NUMERICAL MODELLING OF THE CLASSICAL NOVA OUTBURST

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Abstract: We describe a mechanism that promises to explain how classical nova outbursts take place on white dwarfs of 1 $M_\odot$ or less and for accretion rates of 4 x 10^{-10} $M_\odot$ yr^{-1} or greater.

Observations suggest that the average mass of white dwarfs in classical nova systems is 0.8 $M_\odot$ and that the typical mass transfer rate in such systems is 10^{-9} - 10^{-8} $M_\odot$ yr^{-1} (Patterson 1984). However, model calculations that take the accretion process into account have been unsuccessful in reproducing the classical nova outburst for these parameters. The reason is insufficient confinement of the nuclear runaway zone and, hence, insufficient release of energy (Sparks and Kutter 1987). To overcome this problem, white dwarf masses equal to or greater than 1.25 $M_\odot$, low accretion rates, or hybernation scenarios have been invoked (Kutter and Sparks 1980, Livio and Shara 1987, Prialnik and Kovetz 1984, Starrfield et al. 1985).

We describe here a mechanism that promises to produce nova outbursts for the observational data listed above, though to date we have explored it only for these parameters:

white dwarf	1 $M_\odot$, consisting of ^{12}C and ^{16}O, 10^{-3} $L_\odot$;
accreting matter	4.23 x 10^{-10} $M_\odot$ yr^{-1}, solar mix with ^{12}C and ^{16}O each enhanced to 10% by mass, arriving on white dwarf with Keplerian angular momentum.

The computational method is described in Kutter and Sparks (1987) and Sparks and Kutter (1987).

The shear created on the white dwarf's surface by the rotational velocities of the accreting H-rich matter produces an accretion belt of mixed stellar and accreted matter. After 7,080 years, the surface of the belt rotates as rapidly as the newly arriving matter and shear mixing ceases. Accretion continues to age 256,400 years, when nuclear burning exceeds 10^6 erg/(g·sec) at a fractional mass from the star's surface of $Q = 2.570 \times 10^{-4}$ and the nuclear runaway gets under way. Up to this point the

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star's evolution resembles the models described in Sparks and Kutter (1987); and, if the evolution calculations are continued, 7.6 years later the nuclear runaway peaks with $\varepsilon_{nuc} = 2.26 \times 10^{15}$ erg/(g·sec). No nova results.

According to our experiences, a nova outburst will occur on a 1 $M_{\odot}$ white dwarf and for accretion parameters shown above only if the nuclear reactions run away at greater depth than in the above calculations and/or if the white dwarf's envelope rids itself of some of its angular momentum during the early phase of the runaway. The greater depth increases the gravitational confinement of the burning region; and the loss of angular momentum increases the mechanical confinement, due to reduction of the centrifugal forces.

Is there a mechanism capable of moving, during the early phase of the nuclear runaway, the nuclear runaway zone to greater depth and of ridding the envelope of angular momentum? We suggest that it is the convective instability, which in the course of the runaway grows until it reaches the star's surface. Convection mixes matter in the envelope's outer rapidly rotating layers with matter in the inner less rapidly rotating layers and thereby transports angular momentum to the nuclear runaway zone. The resulting shear between that zone and the adjacent layer interior to it creates a Kelvin-Helmholtz instability, which in turn leads to mixing of matter. We think that this mixing moves both the zone of peak nuclear burning and angular momentum inward. It also mixes H-rich matter with layers rich in carbon and oxygen.

To test whether the Kelvin-Helmholtz instability, induced by convection, is capable of producing nova outbursts, we ran our model through a nuclear runaway, artificially moving the zone of peak nuclear burning inward to $Q = 3.072 \times 10^{-4}$ and removing 10% of the envelope's angular momentum. Furthermore, we enhanced the ^{12}C and ^{16}O content of the accreting matter (see above) to simulate the mixing of H-rich and original white dwarf matter. The nuclear reaction rates rise to 2.52×10^{17} erg/(g·sec) and the entire envelope above the runaway zone is ejected with speeds of 190 to 1,600 km sec^{-1}. The mechanism seems to work because rotational kinetic energy of the accreting matter is not immediately released, but only when it is needed to increase the burning region's confinement during the early phase of the nuclear runaway. Details of the results will be presented in an Ap. J. paper now in preparation.

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