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Recent Advances in the Studies of the Nova Outburst

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1 INTRODUCTION

This conference marks 13 years since the first North American Cataclysmic Variable workshop (NACVW) was held in 1976 at the University of Illinois. It, therefore, seems appropriate to briefly review the progress that we have made in understanding the nova outburst. Recent detailed reviews of both the nova binary systems and their outbursts can be found in the proceedings of the Madrid IAU Symposium No. 122 on the "Physics of Classical Novae" (Cassatella and Viotti 1990), Gehrz (1988), Shara (1989), Starrfield (1988, 1989), and Bode and Evans (1989). Because of the existence of these reviews, I will describe only a few of the developments that have had a major impact on studies of the outburst.

2 CHANGES IN OUR UNDERSTANDING OF THE OUTBURST

The list of topics that have strongly influenced our ideas about the cause and evolution of the nova outburst must begin with enhanced abundances in the accreted and ejected material. Some of the other items in the list are: the constant bolometric luminosity, magnetic novae, neon novae, hibernation, shear mixing, diffusion, and boundary layer heating. Observationally, we must consider the infrared studies and the formation of dust and coronal lines, X-ray studies and the turn-off time scale, ultraviolet studies and enhanced abundances, and the relationship between recurrent novae and X-ray novae.

2.1 The Detection of Enhanced Abundances

The optical, infrared, and ultraviolet determinations of abundances in novae ejecta have now convincingly demonstrated both that the CNO_{Ne}Mg nuclei can be strongly enhanced in novae ejecta and, in addition, that there are two abundance classes of novae. However, at NACVW 1, there was, as yet, no reliable evidence for elemental enhancements in novae, since the first reliable abundance measurements did not appear until Williams *et al.* (1978). This emphasizes the predictive nature of the thermonuclear runaway theory (TNR) of the outburst (see Starrfield 1989) since we had already predicted enhanced abundances in novae (Starrfield *et al.* 1972). A major topic at the first workshop, therefore, was a discussion showing how the energetic

requirements of a fast nova outburst demanded enhanced abundances.

It was not until 1977 that Williams and his collaborators began to apply standard nebular analysis techniques to the study of the ejected and resolved *shells* of novae (Williams *et al.* 1978). In addition, Ferland and Shields (1978) showed that V1500 Cyg had enhanced CNO in its ejecta.

A significant advance in studies of nova abundances occurred as a result of IUE observations. The ability of IUE to observe to wavelengths as short as 1100Å has provided us with a wealth of new data on nova abundances (Starrfield and Snijders 1987). Up to this time, the most detailed papers are on V1668 Cyg, U Sco, V693 CrA, GQ Mus, V1370 Aql, PW Vul and QU Vul (see Starrfield and Snijders 1987 for specific references). It is also worth pointing out that some of us (Wehrse *et al.* 1990) are working on a spectrum synthesis method that will be used to determine the abundances for species that are present in the spectra of the optically thick expanding pseudo-photosphere seen in the ultraviolet at maximum light. Finally, recent analyses of coronal lines found in the infrared are providing abundances of novae for some highly ionized species (Greenhouse *et al.* 1990).

2.2 Constant Bolometric Luminosity

At NACVW 1, the prediction of a constant bolometric luminosity phase of the outburst had already appeared in the literature along with confirmation for one nova from UV observations by Gallagher and Code (1974) of FH Ser. This prediction is based on the fact that only part of the envelope material is ejected during the burst phase of the outburst and the rest remains on the rekindled white dwarf (Starrfield, Sparks, and Truran 1974).

Additional support came from IR observations of novae both at maximum and in the dust formation stage (Gehrz 1988). The importance of dust is that it acts as a calorimeter of the EUV and soft X-ray photons emitted by the hot white dwarf at a time when the optical brightness has dropped by many magnitudes (Gehrz 1988). Although the dust studies indicate that a nova should be bright in the EUV or soft X-rays for months after the beginning of the optical decline, it was not until EXOSAT that any novae were detected at these wavelengths (Ögelman, Krautter, and Beuermann 1987). EXOSAT detected 4 novae in outburst and it both provided an estimate of the effective temperature of these novae and, also, showed that they were luminous X-ray emitters for long times.

The IR studies of novae in outburst can provide distances to novae using the black-body expansion parallax technique that was applied to V1500 Cygni by Gallagher and Ney (1976). This same method can be used a second time when dust forms later on in the outburst (Gehrz 1988).

2.4 Magnetic Novae

One of the more exciting results in the study of novae has been the discovery that V1500 Cygni contains a strongly magnetized white dwarf and is, thereby, an AM Her system (Stockman, Schmidt, and Lamb 1988). This nova underwent one of the most unusual outbursts ever studied (Gallagher and Starrfield 1978). I note that the AM Her variables had not even been discovered at the time of the first Workshop. It has recently been proposed that Nova GQ Mus 1983 may also be an AM Her variable and this result may be very important in understanding the characteristics of its outburst.

Livio, Shankar, and Truran (1988) investigated TNR's on magnetic white dwarfs but assumed that the only effect of the strong magnetic field was to reduce the efficiency of convection. This reduction occurs because the strong magnetic fields impact the material flows perpendicular to the magnetic field lines. However, it is also important to consider that the infalling material cannot be spherically symmetric and the distribution of hydrogen-rich material on the surface of the star must be very non-spherical.

2.5 Recurrent Novae

Major changes in our understanding about the nova outburst have come about because of the recent outbursts of recurrent novae such as U Sco, V394 CrA, RS Oph, and V745 Sco. At NACVW 1, it was thought that a recurrent nova was a classical nova that exploded on a short time scale. It now seems likely that the class of recurrent novae contains at least two classes of objects: those with giant secondaries and those with evolved and small radius secondaries. T CrB, RS Oph, and V745 Sco fall into the giant secondary class and may outburst as a result of either an accretion disc or mass-transfer instability. In contrast, U Sco, V394 CrA, and T Pyx have short orbital periods and, therefore, are in the other class. It seems likely that their outbursts are a direct result of a thermonuclear runaway in the accreted envelope. It also seems likely that this second class is directly related to those LMXRB's that arose out of binary evolution and not capture.

3 SUMMARY

It has not been possible in this short paper to review all of the topics that have affected our understanding of the nova outburst. Nevertheless, it is clear that there have been major changes in this field over the past 13 years and it seems likely that this field will continue to change. I would like to point out that there are a number of ideas "looming on the horizon" that could markedly change our current views about novae. For example, it seems like the application of Smooth Particle Hydrodynamic techniques to the evolution of the thermonuclear runaway will allow us to explore the three-dimensional evolution of nova systems and explosions. The recent advances in

calculation of expanding, spherical, stellar atmospheres will allow analyses of nova spectra at very early stages in their outburst. ROSAT will discover a large number of cataclysmic variables and provide many new objects for study. Finally, there should soon be major improvements in our understanding of the emission from accretion disks that will significantly improve our understanding of cataclysmic variables.

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