MASS EJECTION DURING HELIUM SHELL FLASHES FROM A MASSIVE WHITE DWARF

Hideyuki Saio[1], Mariko Kato[2], and Izumi Hachisu[3]

[1]Department of Astronomy, University of Tokyo
[2]Department of Astronomy, Keio University, Yokohama
[3]Department of Physics and Astronomy, Louisiana State University
and Department of Aeronautical Engineering, Kyoto University

Abstract: We have simulated the helium shell flashes on an 1.3 $M_\odot$ white dwarf and estimated the amount of mass loss. Our results may suggest a serious difficulty for the theories of the formation of Type I supernovae and of the accretion-induced formation of neutron stars because a significant amount of envelope mass is ejected during a helium shell flash.

Nova explosion which is caused by thermal flash of the hydrogen burning shell in an accreting white dwarf ejects a large fraction of the mass above the hydrogen burning shell (e.g., Kato 1983, Kato and Hachisu 1988). This poses a serious difficulty for the theories of the formation of Type I supernovae and of the accretion induced formation of a neutron star, because for these theories to work mass must be accumulated efficiently on the white dwarf. One way to avoid this difficulty may be to assume that the accreting matter consists mostly of helium (no hydrogen). Although nova-like explosions due to helium shell flashes may occur, the shell flashes and hence mass ejection are expected to be weaker because the energy liberated per unit mass in helium burning is ten times smaller than that in hydrogen burning. Nearly pure helium accretion onto a white dwarf is expected to occur in a double white dwarf system or a white dwarf-helium star pair. Before constructing senarios for the formations of neutron stars and Type I supernovae, we need to know how much mass is ejected during the helium shell flash as a function of the accretion rate.

First, we have examined whether optically thick wind occurs or not. Using the same method as Kato and Hachisu's (1988) for nova outburst, we have found that the wind occurs in a massive white dwarf ($M \geq 1.23 M_\odot$) if the radius of the envelope extends sufficiently. For a $1.3 M_\odot$ white dwarf, the wind begins when the envelope expands up to about $5 R_\odot$ and ceases when the radius decreases to 2.3 $R_\odot$ after passing the most extended stage. The envelope mass is $3.8 \times 10^{-5} M_\odot$ at the cessation of the wind mass loss. In order to know for what accretion rate the helium shell flash is strong enough to cause mass loss, we have calculated time dependent models for helium accreting white dwarfs of 1.3 $M_\odot$ by using a Henyey type code. The calculations were started with the steady state model for an assumed accretion rate (Kawai, Saio, and Nomoto 1988). It is assumed that when the radius of a model exceeds 1 $R_\odot$ during helium shell flash, mass loss is started at an arbitrarily chosen rate of 2×10^{-5} $M_\odot yr^{-1}$. The mass loss is assumed to continue until the radius decreases down to $0.02 R_\odot$. (If the mass loss is terminated when the radius is considerably larger than the above value the radius begins to increase again.) The calculations were continued until the ratio of the lost mass to the accreted mass became constant from cycle to cycle.

https://doi.org/10.1017/S0252921100093970 Published online by Cambridge University Press

The accretion rates considered are 2×10^{-6}, 1×10^{-6}, 6.6×10^{-7}, 3×10^{-7}, and 1×10^{-7} $M_\odot yr^{-1}$. The envelope mass at the ignition of helium shell flash and the strength are larger for lower accretion rates. After passing the phase of the maximum nuclear luminosity, the radiative luminosity at the photosphere and hence the radius increase. About half of the helium in the envelope is consumed before the mass loss starts. When the envelope mass decreases to $\sim 3.8 \times 10^{-5}$ $M_\odot$ by losing mass, the radius decreases enough for the accretion to start again.

Figure 1 shows the ratio of the lost mass to the accreted mass during one cycle of the helium shell flash as a funciton of accretion rate. The helium shell flash is strong enough to cause wind type mass ejection if the accretion rate is smaller than 1.7×10^{-6} $M_\odot yr^{-1}$. For smaller accretion rates, a larger fraction of the accreted mass is ejected from the system. For example, 20% of the accreted mass is ejected if $M = 1 \times 10^{-6} M_\odot yr^{-1}$, while 90% of the accreted mass is ejected if $M = 1 \times 10^{-7} M_\odot yr^{-1}$. The wind type mass loss affects the evolution of the binary systems because total mass and the angular momentum are lost from the system. These effects are more serious for slower mass accretion onto the white dwarf. The existing scenarios about the formations of a Type I supernova and a neutron star through accretion-induced collapse should be revised, because in these scenarios the mass of the white dwarf must be increased up to about 1.4 $M_\odot$ by mass transfer from the companion. One example of the binary evolutions taking into account the systemic mass loss due to helium shell flashes is demonstrated by Hachisu, Miyaji, and Saio (1987).

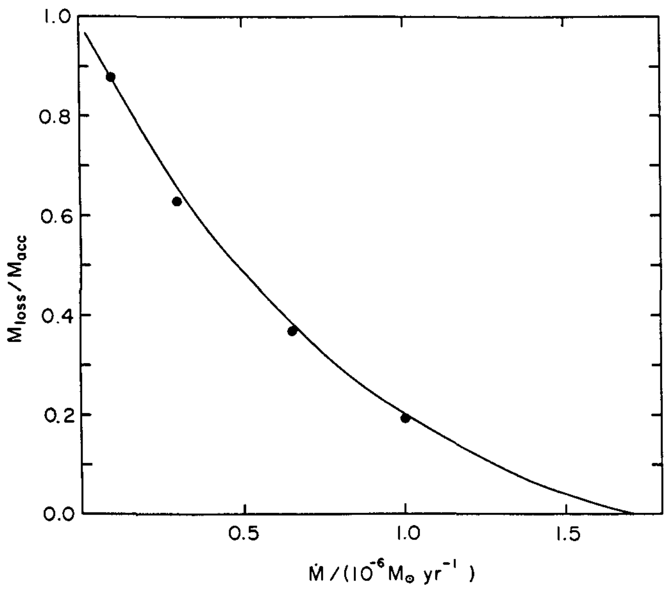

Figure 1: The ratio of the lost mass to the accreted mass for each cycle of helium shell flashes as a function of the helium accretion rate.

References

Hachisu, I., Miyaji, S., and Saio, H. 1987, submitted to Ap. J..
Kato, M. 1983, Pub. Astr. Soc. Japan, **35**, 507.
Kato, M. and Hachisu, I. 1988, submitted to Ap. J..
Kawai, Y., Saio, H., and Nomoto, K. 1987, Ap. J. in press.

https://doi.org/10.1017/S0252921100093970 Published online by Cambridge University Press