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SPACEWATCH® Observations of Virtual Impactors and other Priority Near-Earth Asteroids

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Abstract

For planetary defense, it is imperative to discover and monitor hazardous near-Earth objects (NEOs). At Spacewatch, we strive to reduce the uncertainty in orbital elements of NEOs and extend their spatial and temporal observation arcs. We present details and results from our Target-of-Opportunity program to recover faint Virtual Impactors using non-classically scheduled time on larger telescopes.

1. Introduction

Spacewatch conducts full-time follow-up astrometry of NEOs primarily with a 1.8-m and a 0.9-m telescope on Kitt Peak, Arizona. We prioritize observing Virtual Impactors (VIs), Potentially Hazardous Asteroids, objects on the Minor Planet Center's Confirmation Page, Yarkovsky effect candidates, potential radar targets, NEOs with characterization data (especially targets of NEOWISE), potential destinations of spacecraft, and other objects of interest to the community. Virtual Impactors have uncertainties in their orbital elements such that some of the possible orbit solutions predict a future impact with the Earth within the next 100 years. Potentially Hazardous Asteroids (PHAs) are NEOs with absolute magnitudes $\leq$ 22.0 and Earth Minimum Orbit Intersection Distances (MOID) $\leq$ 0.05 au. In 2018, we began a Target-of-Opportunity (ToO) program to observe faint VIs on larger telescopes in order to rule out (or confirm) predicted impacts, extend observation arcs, and prevent loss due to uncertainty.

2. Target-of-Opportunity Program

Target-of-Opportunity time is a small amount of time that is competitively awarded but interrupts the schedule instead of being classically scheduled ahead of time. When a target is selected that requires prompt observations, the ToO is triggered by contacting the observatory to interrupt the scheduled observers' time. For our ToO program, we focus on VIs since they have a (usually very low probability) potential to impact the Earth within the next 100 years. If VIs accrue large uncertainties while they are too faint to be observed using normal NEO follow-up assets, their recovery once brighter can require extensive time and resources and may not be possible. To prevent the need for extensive effort in the future, we extend the current arc of observations by days to weeks longer than smaller telescopes can by using interrupt time on larger telescopes. These telescopes can detect fainter and/or faster-moving VIs than the typical NEO astrometric follow-up assets, which are mostly in the one to two meter range. Longer arcs lead to lower orbital uncertainties, which in turn lead to more accurate impact predictions. In 2018, 208 new VIs were added to JPL's Sentry risk list and 91 (44%) remain on the list of potential impactors. We want to improve the knowledge of VI orbits in order to eliminate orbit solutions containing high priority impact predictions.

Beginning with the 2018A observing semester and continuing through 2019A, we have been awarded ToO time on the Victor Blanco 4-m Telescope and the Southern Astrophysical Research Telescope (SOAR) at Cerro Tololo Inter-American Observatory in Chile, the W. M. Keck Observatory in Hawai'i, the WIYN 3.5-m Observatory at Kitt Peak National Observatory in Arizona, and the Large Binocular Telescope Observatory on Mt. Graham in Arizona. We have been conservative about triggering ToOs in order to focus our efforts on objects with high potential hazard. We triggered ToO time in 2018A, 2018B, and 2019A at the Blanco Telescope and in 2018A at the WIYN Telescope. We successfully measured the target VI for each of our observations at the Blanco. Our 2018A observations contributed to the removal of the minor planet 2017 TA6 from the risk list. In 2019A, we observed 2019 GD4 on 2019 April 28. Table 1 shows the improvement in orbital elements as found in JPL's

Small-Body Database Browser before and after our observations (2019 April 27 and May 2).

3. Target Selection

To select the best targets for our limited number of telescope interrupts, we give higher weight to VIs with first possible impacts that might occur before they become bright enough to be rediscovered. We calculate a 'priority' factor using the cumulative impact probability, the date of first possible impact (temporal urgency), and the reliability of the impact predictions (related to the observational arc length). Object size and observability are considered separately. In addition to our prioritization scheme, we confer with JPL regarding impact priorities and with other follow-up observing groups. Figure 1 illustrates how a long list of VIs can be narrowed down those most in need of prompt astrometry. The most urgent VIs lie in the upper part of Figure 1. If a VI has a priority value greater than -2, then it will be given highest consideration over other VIs.

4. Figure

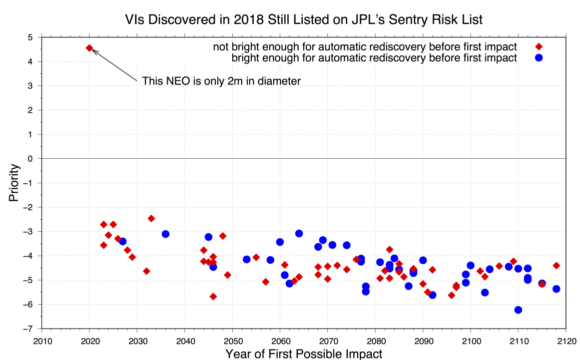

Figure 1: *Priority Factor for VIs Discovered in 2018.* Plotted is the set of VIs discovered in 2018 that were still listed by JPL on 2019 April 30. The blue circles are VIs that will become bright enough ($V < 22$) for serendipitous rediscovery by current all-sky surveys before their first possible impact. The red diamonds are VIs that will not become bright enough and thus are given precedence. The priority is a logarithmic function of cumulative impact probability, temporal urgency, and reliability of impact predictions. We did not use a ToO for the VI in the upper left of the plot due to its small size. An object with an estimated diameter of 2-m will break up in Earth's atmosphere into pieces too small to cause serious damage.

5. Table

Table 1: Orbital Elements of 2019 GD4

Element	Value[1]	Uncert.[1]	Value[2]	Uncert.[2]
e	0.46660	0.00054	0.46651	0.00042
a *(au)*	1.7995	0.0018	1.7993	0.0014
i *(deg)*	0.38104	0.00035	0.38098	0.00027
Ω *(deg)*	320.280	0.011	320.282	0.009
ω *(deg)*	197.813	0.011	197.812	0.009
M *(deg)*	21.454	0.034	21.460	0.026

[1]2019 April 27, before ToO
[2]2019 May 2, after ToO

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