EPSC Abstracts
Vol. 11, EPSC2017-53, 2017
European Planetary Science Congress 2017

Can Oort clouds pollute their parent stars after they become white dwarfs?

Dimitri Veras (1), Andrew Shannon (2), Boris T. Gänsicke (1)
(1) Department of Physics, University of Warwick, Coventry CV4 7AL, UK
(2) Institute of Astronomy, University of Cambridge, Cambridge CB3 0HA, UK
(d.veras@warwick.ac.uk)
Based on MNRAS (2014), 445, 4175-4185

Abstract

Comets impact the Sun frequently. In fact, coronographs like those which are part of Solar and Heliospheric Observatory (SOHO)/Large Angle and Spectrometric Coronagraph Experiment (LASCO) reveal that a comet grazes the Sun every few days, with a total of about 2400 grazers from 1996 to 2008 [1].

This frequency underscores an outstanding question in the quest to understand planetary systems: what types of small bodies — pebbles, asteroids, comets or moons — are the primary polluter of white dwarfs?

We determine how often remnant exo-Oort clouds, freshly excited from post-main-sequence stellar mass loss, dynamically inject comets inside the white dwarf's Roche radius (also see [2]). We improve upon previous studies by considering a representative range of single white dwarf masses (0.52–1.00 M⊙) and incorporating different cloud architectures, giant branch stellar mass loss, stellar flybys, Galactic tides and a realistic escape ellipsoid in self-consistent numerical simulations that integrate beyond 8 Gyr ages of white dwarf cooling. We find that $\sim 10^{-5}$ of the material in an exo-Oort cloud is typically amassed onto the white dwarf, and that hydrogen deposits accumulate even as the cloud dissipates. This accumulation may account for the relatively large amount of trace hydrogen, 10^{22} -10^{25} g, that is determined frequently among white dwarfs with cooling ages ≥1 Gyr. Our results also reaffirm the notion that exo-Oort cloud comets are not the primary agents of the metal budgets observed in polluted white dwarf atmospheres.

1. Simulation Details

In order to self-consistently model mass loss, Galactic tidal perturbations and multiple stellar flybys in an *N*-body integrator, we have heavily modified the integrator suite MERCURY (Chambers 1999). The modifications include the following.

(i) We incorporate stellar mass loss into the code by splicing in-between Bulirsch–Stoer time steps, which although is perhaps not necessary for test particle systems like ours here, significantly increases the accuracy for multiple massive objects.

(ii) When the star is not losing mass, the standard non-conservative Bulirsch–Stoer integrator is still used because the perturbation on a comet due to a flyby may be arbitrarily large. When perturbations are large, symplectic integrators may become inaccurate.

(iii) Stellar flybys are modelled as perturbative accelerations to all of the comets and the parent star. A new flyby is introduced when a probability threshold is reached after an individual time step.

(iv) We incorporate into the code a prescription for Galactic tides and assume our modelled systems reside in the solar neighbourhood, specifically at 8 kpc from the Galactic Centre. We include both horizontal and vertical tides, and contributions from an exponential disc, a Hernquist bulge and a cored isothermal halo.

(v) Because pollution likely arises from disrupted bodies forming discs or rings around the star, we replace the actual white dwarf radius with the white dwarf Roche radius. This change may significantly affect results relating to close encounters with the star.

(vi) We explicitly incorporate the Hill escape ellipsoid into MERCURY for every system sampled to flag ejection, thereby allowing us to quantify escape in preferential directions. This ellipsoid is dependent on both the stellar mass and the Galactic tidal prescription used.

2. Figures

Figures 1-3 illustrate the results of our simulations.

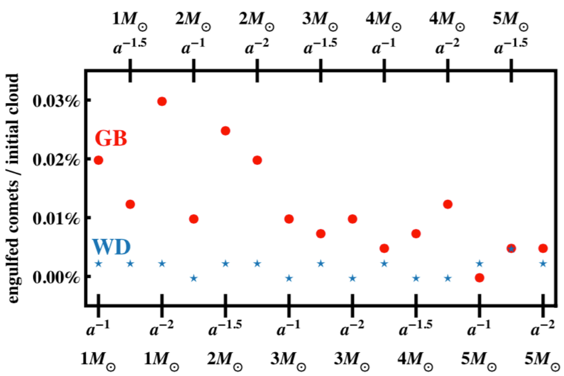

Figure 1: The fraction of comets in exo-Oort clouds which enter the Roche radius of the star when it is a giant branch star (GB; red filled dots) or a white dwarf (WD; blue stars). The results are binned according to the main-sequence stellar mass (and the mass-losing phase). Hence, comets are expect to hit the white dwarf at a rate of about one per 10,000 yr.

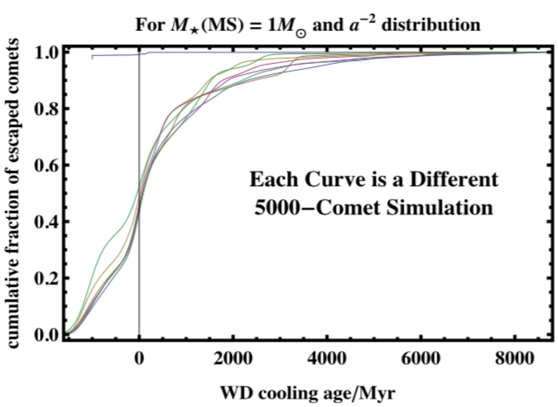

Figure 2: Cloud dissipation: the cumulative distributions of escaped exo-Oort cloud comets as a function of time.

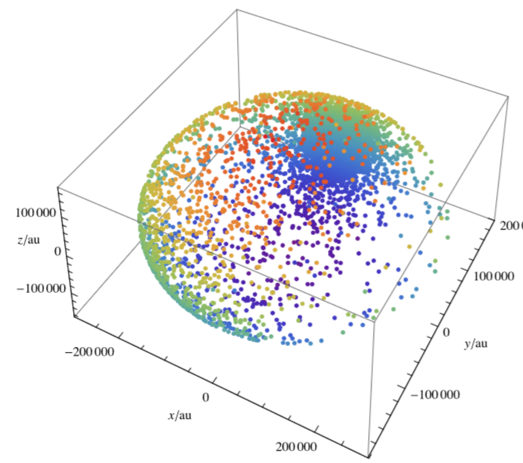

Figure 3: Patchy escape due to an intrusive stellar flyby: the Cartesian (x,y,z) locations where comets escape the Hill ellipsoid for a single 5000-comet 10 Gyr simulation with a stellar progenitor mass of 1 Solar mass.

Acknowledgements

DV and BTG have received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/ 2007-2013)/ERC Grant Agreement no. 320964 (WDTracer). AS has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/ 2007-2013)/ERC Grant Agreement no. 279973 (DEBRIS).

References

[1] Lamy, P., Faury, G., Llebaria, A., Knight, M.M., A'Hearn, M.F., Battams, K.: Sunskirting comets discovered with the LASCO coronagraphs over the decade 1996-2008, Icarus, Vol. 226, 1350-1398, 2013.

[2] Veras, D., Shannon, A., Gänsicke, B.T.: Hydrogen delivery onto white dwarfs from remnant exo-Oort cloud comets, MNRAS, Vol. 445, 4175-4185, 2014.