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Thermal and tidal destruction of near-Earth objects

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Abstract

The general assumption for the fate of near-Earth objects (NEOs) was that most of them plunge into the Sun [1], roughly a quarter are cleared by Jupiter, and the remaining few percent impact the terrestrial planets, most often the Earth. A more complex picture for the fate of NEOs is starting to emerge as a result of efforts to understand the debiased orbit and absolute magnitude distributions for NEOs. Two particularly interesting phenomena are the thermal destruction of asteroids at small perihelion distances and the tidal disruption of asteroids during close encounters with terrestrial planets. It is likely that detailed physical modeling of these phenomena will allow us to place useful constraints on asteroid bulk composition and interior structure using data from, primarily, ongoing (e.g., Catalina Sky Survey, Panoramic Survey Telescope And Rapid Response System) and planned NEO surveys (e.g., Large Synoptic Survey Telescope).

1. Thermal destruction

By comparing predicted distributions of near-Earth-object (NEO) orbits and absolute magnitudes with observations by the CSS during 2005–2012 it was recently shown that there are up 10x fewer NEOs observed than predicted on orbits with small perihelion distances. The only way to reconcile the discrepancy is to assume that most NEOs are destroyed when reaching small, yet non-trivial distances from the Sun [2]. The (primary) physical mechanism causing these super-catastrophic disruptions is still undefined but it is most likely thermally driven. The most obvious alternatives have already been ruled out (Fig. 1).

2. Tidal disruption

It has been proposed that some (small) fraction of NEOs may be tidally disrupted during close encounters with terrestrial planets [3], although this has so far not been backed up by population-wide observational evidence. See [4] for evidence for a possible tidal re-shaping of (1620) Geographos. Further analysis of the distribution of perihelion distances [2] shows that the model underoverpredicts the number of NEOs with perihelion distance coinciding with the semimajor axes of Venus and the Earth (Fig. 2). This agrees with the prediction for tidal disruptions [5, 6] and cannot be explained by selection effects or orbital dynamics.

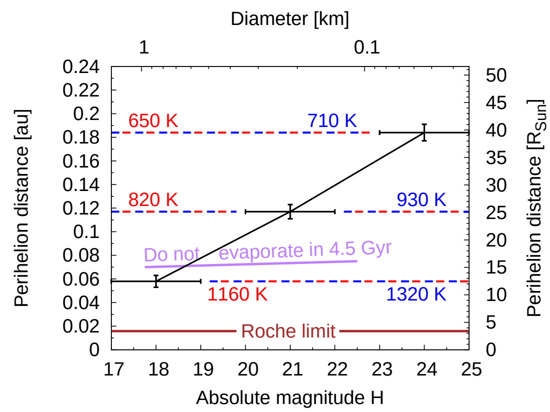

Figure 1: The typical disruption distance as a function of NEO size based on model fits to observed NEO population [2]. The horizontal dashed lines show estimated ranges for surface temperature. Direct evaporation and tidal disruption during close encounters with the Sun are ruled out as disruption mechanisms.

Acknowledgements

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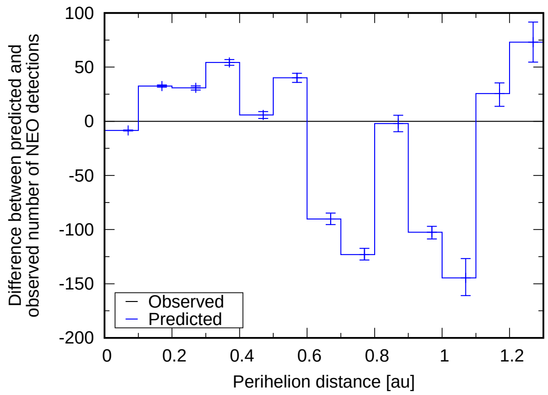

Figure 2: Difference between predicted and observed number of NEO detections by CSS as a function of perihelion distance. The prediction assumes a super-catastrophic and thermally-driven disruption when the perihelion distance reaches below 0.076 au [2] but it does not account for tidal disruptions. The same observed excess at the semimajor axes of Venus (∼0.7 au) and the Earth (∼1 au) is also seen for models not accounting for thermally-driven disruption.

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