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TARGET-OF-OPPORTUNITY CHARACTERIZATION OF SUB-200 METER NEAR-EARTH ASTEROIDS

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Assessing the threat from the near-Earth asteroid (NEA) population requires an understanding of the population itself, as well as the dynamics and mechanisms of collisional evolution of small body systems. Knowledge of the latter can be gained by studies of both Main Belt and near-Earth asteroids and the larger members of these populations have been examined for decades. However, the role smaller objects play in the asteroid threat has been demonstrated by the Carancas, Peru cratering impact in 2007, the airburst of 2008 TC_3 in the Sudan, and of course, the Tunguska airburst in Siberia in 1908, all of which fortunately hit in less populated regions. Although these sub-200 meter objects do not fit into the 'planet killer' category, they do have the potential to cause significant local damage. If there is any lingering doubt regarding the danger posed by smaller objects, the airburst event on February 15, 2013 in Chelyabinsk, Russia should have put that to rest. Furthermore, the fact that, aside from Tunguska, all of these incidents occurred in the last decade demonstrates that the frequency of these events make them very real threats. Characterization studies that determine physical properties such as spin rates and orientations, shapes, material type and internal structure/strength are important for properly addressing and mitigating any potential risk from these objects.

Researchers at the Magdalena Ridge Observatory's (MRO) 2.4-meter Telescope have been undertaking a program to derive physical characterization information concentrating on the smallest (less than 200 meters in diameter) objects in the NEA population since 2008. This has been pursued in conjunction with a program to provide astrometric follow-up of recently discovered NEA candidates. Previous work included the determination of over 77 rotations rates for NEOs with H < 22. Of this sample, about 70% of the small NEOs had rotation rates faster than 2 hrs, with many having spin rates on the order of minutes, one as fast as 24.5 seconds. Further, between 10 - 20% of the objects also appear to be tumbling. A recently added visible wavelength spectroscopic capability (the Magdalena Optical Spectroscopy System, MOSS) has resulted in rough compositional information for ~11 NEAs. The database thus far contains NEAs of compositions C-, S-, A-, and Sq-type. This R~300 spectrometer has been vetted to be sensitive to V~19, and is permanently mounted at the Nasmyth port opposite the imager port (CCD camera) of the telescope and is accessible within 30 seconds via repositioning of a tertiary mirror. To augment this, we also employ a simple filter-wheel mounted grating system which has been tested to produce reliable compositional information to V~17. Figure 1 compares the spectral signature of NEA 2014 EC obtained via the slitless grating and the slit-based MOSS spectrometer. It is clear that the MOSS spectrometer provides a less noisy spectrum than the simple slitless grating system under similar conditions. However, the Sq/Q nature of 2014 EC is still easily discernible.

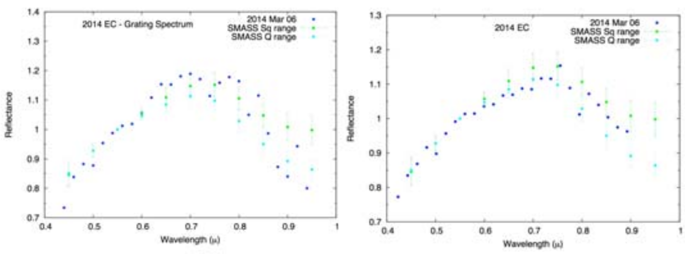

Figure 1. Spectra of 2014 EC obtained by the slitless grating system (left) and the slit-based MOSS spectrometer (right).

Robust characterization of sub-200 meter objects is usually limited to when these asteroids make close approaches to the Earth. The observing window for these studies is usually weeks, days, or, for the smallest members of this population, just a single day or two bracketing their closest approach to Earth. For many, the only optimal occasions for study that present themselves for the foreseeable future occur as soon after discovery as possible. Therefore, these are truly targets-of-opportunity.

Figure 2 shows a schematic demonstrating the Earth-centric observing space using the MRO 2.4-meter for characterization of hypothetical H=23.5 and H=27.0 asteroids. The darker region represents the space where the target will be V<18 yielding high quality spectra and good temporal and photometric resolution lightcurves. The lighter region represents the V<19 region where spectral characterization is still achievable, but at a lesser quality (Ryan and Ryan 2014). Assuming a nominal delta-V of ~10 km/sec, an H~23.5 target crossing the “characterization zone” will remain there for 10 days or more. However, the observation window for an H~27 or smaller asteroid can be 1 - 2 days or less. Since this also tends to be the optimal time for the discovery of fast moving objects, it is most beneficial to observe these objects as soon after they are found as possible since they may have already traveled through a large portion of this region by the time of discovery.

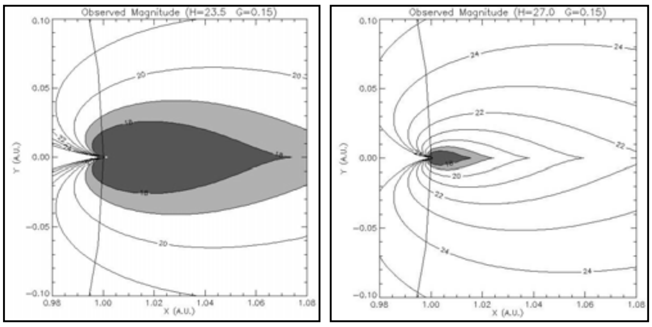

Figure 2. Contour plots showing the apparent visual magnitude of an H=23.5 (diameter ~50-120m) and an H=27.0 (diameter ~10 - 25m) NEA as a function of position in the near-Earth vicinity. The Earth’s location is at (1, 0) and the partial circle represents the Earth’s orbit. The shadings represent the regions where V<18 (darker interior) and V < 19 (lighter shade), and can be thought of as a ”characterization-observable” zone.

An example of a lightcurve for an object that falls into the larger of these two modeled characterization capability cases is shown in Figure 3. The tumbling nature of 2015 FP_{35} was initially identified on a previous non-photometric night while it was still an NEO confirmation object. However, due to the less urgent observing window for this asteroid, it was able to be re-observed on a photometric night, confirming its multi-period behavior.

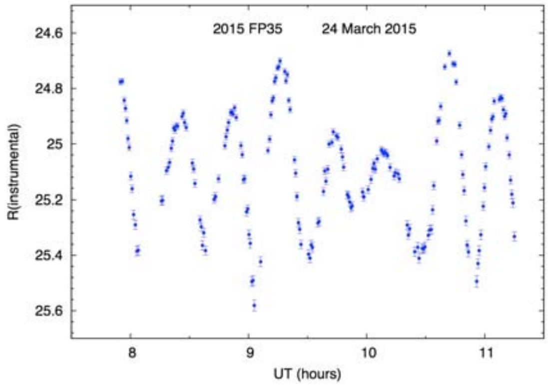

Figure 3. The lightcurve for 2015 FP_{35} (H~24.3) exhibits tumbling behavior with a primary periodicity of ~1 hour.

An example of the characterization of an object that falls into the smaller of the modeled cases illustrated in Figure 2 is shown below. 2015 DB appeared on the NEO confirmation page on a photometric night and characterization commenced soon after discovery. Figure 4 shows a lightcurve and grating-derived spectra for this object, yielding a rotation period of about 6 minutes for an S- or A-type object. The brighter albedo anticipated for this spectral result constrains the diameter toward the smaller end of the range for this particular H~27.7 object at ~10 meters or less.

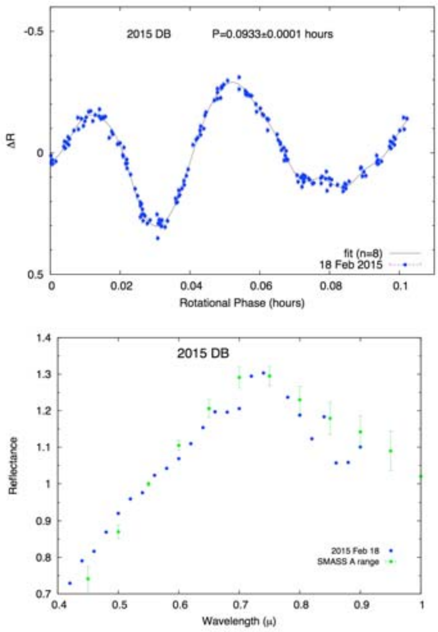

Figure 4. Lightcurve (top) for 2015 DB (H~27.7) which only stayed in the characterization zone for a day or two. A visible grating-derived spectra is shown on the bottom, with SMASS A-type ranges overplotted. The spectra is derived from twenty 60 second exposures summed and calibrated with solar standard Landolt SA 102-1081.

A final example of a limited observing window object is shown in Figure 5. Asteroid 2015 FM_{118} was moving at approximately 80 arc-seconds per minute through a crowded star field, which made a full-field grating spectra difficult to impossible to obtain. However, a lightcurve was acquired yielding the approximately 61 second rotation period as shown in Figure 5.

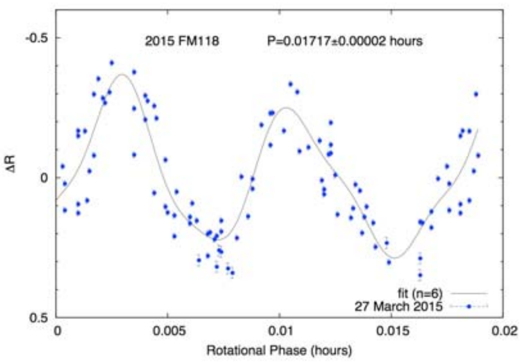

Figure 5. The lightcurve for NEA 2015 FM_{118} (H~28.7) is shown having a spin rate of 0.017 hours. This target was in the observable characterization zone for an extremely short time, so observations needed to be taken almost immediately.

Additional characterization studies of these types of targets are ongoing in the program at MRO. Although sub-200 meter asteroids do not pose a global threat, they do have the potential to cause local damage. Since the observing window for these objects can be very limited, characterization data for this population is still very sparse. This can be partially remedied by interrupting routine astrometric follow up of NEO confirmation page targets to do characterization soon after discovery.

References

Ryan, W.H., and E.V. Ryan (2014).”Real-time Characterization of Near-Earth Objects: New Spectral Capabilities at the Magdalena Ridge Observatory 2.4-meter”, 46th *Annual Meeting of the Division of Planetary Sciences*, Tucson, AZ.