GROWTH RATE OF WHITE DWARF MASS IN BINARIES

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ABSTRACT: The growth rate of a white dwarf which accretes hydrogen-rich or helium matter is studied. If the accretion rate is relatively small, unstable shell flash occurs and during which the envelope mass is lost. We have followed the evolutions of shell flashes by steady state approach with wind mass loss solutions to determined the mass lost from the system for wide range of binary parameters. The time-dependent models are also calculated in some cases. The mass loss due to the Roche lobe overflow are taken into account. This results seriously affects the existing scenarios on the origin of the type I supernova or on the neutron star formation induced by accretion.

Some neutron stars in low-mass X-ray binaries and binary radio pulsars are suggested to be formed through the accretion-induced collapse of white dwarfs (e.g., Taam and van den Heuvel 1986 and references therein). This accretion-induced collapse is based on the assumption that the accreting white dwarfs can grow to the Chandrasekhar mass. However, once a strong nova explosion occurs, a significant part of the envelope mass is ejected from the system (see, e.g., Prialnik 1986). When the mass accretion rate is higher than $\sim$ 2×10^{-7} $M_{\odot}$ yr^{-1}, the hydrogen shell burning is stable but helium shell

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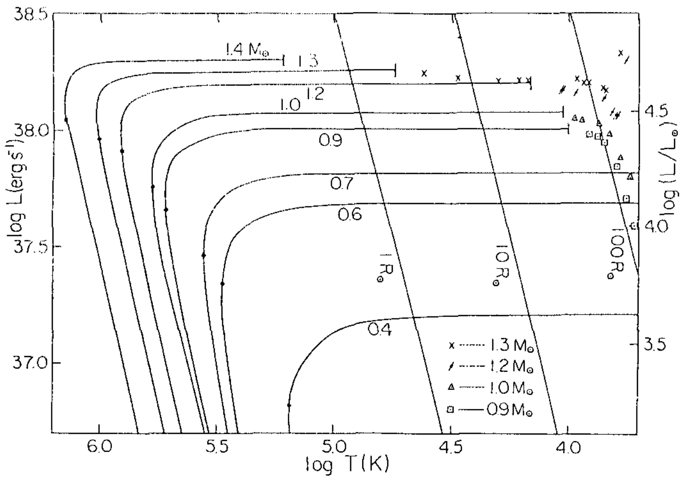
burning is unstable. Therefore we studied whether white dwarfs can grow to the Chandrasekhar mass or not.

We have solved steady state equations with mass loss for the cases of nova and helium nova and obtain sequences of optically thick wind solutions. The wind is accelerated by continuum radiation. When the wind does not occur we solved static equations. The formulation of the wind and the basic envelope structures are explained in Kato (1983).

An evolutionary path of a nova can be followed by a sequence consisting of this static and steady state models with mass loss. Figure 1 shows that the mass loss solutions and static solutions for decay phase of nova for various white dwarf masses obtained by Kato and Hachisu (1988b). A complete cycle of nova for a 1.3 $M_\odot$ white dwarf is described in a similar way in Kato and Hachisu (1988a).



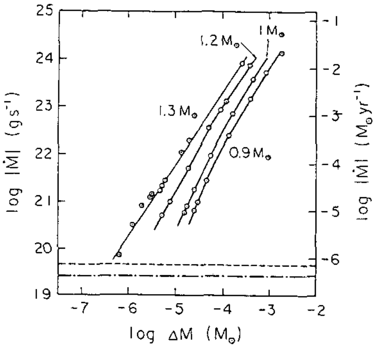


Fig. 1: The theoretical decay phase of novae. The wind solutions are denoted by the crosses or the other symbols. This wind ceases at the point with short vertical bar. Thin solid lines denote the constant radius lines.

Fig. 2: The mass loss rate of the steady mass-loss solution for nova against the envelope mass.

The mass loss rate of these wind solutions is plotted in Figure 2 against the hydrogen envelope mass Δ M. The mass loss rate is large when the photospheric temperature is low and it becomes smaller as the star moves blueward in the H-R diagram. Dashed and dot-dashed lines denote the mass decreasing rate due to the hydrogen burning for 1.3 and $0.9M_\odot$, respectively.

Figure 3 depicts evolutionary tracks of one cycle of helium nova.The terminology "helium nova" is used to stress the observational aspects of helium shell flashes on a white dwarf surface.

The evolutionary track in the rising phase depends on the ignition mass: three tracks are plotted for three ignition masses. The optically thick wind occurs at the filled circles and terminates at the point with the short vertical bar. Contrary to the initial phase, the evolutionary track in the decay phase is independent of the ignition mass, because the decay phase is assumed to be in the thermal equilibrium.

The mass loss rate of these solutions are plotted in figure 4. The mass decreasing rate due to nuclear burning is also shown.

We have also calculated time-dependent models These two results are in good agreement with each other.

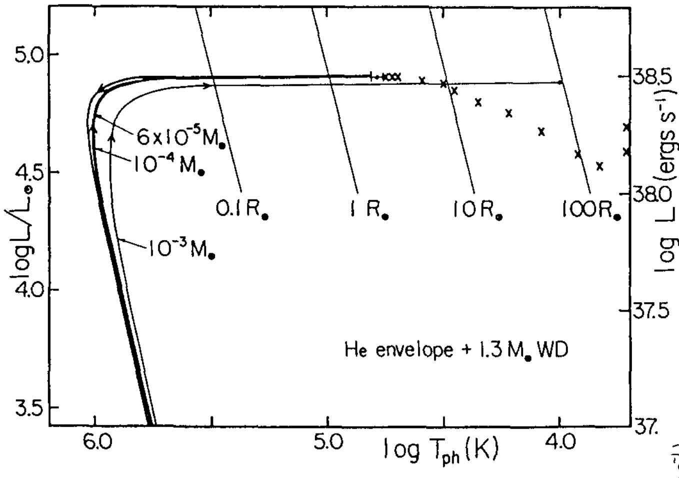


Fig. 3: The one cycle of helium nova in H-R diagram. The rising phase depends on the initial envelope mass which is attached to each curve. Wind mass loss begins at filled circles. The crosses denote the wind mass loss solutions in decay phase.

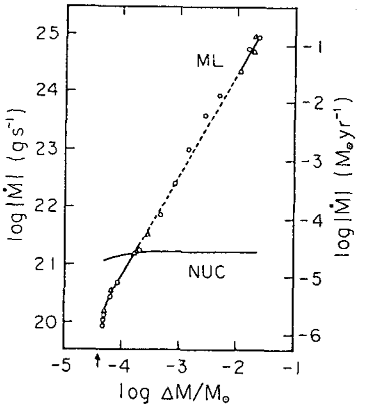


Fig. 4: The mass loss rate of the steady mass-loss solutions against the helium envelope mass for $1.3M_\odot$ white dwarf.

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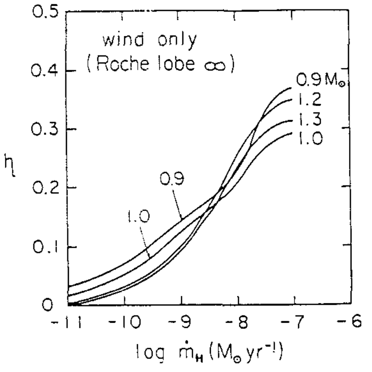
We have obtained how much mass is lost from the system or how much mass accumulates on the white dwarf. The mass accumulation ratio is calculated as follows. When the Roche lobe is large enough the envelope lose its mass due to the wind mass loss. We have mass loss rate during wind phase. The nuclear burning always produces processed matter which accumulate on the white dwarf surface except the first stage in which the convection prevents the production to accumulate. From these values (in figures 2 and 4) we have calculated the mass of the processed matter accumulated on the white dwarf. If the Roche lobe is small enough, the Roche lobe overflow is effectively occurs. We assumed that the matter outside of the Roche lobe is quickly removed.

Figure 5 shows that the mass accumulation ratio, i.e., the growth rate of the white dwarf mass. Figure 5a is for the nova case with large Roche lobe (For the small Roche lobe see Kato and Hachisu 1988a, b). Figure 5b shows for the growth rate of the $1.3M_\odot$ white dwarf. The crosses denote the results obtained from the time-dependent calculation in which $1R_\odot$ Roche lobe are assumed. Solid curves are from the steady state approach. (For detail see Kato, Saio, and Hachisu 1988).



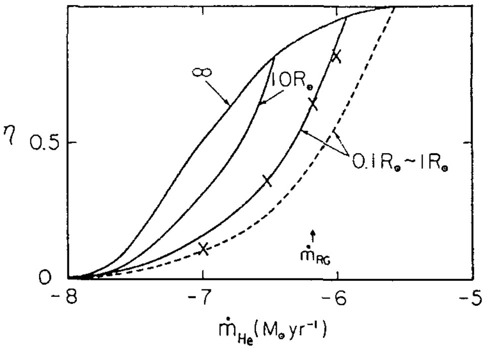


Fig. 5: The growth rate of the white dwarf is plotted against the accretion rate. a) Nova. b) Helium nova. The size of the Roche lobe are attached to each curve.

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