A Super-Eddington Wind Scenario for the Progenitors of Type Ia Supernovae

The accretion of hydrogen-rich material on to carbon-oxygen white dwarfs (CO WDs) is crucial for understanding Type Ia supernova (SN Ia) from the single-degenerate model, but this process has not been well understood due to the numerical difficulties in treating H and He flashes during the accretion. For CO WD masses from 0.5 to 1.378 $M_{\odot}$ and accretion rates in the range from 10^{-8} to 10^{-5} $M_{\odot}yr^{-1}$, we simulated the accretion of solar-composition material on to CO WDs using the state-of-the-art stellar evolution code of MESA. For comparison with steady-state models, we first ignored the contribution from nuclear burning to the luminosity when determining the Eddington accretion rate, and found that the properties of H burning in our accreting CO WD models are similar to those from the steady-state models, except that the critical accretion rates at which the WDs turn into red giants or H-shell flashes occur on their surfaces are slightly higher than those from the steady-state models. However, the super-Eddington wind is triggered at much lower accretion rates than previously thought, when the contribution of nuclear burning to the total luminosity is included. This super-Eddington wind naturally prevents the CO WDs with high accretion rates from becoming red giants, thus presenting an alternative to the optically thick wind proposed by Hachisu et al. (1996, ApJL, 470, L97). Furthermore, the super-Eddington wind works in low-metallicity environments, which may explain SNe Ia observed at high redshifts (see Ma et al. 2013, ApJ, 778, L32).

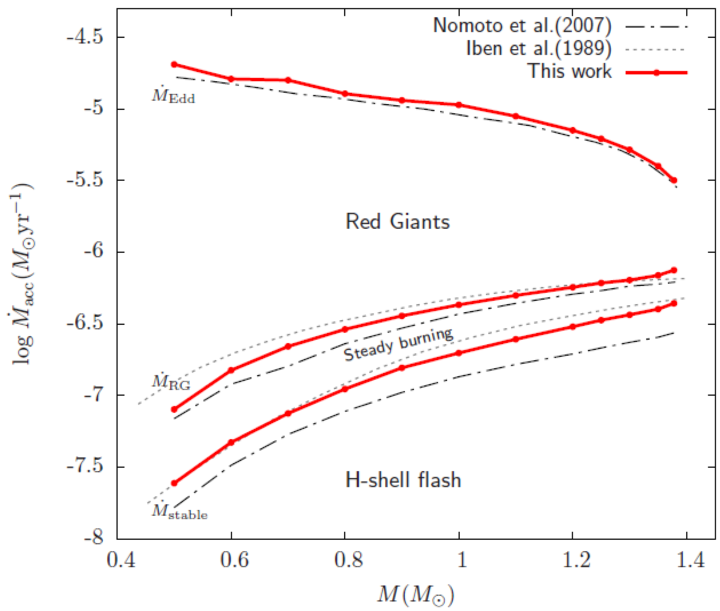

Figure 2: Properties of H burning on the surfaces of accreting CO WDs in the WD mass-accretion rate plane. The super-Eddington wind is triggered when $L_{acc} = L_{Edd}$. The red solid curves are the results of our calculations. The black dot-dashed curves and the gray dotted curves are from Nomoto et al. (2007, ApJ, 663, 1269) and Iben & Tutukov (1989, ApJ, 342, 430), respectively.

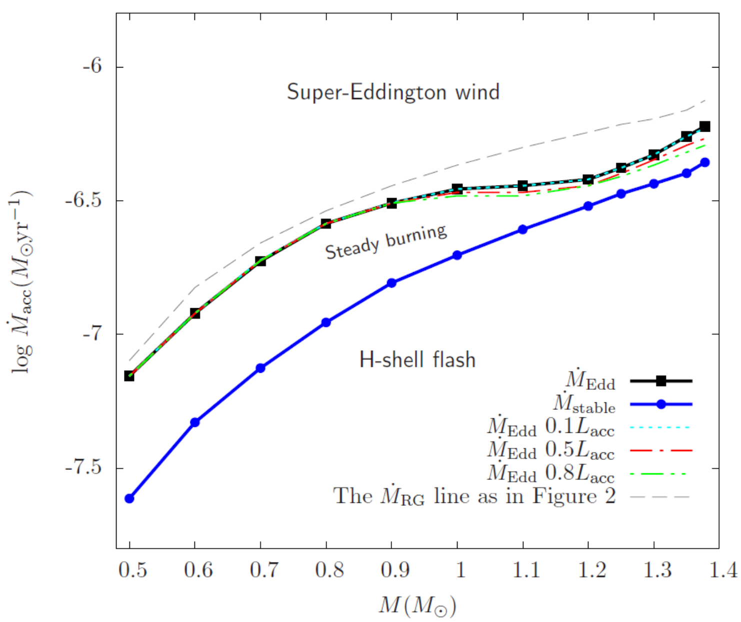

Figure 1: Properties Similar to Figure 2, but the super-Eddington wind is triggered when $L_* = L_{Edd}$ (thick solid curves). The light blue dotted, red dot-dashed, and green dash-dotted lines show the Eddington accretion limits by adopting $L_{Edd} = L_* + 0.1L_{acc}$, $L_{Edd} = L_* + 0.5L_{acc}$, and $L_{edd} = L_* + 0.8L_{acc}$, respectively. The super-Eddington wind starts much earlier and the boundary of dM_{RG}/dt does not exist in this condition. For a comparison, the grey dashed curve shows the boundary of dM_{RG}/dt presented in Figure 2.

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