NEO FOLLOW-UP AND PHYSICAL CHARACTERIZATION AT APACHE POINT OBSERVATORY.

M. Hammergren[1], M. J. Brucker[1], K. A. Nault[1], G. Gyuk[1], and M. R. Solontoi[2], [1]Adler Planetarium, 1300 S. Lake Shore Drive, Chicago IL 60605, mhammergren@adlerplanetarium.org, [2]Lynchburg College, Lynchburg VA.

Introduction: We have recently begun a two-year, NASA-funded program of Near-Earth Object (NEO) astrometric follow-up and characterization using the Astrophysical Research Consortium (ARC) 3.5-meter telescope at Apache Point Observatory (APO). A 17% share of observing time has been leased from ARC, amounting to 500 hours (or 50 whole nights) per year, currently scheduled as two hour blocks in the middle of every other night, several half-night campaigns per month, and one to two target-of-opportunity interrupts per month. Under typical recent weather conditions (35% loss), we expect to provide astrometry on more than a thousand NEOs per year, along with spectra of around 150 objects (or light curves of around 50-100 objects, more if many are fast-rotators).

Motivation: NEOs are of interest to scientists and the general public for three main reasons: they represent leftovers from the time of planet formation and provide insight into the origin and evolution of the solar system, their potential impacts continue to pose a threat to life on Earth, and they may serve as sources of water and other materials for use in space or return to Earth. Additionally, the detection and characterization of NEOs down to the relatively small size of 140 meters is a mandate of US Public Law (the George E. Brown, Jr. Near-Earth Object Survey Act) [1]. Despite this interest, perhaps only 10% of the NEO population in the 100 – 300 meter size range have been cataloged [2]. It is important to note that discovery, by itself, is not enough to determine a NEO's long-term impact risk; rather, what is needed is a sufficiently well known orbit for the object to permit recovery at a future apparition. This requires follow-up astrometric observations over an extended arc in time and space.

Small NEOs are faint and only observable when they are very close to the Earth. For example, an asteroid with a diameter of 7 m and albedo of 0.05 (appropriate for an C type, carbonaceous chondrite analog) has an absolute magnitude of 29.6, and will only appear brighter than V=23 at opposition when it is within ~0.045 AU (about 18 lunar distances), and V=19 (our limit for reflectance spectroscopy) when it is within ~0.007 AU (about 3 lunar distances). At relative encounter velocities of a few km/s, such objects will transit observable space in only a few days. This severely limits the ability of ground-based observatories to detect, follow up and characterize small NEOs.

Figure 1 displays the total numbers of cataloged NEOs (i.e., those with permanent numbers or provisional designations) as a function of absolute magnitude, the median observational arc for objects (in 1 mag bins), and the number whose arc is one day or less. (The list of NEOs was retrieved from the NASA JPL Small-Body Database Search Engine on Jan. 5, 2015.)

Most cataloged NEOs 140 m in diameter (corresponding to H~21-23) and smaller have been observed for less than one lunation, and most in the ~5m range have been observed for only one or two nights.

This situation highlights the great need both for extended astrometric follow-up and for frequent and responsive telescope scheduling. The observing schedule we have demonstrated at APO, coupled with the broad and rapidly changeable instrumentation described below, provide a valuable resource for NEO follow-up and characterization.

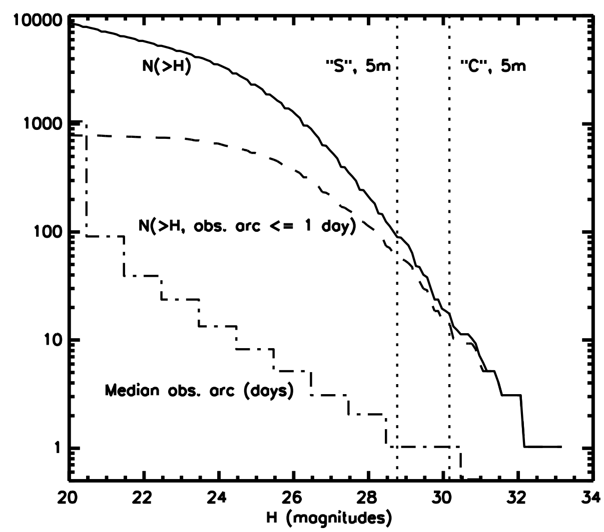

Figure 1. Number of cataloged NEOs and observational arc versus absolute magnitude.

Observatory and Instrumentation: The ARC 3.5-meter telescope and its existing, extensively tested suite of instruments are very well suited for observations of faint, fast-moving targets. The telescope offers accurate pointing (5-6" rms across the whole sky) and is capable of tracking objects at rapid (and even accelerating) non-sidereal rates (up to 1.25 degrees per second in azimuth, with open-loop accuracy of 3-4" rms per hour). Swapping between most instruments takes 15 minutes, except to or from the high-speed imager, which takes 1-2 minutes. The telescope was designed for remote observation operations over the internet, and is most often used in this mode. The custom Telescope User Interface (TUI) remote observing client is written in Python and is available for Mac, Windows, and Unix platforms.

Compositional studies are accomplished with low- to moderate resolution visible-wavelength reflectance spectroscopy using the Dual Imaging Spectrograph (DIS), which provides complete spectral coverage from 0.36 – 1.0 micron; and near-infrared reflectance spectroscopy with TripleSpec, a medium resolution, cross-dispersed spectrograph with simultaneous coverage from 0.95 to 2.46 micron in five spectral orders. Reflectance spectra with peak SNR~25 (per 0.2 micron bin) can be obtained to V~19 with DIS and V~17.5 with TripleSpec in 3x20 minute exposures.

Astrometric and spectrophotometric imaging currently are most often performed using SPICAM, a 2K x 2K CCD imager with a 4.78’ FOV, capable of 2% photometry to r~20.5, and 5-sigma detection to r~23.5 in 60s. DIS may also be used in imaging mode, providing simultaneous g and r images with a 4.0’ FOV to a 5-sigma detection limit of g~23 in 60s. Multi-color spectrophotometry will permit taxonomic classification in an established system, and even a single g-r color can help distinguish S and C class asteroids. A new general purpose imager (ARCTIC), offering a larger field of view and faster readout, is under construction and is planned to be available for shared-risk use in 3^{rd} quarter 2015.

Rotational light curves are most often obtained using AGILE, a high-speed frame transfer CCD with 1K x 1K active pixels and a 2.5’ FOV. In image transfer mode, there is no dead time between images, with exposure times as short as 1.1s (and even shorter with on-chip binning).

Overview of Early Observations: We entered a prototyping phase of this program in the 4^{th} quarter of 2014, with 4 half-nights of regularly scheduled time devoted to physical characterization of NEOs (16 targeted for reflectance spectroscopy, and 7 for rotational light curves) and 29 two hour slots primarily for astrometric follow-up (158 objects targeted). Detailed results on these objects and those observed in January and February 2015 will be reported by M. Brucker in another presentation.

Invitation to Collaborate: We eagerly invite proposals for collaboration on specific targets, even on very short notice. Our frequent schedule and ability to invoke target of opportunity time, combined with the range and flexibility of instrumentation on the ARC 3.5-meter, provide the opportunity for responding to urgent requests as well as more regularly scheduled campaigns.

References:

[1] US Congress (2005) Public Law No. 109-155. [2] Bolden, C. (2013) Testimony before the US House of Representatives Committee on Science, Space and Technology.

Acknowledgements: Based on observations obtained with the Apache Point Observatory 3.5-meter telescope, which is owned and operated by the Astrophysical Research Consortium. We gratefully acknowledge support from NASA NEOO award NNX14AL17G, and thank the University of Chicago Department of Astronomy and Astrophysics for observing time in 2014.