Binary Asteroid Scattering around White Dwarfs

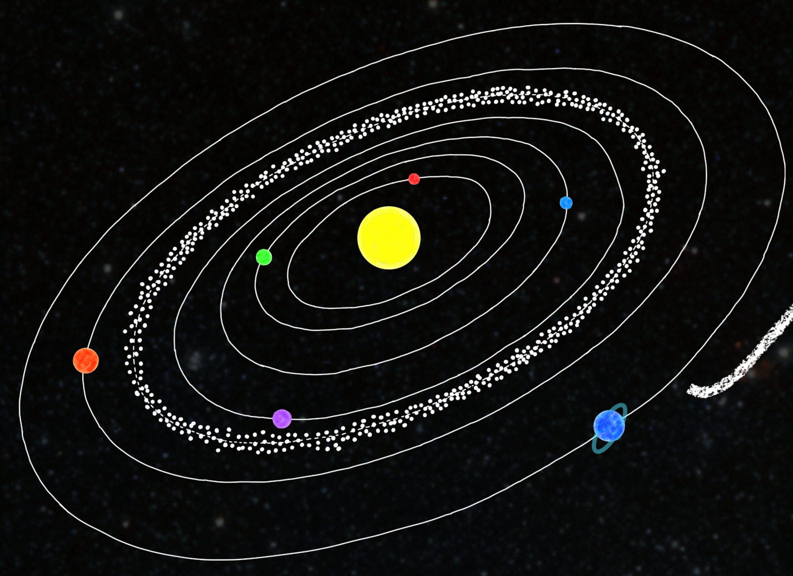
Catriona McDonald[1,2], Dimitri Veras[1,2,3]

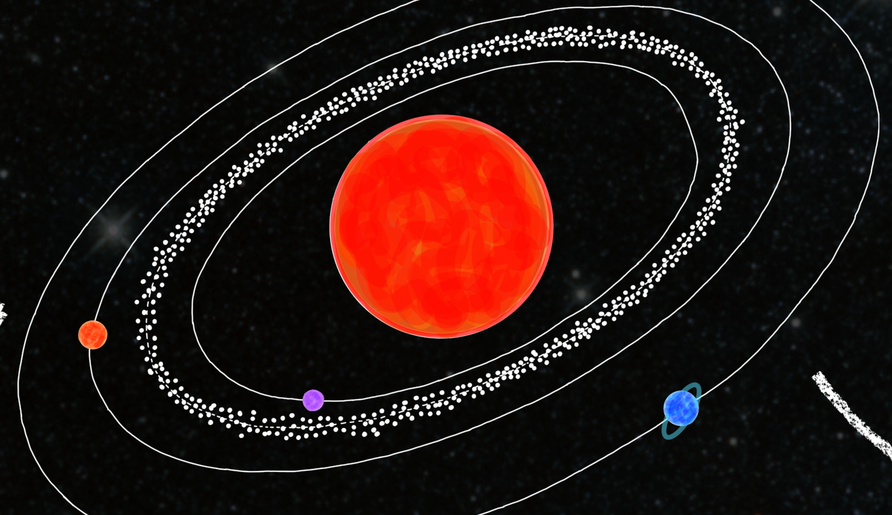
[1]Centre for Exoplanets and Habitability, University of Warwick, Coventry, CV4 7AL, UK
[2]Department of Physics, University of Warwick, Coventry, CV4 7AL, UK
[3]Centre for Space Domain Awareness, University of Warwick, Coventry, CV4 7AL, UK

Planetary Systems Through Stellar Evolution

Main Sequence

- Majority of stars in the Milky Way host at least one planet [1]



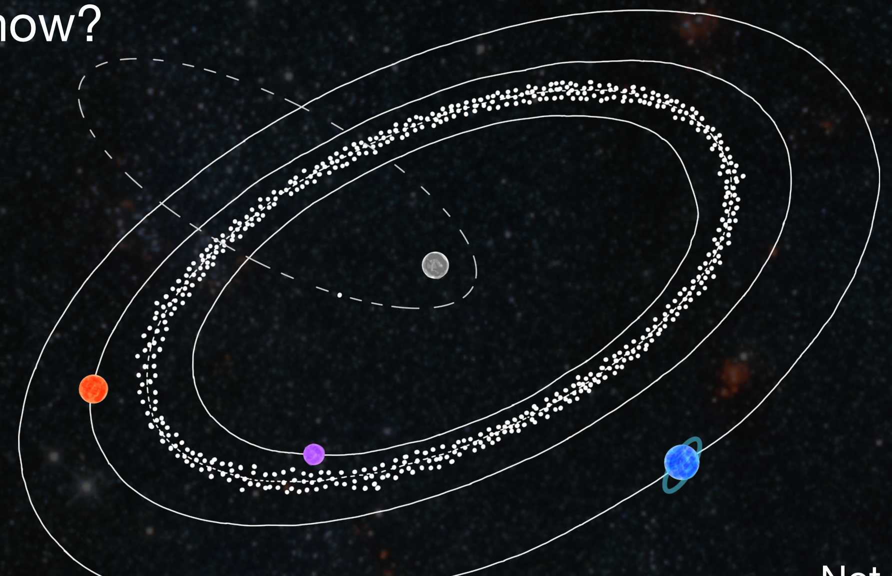


Giant Branches

- Star loses up to 80% of its mass and becomes 1000x larger and brighter
- Close in planets are engulfed
- Planetary orbits get 2-3x larger [2]

White Dwarf

- 95% of stars in the Milky Way will become white dwarfs [3]
- Extremely small and dense (1/2 the mass of the Sun but 80x smaller)
- Unstable remnant planetary systems
- Observed transits of close in asteroids breaking up [4,5]
- Up to 50% show planetary material inside their photospheres [6]
- Asteroids are being destroyed and accreted onto white dwarfs, but how?



Not to scale!

Binary Asteroids

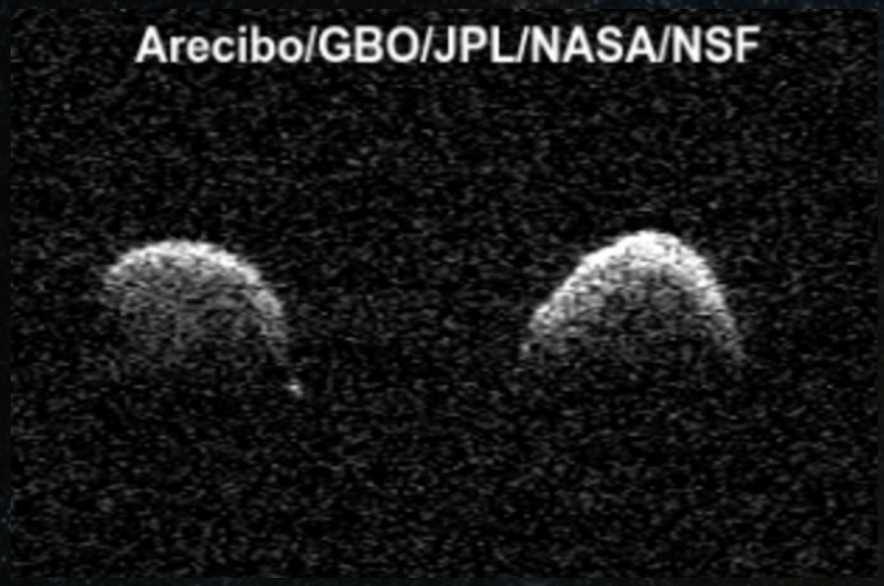


Figure 1. Near equal-sized NEA 2017 YE5.

Binary asteroids are ubiquitous throughout the Solar System. 20-30% of the cold classical Kuiper belt objects are binaries [7] with a significant proportion of nearly equal mass components [8].

It is likely that extrasolar systems also host binary asteroids in the regions which are most likely to survive violent stellar evolution, thus we need to consider their post-main-sequence evolution.

A Solar System Analogue

We carry out N-body simulations using REBOUND [9] including:

- $0.6 M_\odot$ central white dwarf
- The four giant planets with doubled semi-major axes
- 100 equal mass binary asteroids with
  - 84 au $< a < 94$ au
  - Component radius $r = 125$km
  - 1500 km $< a_B < 1.5 \times 10^5$ km

Binary dissociates:
$a_B > R_{Hill}$

Binary is ejected if circumstellar distance $d > 2.4 \times 10^5$ au

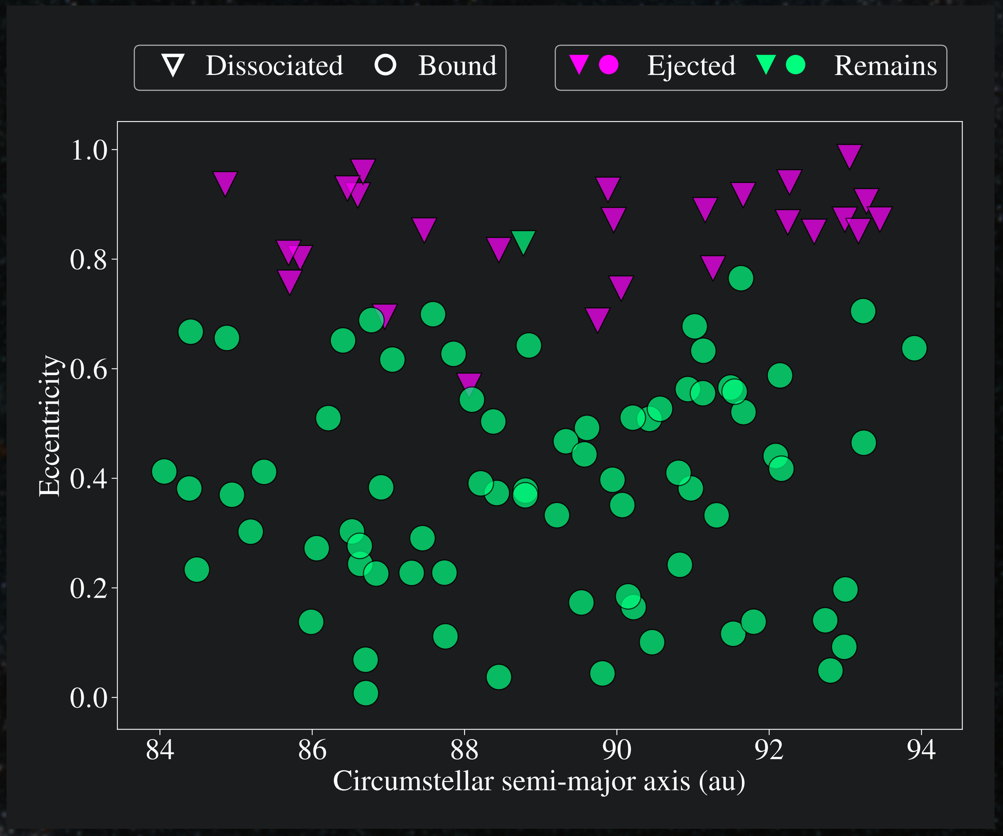


Figure 2. The initial circumstellar semi-major axes and eccentricities for the 100 binaries simulated. The outcome of the binary orbit is indicated by shape and outcome of stellar orbit by colour.

Outcomes

Approaches towards the white dwarf :

Binarity does not affect how close a body can get to the white dwarf.

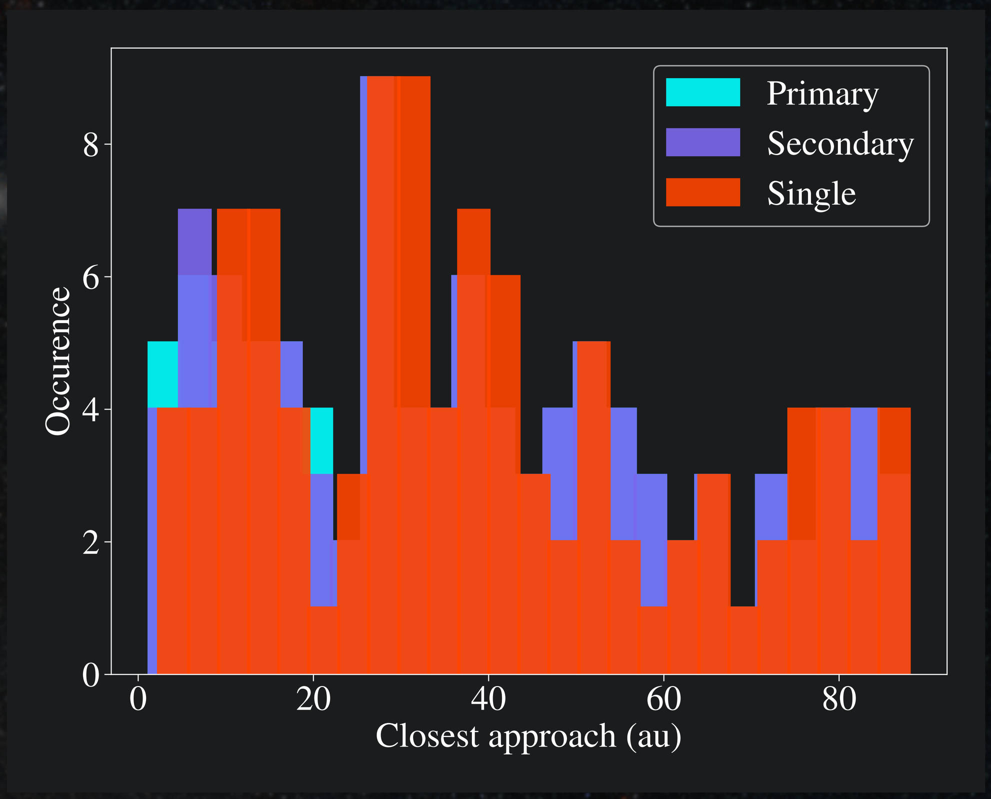


Figure 3. Histogram of the closest approach to the white dwarf for each binary component and an identical single component asteroid.

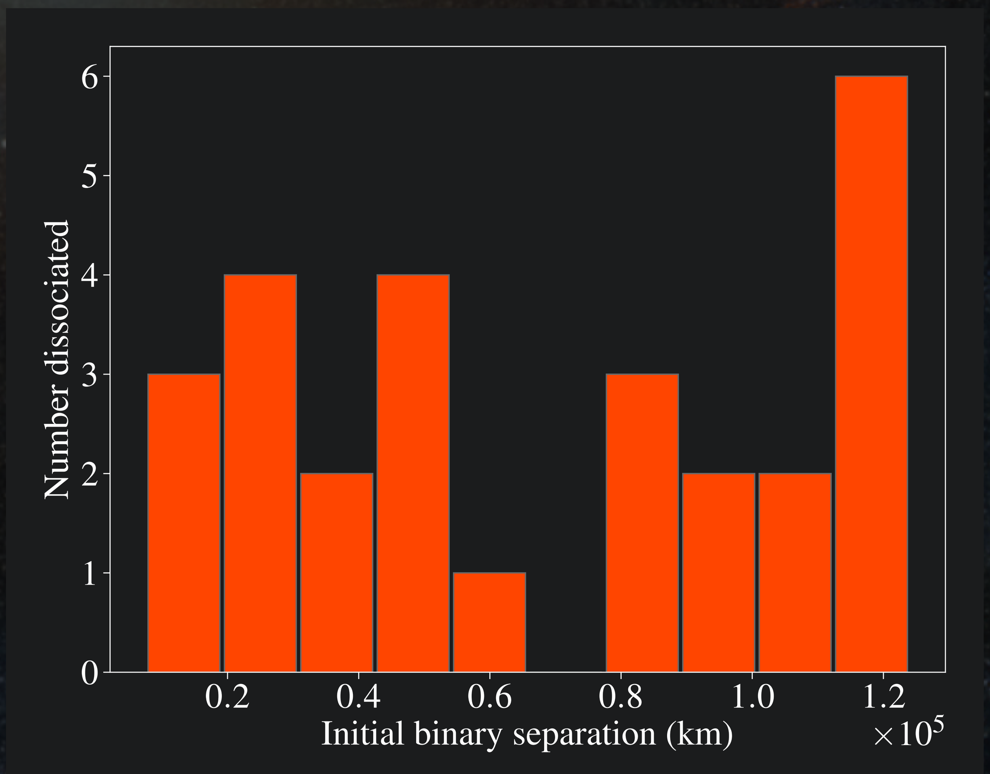


Figure 4. Occurrence of binary dissociations per initial binary separation.

Binary dissociations:

Circumstellar eccentricity has a larger effect on binary dissociation than binary separation.

Ejections from the system:

Approximately 25% ejected. Binary components often not ejected simultaneously.

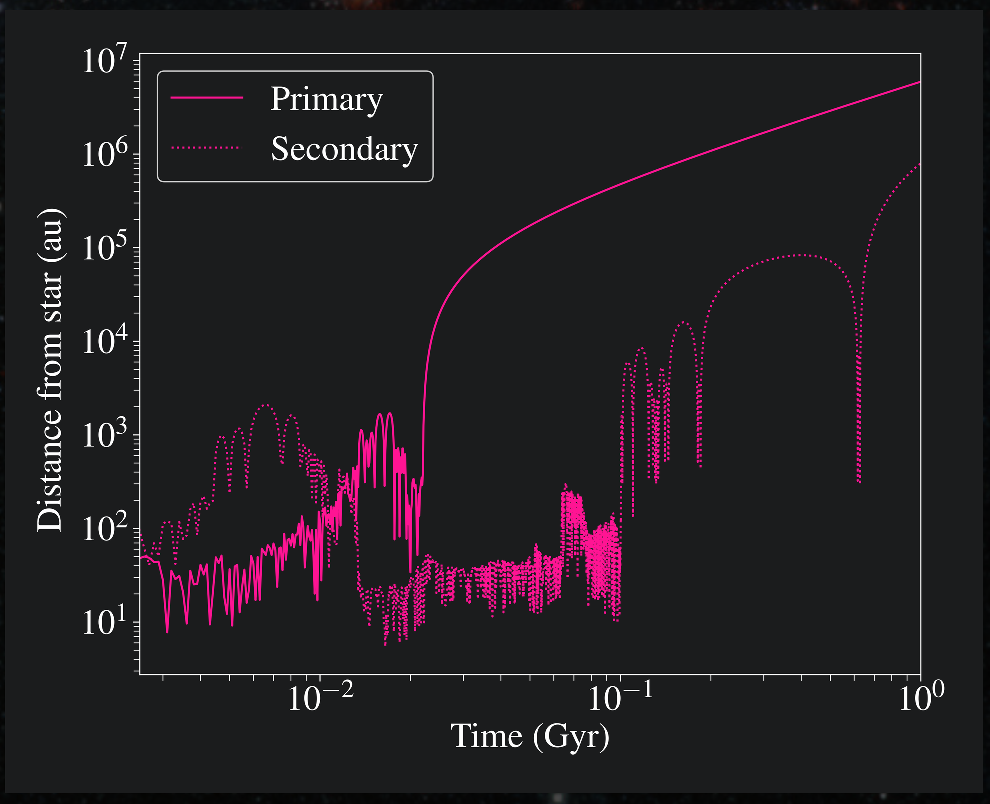


Figure 5. The distance from the central star for a dissociated binary whose components were both ejected

Conclusions

- No binaries directly cross the white dwarf Roche limit and tidally disrupt, but 15% cross Jupiter's orbit and could undergo further perturbations.
- A large fraction of binaries are dissociated and subsequently ejected from their system and become free-floating in processes which can last Myr.
- Binaries which do not dissociate can remain in the white dwarf Solar System for at least a Gyr with changing circumstellar and binary orbits.

References

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Email: catriona.mcdonald@warwick.ac.uk