meters) near-Earth asteroids (NEAs) are interesting because they are more probable than previously thought and have been seen to cause extensive damage. On February 15, 2013, a 17-20-meter-diameter asteroid entered the Earth's atmosphere over Chelyabinsk, Russia, and disintegrated in an airburst with an estimated energy of ~500±100 kilotons of TNT (Brown et al. 2013). As a result, well over 1000 people were injured and there was an enormous financial cost in damages to buildings. NEAs in this size range in near-Earth space deliver meteoritic material to Earth on a regular basis. A review of bolide events over the last 20 years suggests that on an average 27 objects between 1-20 meters impact the Earth every year.

Recently, there has been increased interest in 'exploring' small NEAs, as evidenced by NASA's Asteroid Redirect Mission concept. Prior to mounting any spacecraft mission to such a small body, extensive observations (e.g., astrometric, spectroscopic, radar, etc.) are required to better characterize the NEA.

The central focus of our NASA-supported Near-Earth Object Observation Program grant is to determine the compositions and albedos of small NEOs in order: (a) to better understand their relationships to meteorites and main-belt asteroids, and (b) to address the specific NASA NEOO program goal of improving our assessment of the NEO impact hazard. A majority of NEA physical characterization studies have thus far focused on objects >1 km primarily due to the earlier Spaceguard goal to discover 90% of NEAs larger than 1 km within a decade, and due to the 17.5 V-magnitude limit of the NASA Infrared Telescope Facility's (IRTF) SpeX instrument. These two factors have been partly negated now as the survey goal has been changed to discovering and characterizing 90% of NEAs ≥140 meters by the year 2020. The upgrade of the SpeX sensor has enabled us to characterize asteroids down to a V-magnitude of 20.0, including several objects in the 20-meter size range.

Following the Chelyabinsk event, we began a systematic physical characterization study of NEAs ~20 meters in diameter in an effort to constrain their surface composition, albedo, rotation state, and binary frequency using ground-based telescopes. When possible, we also used archival data to enhance our existing sample size.

Here we present preliminary results on five NEAs with absolute magnitude (H) >26.0 or diameter ~20 meters assuming albedo of ~0.15. Due to their inherent small size and extremely limited observing windows, the number of observable targets is very low in a given year. Results presented here focus on constraining the mineralogy, albedo, and meteorite analogs.

Observations —

Near-IR spectral observations (0.75-2.5 μm) of our target NEAs were made at the NASA IRTF on Mauna Kea, Hawai'i, using the SpeX instrument in low-resolution prism mode (Rayner et al. 2005). Due to the faintness of some of our targets, visible wavelength guider MORIS was used to guide on the asteroids (Gulbis et al. 2011). When MORIS was used, the spectral range decreased to 0.8-2.5 μm due to the use of 0.8 μm dichroic. All spectral data were reduced using Spextool, an IDL-based software package provided by the IRTF (Cushing et al. 2004). Spectral band parameters were extracted with a Matlab-based tool using methods described in (Reddy, 2009). Thermal modeling to constrain the albedo was performed using Thermflx code (Reddy, 2009).

Results —

2009 KW2. The asteroid was observed during a close flyby on May 25, 2009. Figure 1 shows its near-IR spectrum with weak absorption bands. Band I is centered at 0.915±0.002 μm with a depth of 3±1%. The Band II center is located at 2.08±0.05 μm with a depth of 4±1%. The ratio of Band II to Band I area (Band Area Ratio or BAR) is 3±2. The large uncertaintiy in BAR is due to Band II area uncertainties. The asteroid plots to the right of the S(VII) region on the Band I center vs. BAR plot (Gaffey et al. 1993), although the absorption bands are suppressed compared with typical basaltic asteroids, such as (4) Vesta. This could be due a variety of factors including a low abundance of absorbing species such as iron in the pyroxene, presence of endogenic opaques such as impact melts, or exogenic carbon.

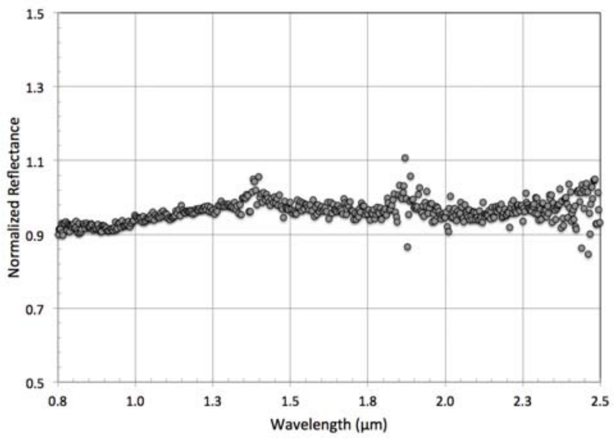

Figure 1: Spectrum of 2009 KW2 showing weak bands at 1- and 2-μm. The scatter at 1.4 and 1.9 μm is due to incomplete correction of telluric bands.

2014 WY119. The asteroid was observed during a close flyby on November 24, 2014. Figure 2 shows the NIR spectrum with moderately deep absorption bands. The Band I center is at 0.976±0.01 μm with a depth of 14±0.5%. The Band II center is located at 2.06±0.05 μm with a depth of 22±2%. The BAR is 2.7±0.3. The asteroid plots to the above the basaltic achondrite zone on the Band I center vs. BAR plot (Gaffey et al. 1993). The shape and center of Band II suggests the domination of clinopyroxene indicative of an igneous origin (Schade et al. 2004; Sunshine et al. 2004).

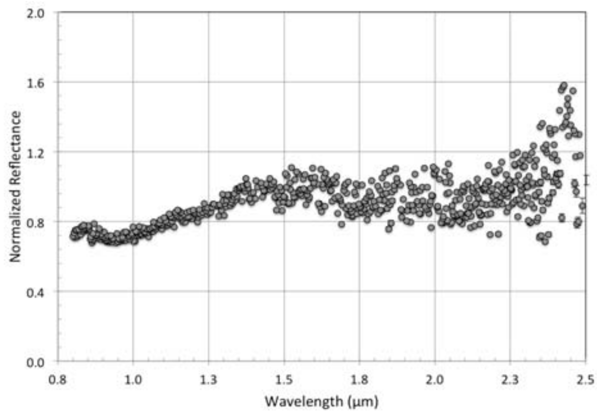

Figure 2: Spectrum of 2014 WY119 showing weak absorption bands at 1-μm and a possible 2-μm. band.

2014 WC201. This asteroid was observed during a close flyby of the Earth on December 1, 2014. Figure 3 shows a NIR spectrum with moderately deep absorption bands. Band I has a center at 0.932±0.001 μm and a depth of 17±0.5%. The Band II center is located at 1.95±0.02 μm with a depth of 12±2%. The BAR is 1.16±0.05. The asteroid plots to the edge of the S(IV) region on the Band I center vs. BAR plot (Gaffey et al. 1993). Asteroids that plot in this part of the S(IV) zone have composition similar to H-type ordinary chondrites (Dunn et al. 2010; Kelley et al. 2014).

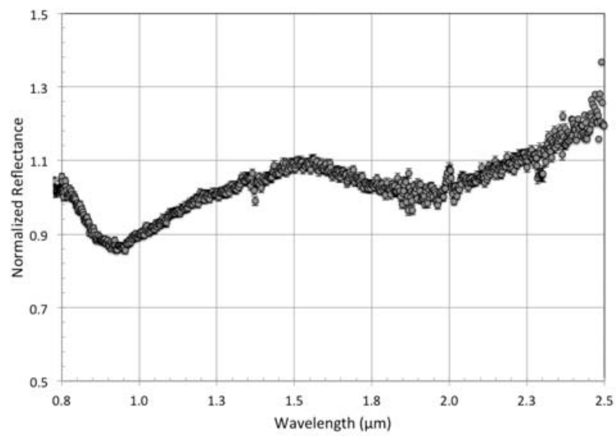

Figure 3: Near-IR spectrum of 2014 WC201 showing weak absorption bands at 1- and 2-μm due to the minerals olivine and pyroxene. The scatter at 1.4 and 1.9 μm is due to incomplete correction of telluric bands.

2014 UV210 and *2014 XB6.* These asteroids were observed during a close flyby of the Earth on December 15, 2014. The spectra (Fig. 4 and 5) show thermal tails of the Planck curve beyond ~2.0 μm, which could be used to constrain their albedo and diameter. Thermal modeling of the spectrum of 2014 XB6 suggests that its albedo is between 1-5% confirming its primitive composition.

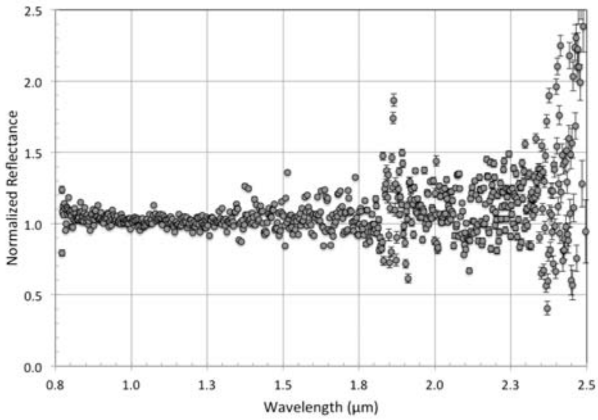

Figure 4: Near-IR spectrum of 2014 UV210 a rise in reflectance beyond 2.3 µm due to the shorter wavelength end of the Planck curve being shifted to near-IR wavelengths. This would suggest that the object has a relatively low albedo (<0.10). The asteroid was at *V* magnitude 18.7 at the time of observations.

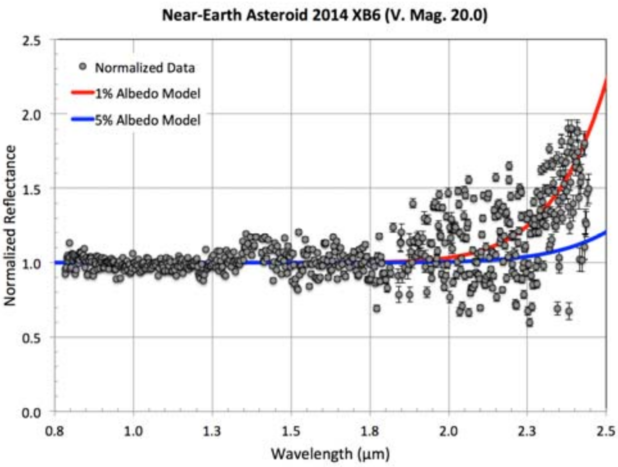

Figure 5: Near-IR spectrum of 2014 XB6 along with two thermal models (1% and 5%) suggesting a low albedo and primitive origin. The asteroid was at *V* magnitude 20.0 at the time of observations.

Summary —

Recent enhancements to NASA's Near-Earth Asteroids Objects Observations Program have led to 45% increase in NEO discovery rate over the past year. The new survey efforts are yielding close Earth encounter predictions, which in turn provide substantial opportunities for the IRTF to characterize a population of objects that includes Earth impactors such as Chelyabinsk, 2008 TC3 and 2014 AA.

NEA	*V. Mag*	*H. Mag*	*Size*	*Spectral Type*
2014 WC201	16.5	26.1	17 m	H-chondrite
2014 WY119	18.12	26.3	11 m	Basaltic
2014 XB6	19.9	26.5	21 m	Carbonaceous
2009 KW2	15.2	26.6	11 m	Basaltic
2014 UV210	18.7	26.8	18 m	Carbonaceous

Acknowledgements —

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