PDC 2025
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Tidal disruptions increase the number of asteroids on Earth-crossing orbits

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Keywords: near-Earth asteroids, orbit distribution, size distribution, tidal disruption, survey science

Numerical modeling has long suggested that gravitationally bound near-Earth asteroids (NEAs) can be destroyed by tidal forces during close and slow encounters with terrestrial planets [1, 2]. An asteroid's likelihood of experiencing tidal disruption is mainly determined by how close it gets to a planet at its closest approach and its velocity relative to the planet during the encounter. The asteroids most likely to experience tidal disruption during close and slow encounters with the Earth are those that also have a high likelihood of impacting the Earth. However, so far there has been hardly any undisputable evidence of tidal disruptions actually occurring in the innermost regions of the Solar System.

We present population-level evidence for the tidal disruption of NEAs during close encounters with the Earth and Venus. A comparison between observations and model distributions for NEA orbits and absolute magnitudes shows that the earlier models [3, 4] underestimate the number of NEAs with perihelion distance coinciding with the semimajor axes of Venus and the Earth ([5], Fig. 1).

A detailed analysis of the excess NEAs shows that their characteristics agree with the prediction for tidal disruptions, and they cannot be explained by observational selection effects or orbital dynamics [5]. These findings have later been independently verified by other studies [6].

Tidal disruptions may solve the long-standing puzzle of bolide-detection networks observing approximately an order of magnitude more decameter-sized Earth impactors than models based on telescopic asteroid surveys predict. Very recent studies focusing on meteors and bolides have not found further orbital evidence for tidal disruptions, but have concluded that the lack of evidence can be a result of the small sample size [7, 8].

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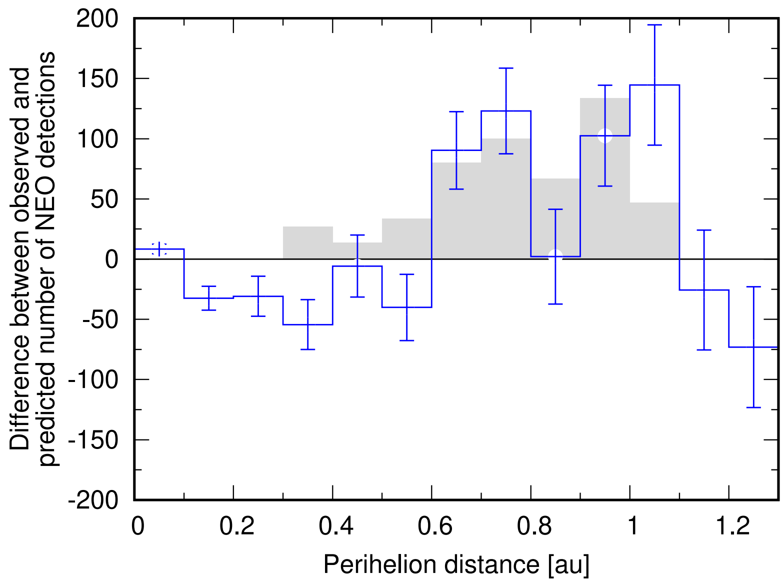

Figure 1: The difference between observed and predicted number of NEO detections by Catalina Sky Survey (CSS) during the years 2005–2012 as a function of perihelion distance q (blue line). The model prediction assumes a super-catastrophic disruption when $q \sim 0.076$ au [3]. The observed population is substantially larger than the predicted population for $q \sim a_{\rm Venus} \sim 0.7$ au and $q \sim a_{\rm Earth} \sim 1$ au. The difference cannot be explained by selection effects or orbital dynamics. The gray histogram shows an arbitrarily normalized distribution of the perihelion distances of synthetic gravitational aggregates that in numerical simulations have undergone tidal disruptions during encounters with the Earth or Venus. Figure from [5].

Preliminary findings suggest that even the 370-meter-diameter Apophis ($q \sim 0.75$ au, aphelion distance $Q \sim 1.1$ au) may be a fragment of a tidal disruption event with Venus or the Earth. It would be at least a partial explanation as to why an event, that current models predict should occur once in 7000 years [9], happens just some decades after mankind has become aware of the asteroid-impact hazard. More research is needed on population-level modeling of tidal disruptions, and on timing a hypothetical Apophis-forming event, to resolve the issue.

In summary, future orbital models of the NEA population need to account for the generation of smaller fragments through tidal disruptions of larger NEAs.

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