AN ALGORITHM TO SEARCH FOR BINARY ASTEROIDS IN PRECISE ASTROMETRIC SURVEYS. Noam Segev[1], David Polishook[1], Eran O. Ofek[1]. [1]Dept. of Particle Physics and Astrophysics, Weizmann Institute of Science, 234 Herzl St., Rehovot 7610001 Israel

Introduction: Each of the observational methods used to detect binary asteroids, has its own limitations and biases [1]. High-resolution imaging (e.g., using HST, VLT, [e.g. 1]) is biased for binaries with high separation (~100 mas, about 100 km at 1.5 AU) and is limited to a few available instruments. Measuring eclipses in photometric light curves [e.g. 2] is biased for nearby satellites (few asteroid radii from the asteroid). Radar observations [e.g. 3] requires the asteroid to be extremely close to the telescope. Stellar occultation and spacecraft flybys, are possible only for a tiny fraction of objects. As a result, the parameter space of binary asteroids is incomplete, and set the current 15% binary fraction among asteroids as a lower limit.

Method: we demonstrate a novel method to detect binary asteroids using precise astrometric observations, which will allow to detect the motion of the binary center-of-light around its center of mass. The two differs from each other because the center of mass depends on the radii cube, while the center of light depends on the radii squared. Since the typical astrometric amplitude of binary asteroids is of the order of a few mas, one requires an astrometric dataset with about a 1 mas accuracy. We are using two datasets with precise astrometry: GAIA-DR2, and ZTF with improved astrometry.

- GAIA-DR2 provides low-cadence astrometric observations of about 14,000 asteroids with typical one-dimensional accuracy of 1-3 mas per epoch. A major disadvantage of this dataset is its sparse cadence and small number of epochs, with typical time scales of 108 min, 6 hours, and about 2 months.

- The ZTF data has several advantages, including the high cadence and very large (~1000) number of epochs per asteroid. Currently, PTF/ZTF is limited to accuracy of 3 mas (systematic, over hundreds of images, Segev et al., in prep., [4]).

We developed a full forward modeling of the binary problem. Specifically, starting with a binary asteroid with a known orbit around the Sun and specific satellite (unknown) orbital parameters, we can predict the observed astrometric residual of the center of light compared with the center of mass. This involve light time correction, and multiple projections. Our code is able to scan the entire parameter space of a single binary asteroid in a few hours on a single CPU.

Results: With a separation of 1 to 10 mas, it is possible to detect satellites at a separation of ~10 kilometers (outer main belt), a few kilometers (inner main belt asteroids), and hundreds of meters (Near-Earth asteroids). The maximal amplitude of the center-of-light around its center of mass can reach >20 mas at a radius ratio R2/R1 of 0.2, when the asteroid has a radius of R1=10 km, and an orbital period of > 100 h. Therefore, the astrometric approach can detect satellites with parameters that are rare among known binary asteroids (Fig. 1).

With known binary fraction of ~15%, and ~10^5 inner main belt asteroids in ZTF with hundreds of images, we expect to be able to detect many new binary asteroids.

References: [1] Margot, J.-L. et al. (2015). *Asteroids IV,* University of Arizona Press, 355-374. [2] Pravec, P. et al. (2006). *Icarus* **181**, 63-93. [3] Ostro, S. et al. (2006). *Science* **314**, 1276-1280. [4] Ofek, O.E. (2019). *PASP* **131**, 999-54504.

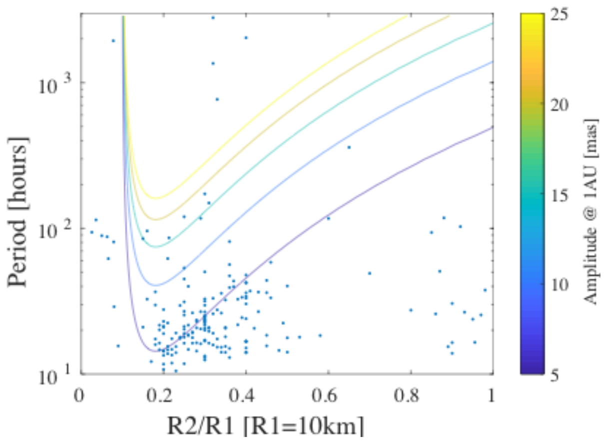

Figure 1: Lines of equal center-of-light shift (5, 10, 15, 20, 25) mas (bottom up) as a function of R2=R1 radius ratio and the orbital period. This is calculated assuming primary with R1 = 10 km, and asteroids density of 3 g cm^{-3}. The approximated (due to the constant R1) position of known binary asteroids is shown as dots. It is clear that the astrometric method is sensitive in regions which are harder to probe using other methods.