NOVA EJECTA ABUNDANCES RESULTING FROM MULTI–CYCLE EVOLUTIONARY CALCULATIONS

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1. Introduction

The theory of nova outbursts invokes accretion of hydrogen-rich material by a white dwarf (WD) in a close binary system, due to Roche lobe overflow of a red dwarf companion, leading to periodic outbursts — powered by thermonuclear runaways — that result in mass ejection. Observed characteristics of novae are reproduced by varying the values of three basic and independent parameters: the accreting white dwarf's mass, its core temperature, and the mass transfer rate. In a recent study (Prialnik & Kovetz 1995) we have carried out a systematic investigation of nova outbursts on WD progenitors composed of C and O in equal mass fractions, concluding that the entire range of *observed* nova characteristics could be accounted for. A subset of 34 out of 64 evolutionary sequences (obtained with different parameter combinations) reproduced classical novae, and here we focus on the break-up of the heavy element abundances in the ejecta of these models, in comparison with observations, based on a recent analysis of observed nova abundances by Livio & Truran (1994).

The source of heavy elements in nova ejecta is material dredged up from the WD core (by the diffusion-convection mechanism in our case). Most calculations to date have assumed C and O in equal mass fractions, as indicated by Iben & Tutukov (1985)'s extensive study of close binary evolution, which shows that a WD formed in such a system should have, essentially, a C to O ratio very close to 1. An interesting question is, to what extent is the WD composition reflected in the ejecta abundances? And, does the WD composition affect other nova characteristics? A different question is, do novae constitute a significant source of the relatively rare nucleides ^{13}C, ^{15}N and ^{17}O, as concluded by previous calculations and observations?

A. Evans and J. H. Wood (eds.), Cataclysmic Variables and Related Objects, 301–302.

2. Results of evolutionary calculations

2.1. HALF-C, HALF-O PROGENITORS

1. The observed range of variation of C, N, and O abundances is reproduced by the models, leaving out, however, the so-called 'ONeMg novae', which are believed to have ONeMg WD progenitors. Our calculations confirm that their abundances cannot be obtained with CO WD progenitors.
2. The general trend (exhibited by calculations) is for C and a fraction of the O to be converted into N. However, there are many cases of severely depleted O both in calculations and in observations.
3. In spite of the fact that the nuclear reactions network reaches up to ^{31}P, and of the high temperatures attained at outburst, the only abundant species in the ejecta are the isotopes of C, N and O. Neon, the next most important element observed in novae, is entirely insignificant. Hence, it appears that the only way to obtain *any* Ne in the ejecta would be to have it present in the WD composition. Indeed, according to Iben & Tutukov, CO WDs formed in close binary systems do contain a few percent of Ne.
4. There is no marked correlation between the calculated abundances and the basic nova parameters. Nevertheless, extremely high C should be associated with massive WDs and extremely high O with low accretion rates.
5. The isotopes ^{13}C and ^{17}O are in all cases significantly overabundant; ^{15}N, however, is sometimes greatly enhanced and sometimes underabundant.

2.2. PURE-C AND PURE-O PROGENITORS

1. The WD composition is *not* reflected in the abundances of the ejecta: the ejecta of pure-C WDs can be almost completely devoid of C; and similarly for pure-O WDs. The ejecta *cannot* be used to infer the WD composition.
2. There are two observed novae (HR Del and QU Vul) with exceptionally high O/N ratios and no detected C. Such abundances can only be obtained from a WD progenitor with a high O abundance in its outer layers.
3. The Ne abundance is still very low, even for the pure-O progenitors.
4. As to the effect of the progenitor's composition on other nova characteristics, the most important change consists of higher ejected (and accreted) masses — in some cases by a factor of 4 — obtained for pure-O WDs. These higher masses may be a step towards resolving the discrepancy between calculated and observationally derived masses of nova shells.

References

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