Hunting for Super-Fast Rotators with Few kilometer in Size (Winter 2019-2020)

Studying SFRs can help to understand asteroid interior structure. During the iPTF era, we have confirmed the existence of super-fast rotators (SFRs), which are very unlikely to be explained by the traditional rubble-pile structure (i.e., gravitationally bounded aggregations; would could be destroyed by fast spinning, called rotation fission). Cohesion is a possible solution to survive SFRs and, indeed, the currently known SFRs all have a spin-rate under the limit predicted by cohesion model. However, in the 1st year high-cadence solar system survey, we found more SFRs, in which several have diameters up to ~2 km. Although these SFRs with diameters of 1-2 km required unusual high cohesion, they still under the spin-rate limit predicted by the cohesion model. Therefore, to find SFRs with few kilometers in size is important because they propose challenge to the cohesion model (i.e., extremely large cohesion which is hard to be explained). This helps to push the understanding of asteroid interior structure to another level. From our previous studies, we found that the number of SFRs is likely related to their size (i.e., the smaller the asteroid is, the more likely the chance to find SFR). Moreover, it is expected to find one SFR out of 10000 asteroids in the diameter range of few kilometers. To conduct this study, it must rely on a very wide-field high-cadence survey and that is what the ZTF most capable of. Therefore, we propose another high-cadence solar system survey either in the dark run before Nov or after Jan because we need to do the observation at the opposition (i.e., the observation cannot be done during full moon) and avoid the Galactic plane (i.e., about Dec to Jan).

Desired Observations

a. R band.
b. 6 or 12 ZTF fields on the ecliptic plane during dark run.
c. 5 or 10 min cadence
    i. 6 or 12 fields.
    ii. Since the observation time span of the ecliptic plane will be ~8 hours (i.e., air mass < 2) during mid Oct to mid Nov or mid Jan to mid Feb, 2019. The 40-50% observation time per night is ~4 hours. We would like to have the observation of 6 or 12 fields using 5 or 10 min cadence for 4 nights in straight.
d. Request 3-4 repeats of the aforementioned observation
    i. ~16 hours for one observation mentioned above * 3-4 repeats = 48-64 hours in total

Science Rationale

a. Main science goal
   To discover SFRs of few kilometer in size to challenge or constrain the cohesion model.
b. Why are new ZTF observations required?
   Using the 2019 high-cadence solar system survey, we obtained ~4000 reliable rotation periods, in which SFRs were also found and the largest one is ~2km, still not over the limit predicted by cohesion. As mentioned earlier, the expected chance to found SFRs with few kilometers in size is 0.01%. Therefore, we would like to conduct another survey to collect more samples. Moreover, the typical ZTF survey mode (i.e., sparse light curve) is relatively difficult to obtained reliable rotation periods for SFRs and the high-cadence survey would place a better constraint on their rotation periods from the 2019 solar system survey. 2019-2020 Winter and 2020 Spring will be the last chance to carry out high-cadence solar system survey before the end of ZTF operation (i.e., Sept 2020).
c. Does proposed observing plan serve any other science objectives?
   These observations can be used to discover new asteroids, and also benefit a study on asteroid rotation period statistics. In addition, any time-series study require high-cadence observation also benefit.

Near-Earth Objects Survey Enhancement (2019-2020 Winter)

ZTF has proved a uniquely powerful tool for finding NEOs and characterizing the population. ZTF now accounts for about 10% of all NEO discoveries. This has been accomplished using the data stream in parasitic mode, without optimization for NEO finding. The main limiting factor to realizing more of the ZTF potential in this topic is the small number of visits per night; the poor weather in the winter makes it harder to leverage additional visits in subsequent nights. Rather than a large-area dedicated NEO-optimized survey, we propose a supplement to existing surveys with additional visits to reach 5 visits per night where only 2 or 3 happen now. This allows us to reach new science goals for a marginal investment of observing time.

1. Scientific objectives for Winter 2019-2020

ZTF has so far found 261 new asteroids, including 61 and 72 NEOs in 2018 and 2019 respectively. This was achieved by combining the large ZTF surveying speed with specialized pipelines ZMODE and ZSTREAK (including ML modules). The objective now is to test the system in a mode of uniform depth-of-coverage per night for a sustained period of time in a well-defined sky geometry so we can undertake reliable statistical analysis of the results.

2. Requested observing strategy: NEO Survey Enhancement

Of the various surveys making up ZTF the most amenable to augmentation for NEO purposes is the MSIP survey: It covers a large area, visiting it systematically twice a night, and always includes fields at opposition. We request therefore to augment coverage to reach five visits per night for 20 fields on the MSIP target list, all located near opposition. Between the all-sky and the TESS surveys, such fields should be available every night, and require three or fewer additional visits each. We request r band and 30-minute spacings between visits. We will pick the specific fields to complement the sky coverage by Catalina Sky Survey and PanSTARRS, the leading NEO surveys, to maximize the visibility of the ZTF contribution.

3. Plans and resources for data analysis, follow-up, publication, etc.

a. ZStreak and Zmode, already operating as part of the pipeline, will automatically identify NEOs in the augmented survey data. We are funded by NASA to search for NEOs in the ZTF data stream, and continue to develop techniques to enhance efficiency.
b. The GROWTH network will be used to follow up new discoveries.

A paper on ZStreak has already been published (2019PASP..131g8002Y). A systematic analysis of the NEO statistics to date has been started, but needs a stable baseline of coverage as requested here to converge.