Triaxial Asteroids as Reservoirs for Planetary Debris around White Dwarfs

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White Dwarf Pollution From Asteroids

A large number of white dwarfs show evidence of terrestrial planetary elements in their atmospheres, indicative of recent accretion (Koester et al., 2014, Bonsor et al., 2020).

Direct observations of disrupting exo-asteroids (Vanderburg et al., 2015, Vanderbosch et al., 2019) have opened questions about the processes which lead to small body disruption.

Theoretical work to date has used spherical approximations, but Solar System asteroids have been well modelled by triaxial ellipsoids.

Here we simulate asteroids with six different ellipsoidal shape models (see interactive shape models here) and three possible sets of material properties simulating snowy, rocky and iron asteroids.

Disruption Outcomes

Using an analytical framework to compare an asteroid's sublimated size with the tidal disruption condition, what happens to an asteroid on an extremely eccentric orbit (e ~ 1) can be divided into three categories.

- *Sublimation:* incident starlight causes the asteroid to totally sublime.
- *Fragmentation:* tidal forces overcome self-binding forces and the asteroid fragments into smaller pieces.
- *Impacts:* the asteroid impacts directly onto the surface of the white dwarf.

Main Belt Analogue

An exo-main belt could survive a star's giant branch evolution and provide an ample reservoir for white dwarf pollution.

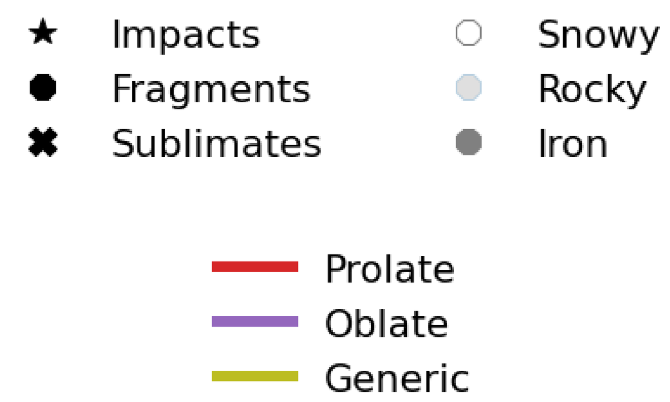
Here we construct a simplified Main Belt analogue with the following properties:

- 100 asteroids
- Power law size distribution (n ~ 0.9 for a > 1km and n ~ 0.26 for a < 1km) (Peña et al., 2020)
- Each asteroid has randomly selected shape model
- Each asteroid has randomly selected material properties (snowy, rocky or iron)

For each body in the belt we identify which destruction regime will befall the body as it approaches the white dwarf.

Results

For two different white dwarf temperatures and ages (Fig 1: hot and young; Fig 2: old and cold), we show the outcomes if every single asteroid approaches the white dwarf.



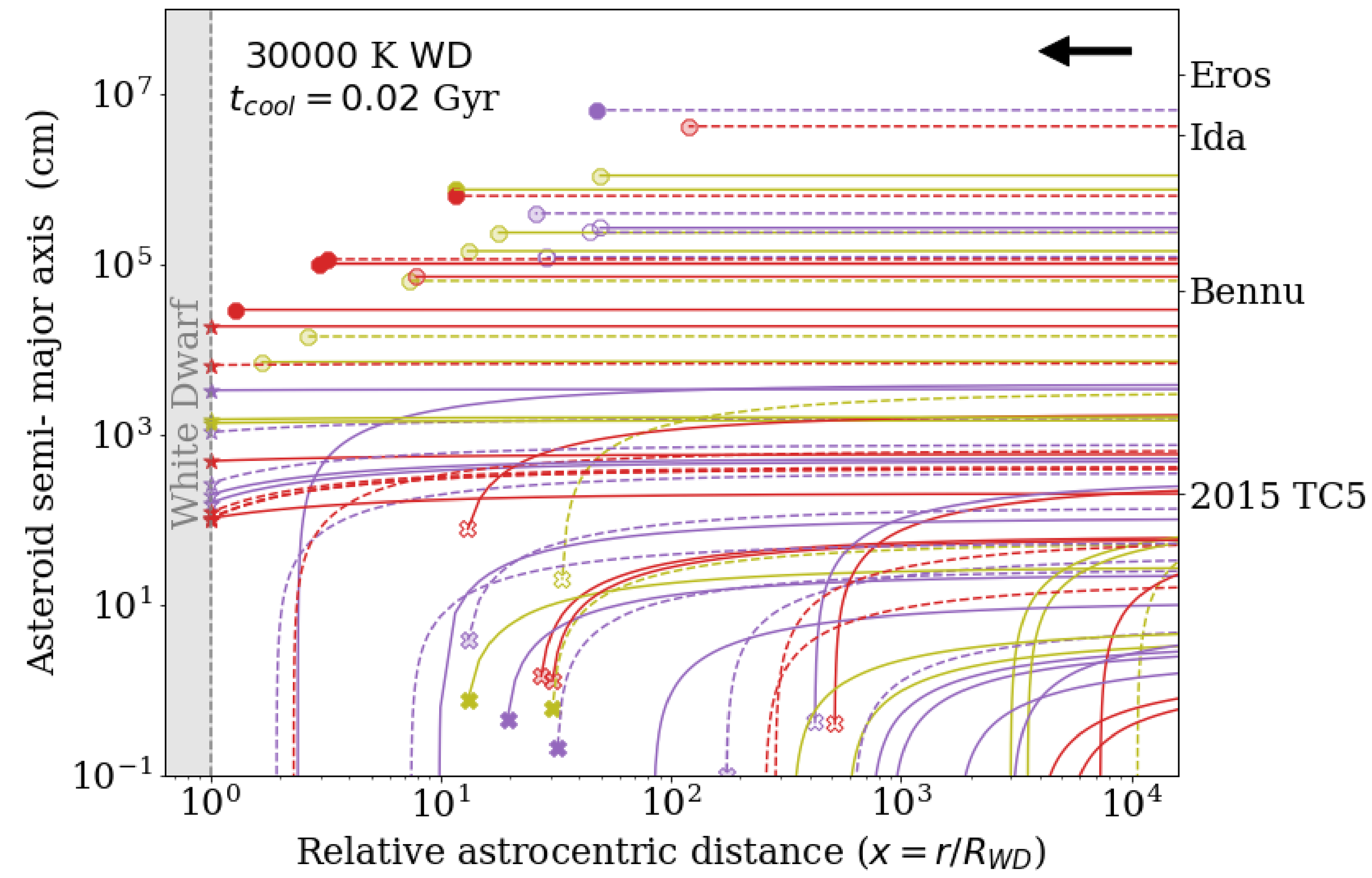


Figure 1: Distance from the white dwarf, mode of destruction and final largest semi-axis size for an asteroid around a young and hot white dwarf. Some Solar System asteroid sizes are inidicated on the right-hand axis.

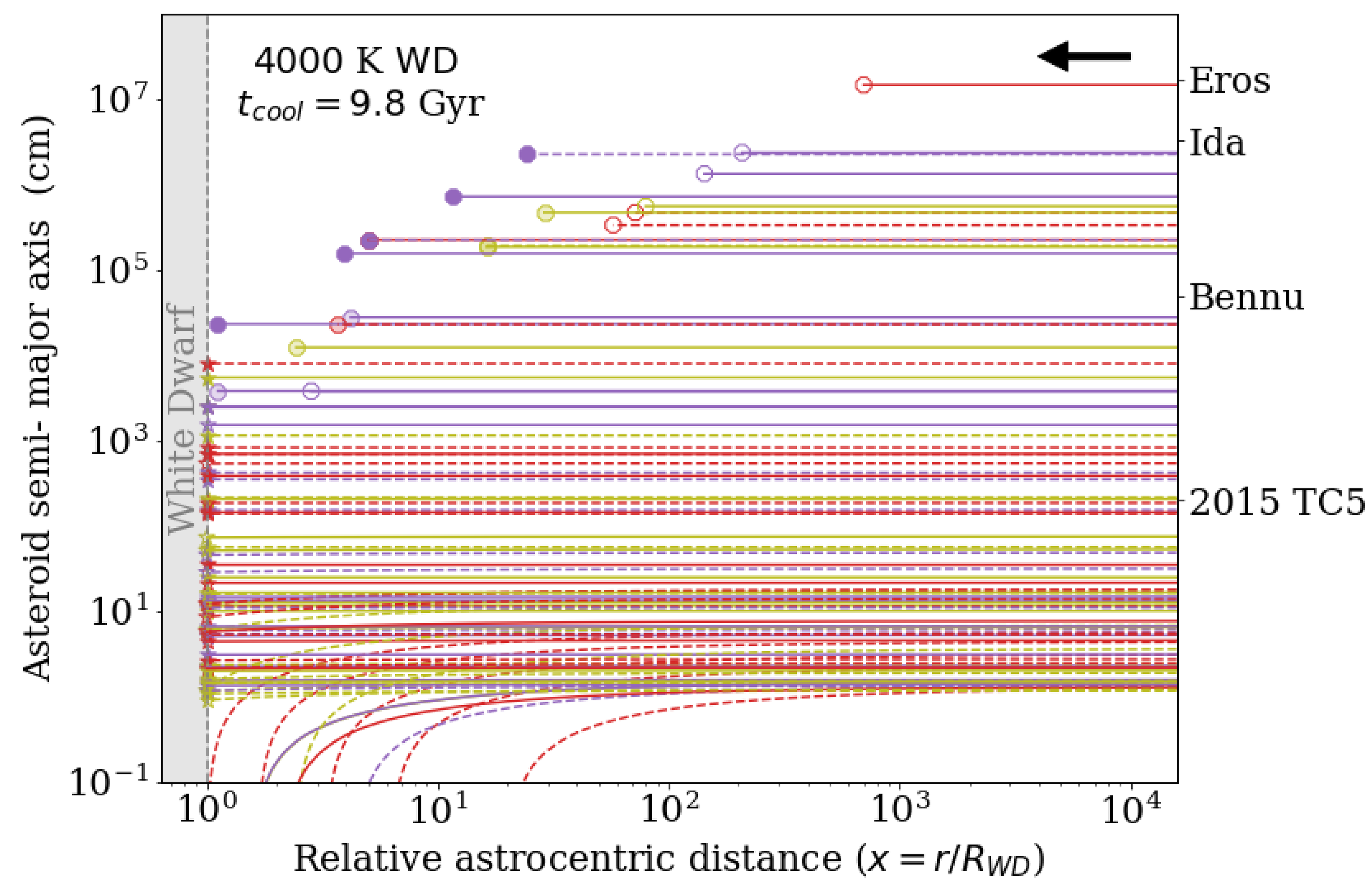


Figure 2: Distance from the white dwarf, mode of destruction and final largest semi-axis size for an asteroid around an old and cold white dwarf. Some Solar System asteroid sizes are indicated on the right-hand axis.

Conclusions

- Using a spherical shape model can underestimate the distance at which a body will sublimate.
- Fragmentation occurs at consistent sizes regardless of individual shape model.
- Around hotter white dwarfs, larger bodies can sublimate at greater distances, predicting a wider belt of gaseous debris.
- Cooler, older white dwarfs are more likely to have bodies enter directly into the white dwarf's photosphere.
- Asteroids up to 100m in diameter can impact across all white dwarf temperatures.
- Fragmentation only occurs for the largest bodies and the fragments will will then be subjected to either sublimation or impact.

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