PHYSICAL CHARACTERIZATION OF CHELYABINSK-SIZED (~20 METER) NEAR-EARTH ASTEROIDS: IMPLICATIONS FOR IMPACT HAZARD, METEORITE SOURCE BODIES, AND HUMAN EXPLORATION. V. Reddy[1], R. R. Landis[2], J. A. Sanchez[1], P. S. Hardersen[3], B. Burt[4], F. E. DeMeo[5], M. J. Gaffey[3], and L. Le Corre[1], [1]Planetary Science Institute, Tucson, AZ 85719, reddy@psi.edu; [2]NASA Wallops Flight Facility, Wallops Island, VA; University of North Dakota, Grand Forks, ND; MIT, Cambridge, MA; Harvard University, Cambridge, MA.

Introduction: Impacts due to small near-Earth asteroids (NEAs) (~20 meters) are interesting because they are more probable than previously thought and can cause damage to life and property as evidenced by the Chelyabinsk event [1]. On February 15, 2013, a 17-20 meter diameter asteroid entered the atmosphere over Chelyabinsk, Russia, and disintegrated in an airburst with an estimated energy of ~500±100 kilotons of TNT [2]. NEAs in this size range are also immediately comparable to meteorite source objects in near-Earth space that deliver material to Earth on a regular basis. A review of bolide events over the last 20 years suggests that on an average 27 objects (Figure 1) between 1-20 meters impact the Earth every year [1].

More recently, there seems to be a new interest to 'explore' small NEAs as evidenced by NASA's Asteroid Redirect Mission concept. Prior to mounting any spaceflight mission to such a small body, extensive observations to better characterize (i.e., astrometric, spectroscopic, radar, etc.) the NEA are required.

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, binary frequency using ground-based telescopes. When possible, we also used archival data (as in the case of 2009 KW2) 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 limited in a given year. Results presented here focus on constraining the mineralogy, albedo, and meteorite analogs.

Observations: Near-IR spectral observations (0.7-2.5 µm) of NEAs were made at the NASA Infrared Telescope Facility on Mauna Kea, Hawai'i, using the SpeX instrument in low-resolution prism mode [3]. Due to the faintness of some of our targets, visible wavelength guider MORIS was used to guide on the asteroids [4]. 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 [5]. Spectral band parameters were extracted using Matlab based tool using methods described in [6]. Thermal modeling to constrain the albedo will be performed using Thermflx code [6].

Results: *2009 KW2.* The asteroid was observed during a close flyby on May 25, 2009. Figure 2 shows near-IR spectrum with weak absorption bands. The Band I has a center at 0.915±0.002 µm and depth of 3±1%. 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 uncertainties 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 [7] although the absorption bands are suppressed compared to typical basaltic asteroids such as (4) Vesta. This could be due a range of factors including low abundance of absorbing species like iron in the pyroxene, presence of endogenic opaques like impact melt or exogenic carbon.

2014 WY119. The asteroid was observed during a close flyby on Nov. 24, 2014. Figure 3 shows NIR spectrum with moderately deep absorption bands. The Band I has a center at 0.976±0.01 µm and depth of 14±0.5%. 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 [7]. The shape and center of Band II suggests the domination of clinopyroxene indicative of an igneous origin [8,9].

2014 WC201. The asteroid was observed during a close flyby of the Earth on Dec. 1, 2014. Figure 4 shows NIR spectrum with moderately deep absorption bands. The Band I has a center at 0.932±0.001 µm and depth of 17±0.5%. 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 [7]. Asteroids that plot in this part of the S(IV) zone have composition similar to H-type ordinary chondrites [10, 11].

2014 UV210 and 2014 XB6. These asteroids were observed during a close flyby of the Earth on December 15, 2014. The spectra (Fig. 5 and 6) show thermal tail of the Planck curve beyond ~2.0 µm, which will be used to constrain their albedo and diameter.

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.

Acknowledgements: This research was funded by NASA Near-Earth Object Observations Program grants NNX14AL06G (PI Reddy) and NNX07AL29G (PI Gaffey).

References: [1] NASA PSD Press Release http://www.jpl.nasa.gov/news/news.php?feature=4380 [2] Brown P. G. et al. (2013) *Nature, 503,* 238–241. [3] Rayner J. et al. (2005) *PASP, 115,* 365. [4] Gulbis, A. A. S. et al. (2011) *PASP 123,* 461. [5] Cushing et al. (2004) *PASP 115,* 389. [6] Reddy. V. (2009) Ph.D Dissertation, Univ. of North Dakota. [7] Gaffey, M. J. et al. (1993), *Icarus 106,* 573-602. [8] Schade, U. et al. (2004), Icarus 168, 80-92. [9] Sunshine, J. M. et al. (2004) MAPS 39-8, 1342-1357. [10] Dunn, T. M. et al. (2010) Icarus 208, 789-797. [11] Kelley, M. S. et al. (2014) Icarus 233, 61-65.

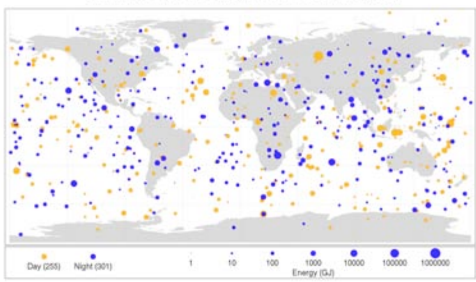

Figure 1: Map showing bolide events due to impact of asteroids (1-20 meters) over the last 20 years [1].

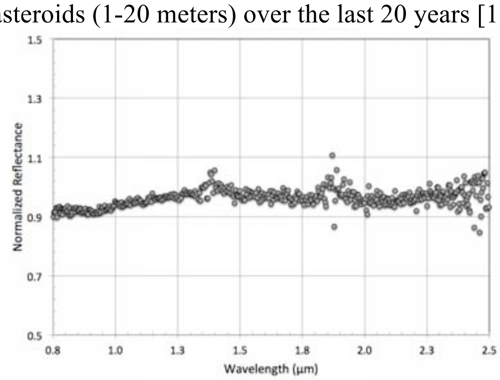

Figure 2: Spectrum of 2009 KW2 showing weak bands at 1- and 2-µm. The scatter at 1.4 and 1.9 µm is due to incomplete correction of telluric bands.

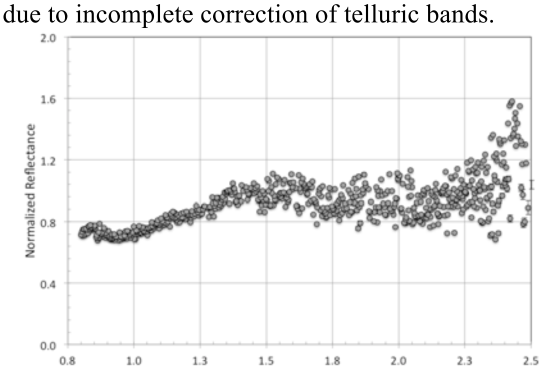

Figure 3: Spectrum of 2014 WY119 showing weak absorption bands at 1-µm and a possible 2-µm. band.

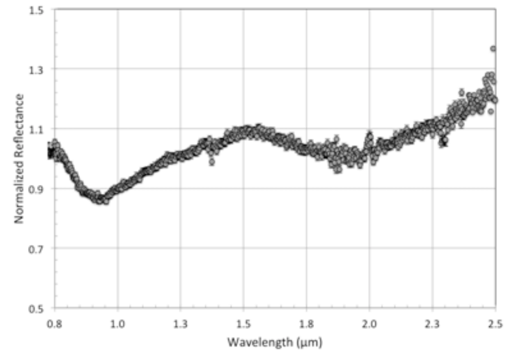

Figure 4: Near-IR spectrum of 2014 WC201 showing weak absorption bands at 1- and 2-µm due to the minerals olivine and pyroxene. The scatter at 1.4 and 1.9 µm is due to incomplete correction of telluric bands.

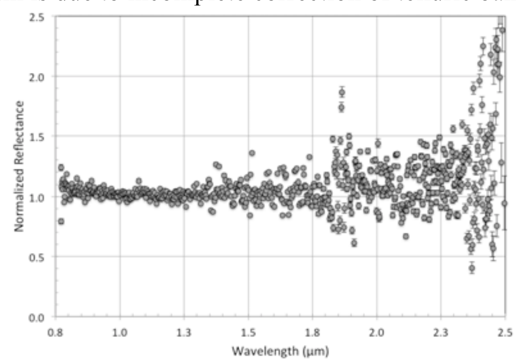

Figure 5: Near-IR spectrum of 2014 UV210 a rise in reflectance beyond 2.3 µm due to the shorter wavelength end of the Planck curve being shifted to near-IR wavelengths. This would suggest that the object has a relatively low albedo (<0.10). The asteroid was at *V* magnitude 18.7 at the time of observations.

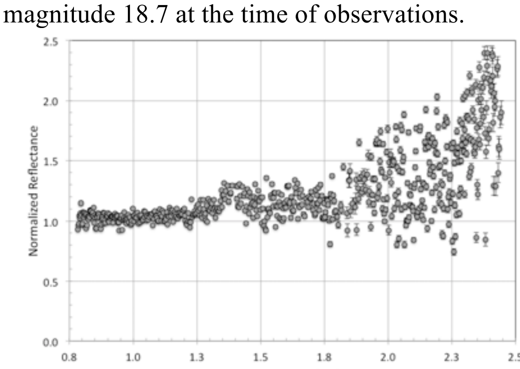

Figure 6: Near-IR spectrum of 2014 XB6 suggests that it is a relatively low albedo (<0.10) like 2014 UV210 based on the thermal tail. The asteroid was at *V* magnitude 19.9 at the time of observations.