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Current and future constraints on the thermal disruption of asteroids

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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. A particularly interesting phenomenon is the thermal destruction of asteroids at small perihelion distances. It is likely that a detailed physical modeling of this phenomenon will allow us to place useful constraints on, at least, the bulk composition of asteroids, and perhaps also on their interior structure. I will summarize our current knowledge of the issue, and explain how survey data from ongoing surveys (e.g., Catalina Sky Survey, Panoramic Survey Telescope And Rapid Response System, ESA Gaia) and planned surveys (e.g., ESA Euclid and the Large Synoptic Survey Telescope) can both directly and indirectly help constrain the mechanism(s) responsible for the destruction of asteroids on orbits with small perihelion distances.

1. Introduction

By comparing predicted distributions of near-Earth-object (NEO) orbits and absolute magnitudes with observations by the CSS during 2005–2012 it has been 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 such as tidal forces caused by the Sun and direct evaporation have already been ruled out (Fig. 1).

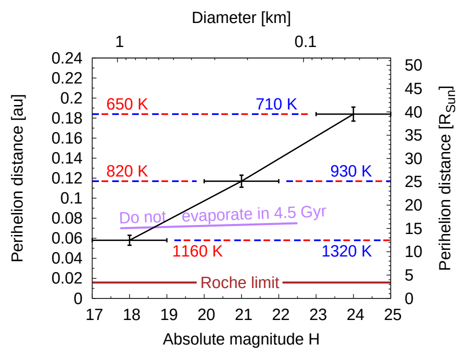

Figure 1: The typical disruption distance as a function of NEO size based on model fits to observed NEO population [2]. The horizontal dashed lines show estimated ranges for surface temperature. Direct evaporation and tidal disruption during close encounters with the Sun are ruled out as disruption mechanisms.

2 Disruption distance is correlated with surface characteristics

Granvik et al. (2016) already showed that the average disruption distance depends on the albedo of the asteroid. In particular they noted that dark objects tend to disrupt farther from the Sun (and thus easier) than their brighter counterparts. This is reasonable considering that dark asteroids are assumed to be richer in volatiles.

Future surveys and future data releases from ongoing surveys will include spectroscopic or spectrophotometric data on asteroids. We can combine this data with our existing models of the NEO population to constrain the disruption distance on the basis of spectroscopic classification rather than albedo alone.

The surveys that provide photometry only are also highly useful in the sense that we can constrain surface characteristics by relying on the information available from photometric phase curves [3]. This opportunity is particularly interesting because it is straightforward to debias the phase curve information as an integral part of the construction of a population model.

3 Other opportunities for constraining the disruption mechanism

We are currently also looking into other potential constraints for the disruption mechanism. We have an ongoing spectroscopic and polarimetric follow-up program at the Nordic Optical Telescope that targets near-Earth objects on orbits with small perihelion distances with the aim of constraining their surface properties.

In terms of laboratory experiments we are currently in the process of constructing a heating experiments for the Asteroid Engineering Lab at Luleå University of Technology in Sweden to understand how asteroid-analogue materials behave in the temperature range encountered by the asteroids. See also E. MacLennan's abstract and presentation on modeling the thermal evolution of asteroids on orbits with small perihelion distances.

In addition, we are modeling meteor and fireball data and focusing on small perihelion distances to understand whether some of the meteoroids actually originate in one of these thermally-driven disruptions [4].

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