The dynamics of polluting white dwarfs with remnant extrasolar Oort Cloud comets

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The progenitors of the abundant metal pollution detected in white dwarf atmospheres is widely thought to be asteroidal, based on measured abundances of heavy elements. Not a single polluted white dwarf yet harbours abundances which are compositionally consistent with the ingestion of cometary material. This finding is surprising given the high frequency of observed Sun-grazing comets in our Solar System from the coronagraphs on SoHO's LASCO.

Here, we consider this puzzle from a dynamical perspective. We determine how often remnant extrasolar Oort clouds, freshly excited from post-main-sequence stellar mass loss, dynamically inject comets inside the white dwarf's Roche radius. We improve upon previous studies by considering a representative range of single white dwarf masses ($0.52 - 1.00 M_{\odot}$) 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 the 5 Gyr ages of the oldest-known polluted white dwarfs. We find that the collision rates with giant branch stars and white dwarfs are roughly one comet per 10^3 and 10^4 yr, respectively (see the Figure). This rate is insufficiently low to account for all of the mass found in the deep convective layers of many polluted DBZ white dwarfs, but high enough to be observable with our current sample of polluted white dwarfs. Hence, we conclude that both the pollution process is not dominated by long-period comets and, alternatively, that we should see some evidence of their accretion as the polluted white dwarf sample increases over the next few years.

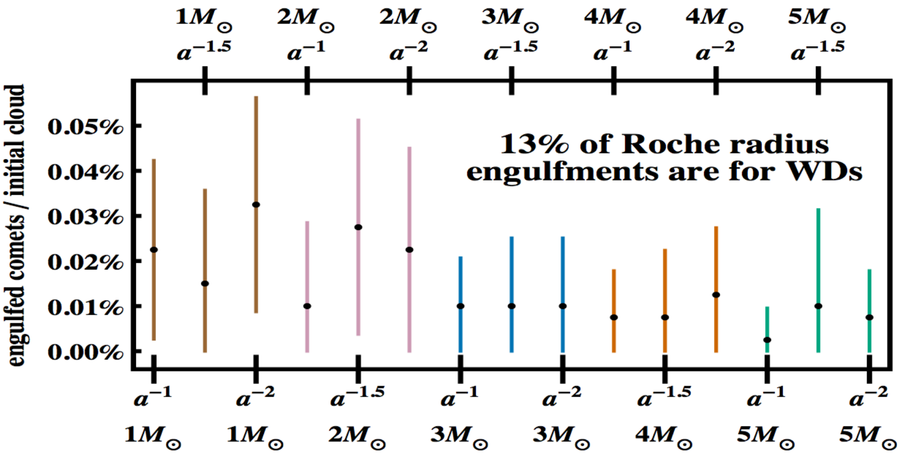

Figure: The fraction of comets in extrasolar Oort clouds which enter the Roche radius of the star after it turns off of the main sequence. The results of all 120 simulations of 5000 comets each are presented, binned according to the main sequence stellar mass and semimiajor axis profile of comets (shown on the top and bottom axes). The black dots refer to mean values across all simulations in each bin, and the lines represent one standard deviation from these mean values in each direction. The line colours correspond to different progenitor masses. About 87 % of all comet break-ups occur between the end of the main sequence and the beginning of the white dwarf stage. Hence, comets are expect to hit the white dwarf at a rate of about one per 10^4 yr.

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