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Discovering Near-Earth Asteroids with the Zwicky Transient Facility

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Abstract

The Zwicky Transient Facility (ZTF) is a new robotic optical time-domain survey that visits the entire northern sky visible from Palomar Observatory every three nights in the *g* and *r* bands, with higher cadences in selected regions [1]. ZTF uses a 47 square degree field with a 600 megapixel camera to scan the sky at rates of ~3760 square degrees/hour to median depths of $r \sim 20.6$ mag (AB, 5σ in 30 sec). ZTF's large field-of-view and mapping speed is ideally suited to search for Near Earth Asteroids (NEAs) as well as characterize their physical properties. Since February 2018, ZTF has been leveraging the massive data stream currently serving other science programs to search for NEAs and Potentially Hazardous Asteroids (PHAs) in near-realtime.

The moving-object processing and vetting systems are located at IPAC/Caltech [2, 3, 4] and consist of two sub-systems: (i) `ZMODE` (ZTF's Moving Object Discovery Engine), which links difference-image-detected *point-sources* from the alert stream to construct tracklets, and (ii) `ZStreak`, which is designed to detect *faster* moving objects (FMOs) that happen to streak in the individual exposures. `ZStreak` is sensitive to objects moving at speeds of ~ 5°/day and potentially up to 100°/day [3].

As of May 8, 2019, ZTF has 45 confirmed NEA discoveries, where most of them are from `ZStreak`. A similar number were lost due to insufficient follow-up. Some recent NEA discoveries are shown in Table 1. Their median *H* magnitude is ~ 26.2 (±1.7, 1σ). This corresponds to diameters of ~ 30m for an assumed albedo of 0.1. All the NEAs so far have diameters of < 150m. Another notable ZTF discovery is that of an Atira-class asteroid, 2019 AQ3. This has an orbit interior to Earth's orbit and has the shortest orbital period of any known asteroid [5]. This was discovered in ZTF's "twilight survey". Figure 1 shows the distribution of Earth-distances for a subset of NEAs.

We review ZTF's contribution to discovering and characterizing NEAs. This includes its dedicated processing sub-systems [2, 3], machine-learned vetting systems and their performance [3, 4], marshaling infrastructure, and planned improvements. We also summarize our discovery statistics and the NEA physical properties, with comparisons to the general PHA population.

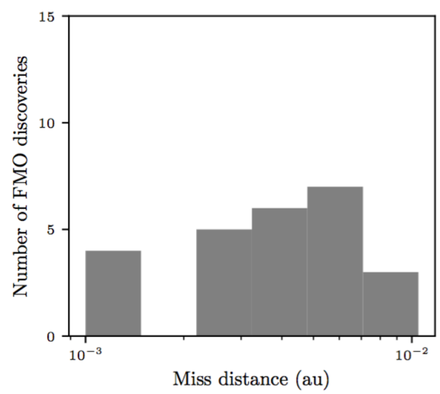

Figure 1: Distribution of miss-distances from Earth for newly discovered Fast Moving Objects from `ZStreak` processing [3].

Table 1: Recent NEAs discovered by ZTF [4].

Prov. des.	Disc. circumstance Disc. date	V mag	Rate (°/day)	Closest dist. (Lunar Distances)	Orbit	*H*
2018 VJ_{10}	2018 Nov. 15	17.5	40	0.5	Apollo	28.6
2018 YM	2018 Dec. 17	19.0	35	4.0	Apollo	27.1
2018 YG_2	2018 Dec. 16	19.2	20	4.5	Apollo	26.0
2018 YO_2	2018 Dec. 29	18.2	20	0.5	Apollo	29.6
2018 YY_2	2018 Dec. 31	18.2	20	4.5	Apollo	25.9
2019 AC_9	2019 Jan. 10	18.3	10	4.0	Apollo	25.7
2019 BZ	2019 Jan. 24	18.6	40	2.4	Apollo	27.5
2019 BU_2	2019 Jan. 25	18.7	10	9.2	Apollo	25.3
2019 BK_2	2019 Jan. 26	18.4	30	2.8	Apollo	26.8
2019 BY_3	2019 Jan. 28	18.9	15	3.2	Apollo	27.4
2019 BL_4	2019 Jan. 28	19.7	10	2.6	Apollo	27.7
2019 BC_5	2019 Jan. 31	19.0	15	7.0	Apollo	25.4
2019 BD_5	2019 Jan. 31	17.7	25	2.8	Apollo	26.7
2019 BE_5	2019 Jan. 31	15.1	50	3.0	Aten	25.0
2019 BF_5	2019 Jan. 28	18.0	20	9.5	Apollo	21.5

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