The Properties of Novae in the LMC and Beyond

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Abstract. Optical searches of nearby galaxies have found large numbers of novae (Shafter 1998) which can be studied both with HST and new missions with larger apertures. Results of these studies will provide information on binary stellar evolution, metallicity, nova composition, the models for the progenitors of Type I Supernovae in a variety of stellar environments, and the distances to the galaxies.

1. Introduction

The nova outburst is a consequence of the accretion of hydrogen-rich material onto a white dwarf in a close binary system. When both the white dwarf luminosity and the rate of mass accretion onto the white dwarf are sufficiently low, so that the deepest layers of the accreted material become electron degenerate, a thermonuclear runaway occurs near the base of these layers. Theory requires and observations show that the accreting material mixes with core material at some time during the outburst. Therefore, abundance determinations of nova ejecta provide information on the composition of the white dwarf. Such studies have also shown that the core material is either carbon and oxygen or oxygen, neon, and magnesium, although there are differences in the values of these elements within the broad composition classes.

These studies have depended on UV spectra of novae ejecta obtained with the IUE and HST satellites. The results of new calculations of thermonuclear runaways on white dwarfs (Starrfield et al. 1998) imply that the metallicity of the donor star (presumably a low-mass main sequence star) has important
effects on the characteristics of the explosion. This may have been verified from comparisons of LMC and Galactic novae.

2. Studies of the LMC Novae

In the past ten years, six classical novae have been observed in the Large Magellanic Cloud (LMC). We have begun a study of these objects using ultraviolet spectra obtained by IUE and optical spectra from nova surveys. Our studies include both analyses of the early, optically thick spectra using model atmospheres (Hauschildt et al. 1992), and the later nebular spectra using optimization of photoionization models (Ferland 1996; James & Roos 1993). By analyzing the LMC novae in a consistent manner, we can both compare them among themselves and use their individual properties to calibrate Galactic novae. For example, both the outbursts and the abundances of LMC 1990#1 and the galactic nova V693 CrA were nearly identical (Vanlandingham 1997). In addition, our studies can be used to determine the elemental abundances of the nova ejecta, the amount of mass ejected, and the contribution of novae to the ISM abundances and, thereby, to the chemical evolution within this external galaxy. To date, we have analyzed Nova LMC 1988#1 (Schwarz et al. 1998) and Nova LMC 1990#1 (Vanlandingham et al. 1998) and have obtained preliminary results for Nova LMC 1991.

The metal content of the LMC is known to be sub-solar and varies as a function of location within the cloud. An abundance analysis of the ejecta of the LMC novae provides important information concerning the effect of initial metal abundances on energetics of the nova outburst. Since the distance to the LMC is well known, many important parameters of the outburst, such as the luminosity, can be determined.

Both galactic and extragalactic novae have been proposed as potential standard candles. Recent work by Della Valle & Livio (1995) has improved on the standard relations (e.g., Schmidt 1957; Pfau 1976; Cohen 1985; Livio 1992) by including novae from the LMC and M31. Unfortunately, the dependence of the nova outburst on metallicity has not been well studied. Recent theoretical work by Starrfield et al. (1998) predicts that the luminosity of the outburst increases with decreasing metal abundances. If there is a dependence of luminosity on metallicity, then it will have to be determined before novae can be used as standard candles.

3. Results and Discussion

Our nebular analysis results for LMC 1990#1 show that all elements represented in our emission-line spectrum are enhanced relative to solar material. We find a high N/O ratio for LMC 1990#1, which is indicative of an outburst on a high-mass white dwarf (Starrfield et al. 1992). This is in agreement with our estimates of the ejected mass, $M_{ej} \approx 4 \times 10^{-4} M_\odot$. We have determined the high-Z metal abundances (e.g., iron) of LMC 1988 #1 and LMC 1991 from model atmosphere analyses of optical and UV spectra obtained near visual maximum. We find an iron abundance of 1/3 solar in LMC 1988#1, typical of the LMC, but Fe = 0.1 Fe_\odot in LMC 1991. This is consistent with the locations of these
novae within the LMC since LMC 1988#1 is located within the “Bar” and LMC 1991 is located in the halo. The visual light curves derived from the best-fit synthetic spectra, when both novae were optically thick, are in excellent agreement with the observed light curves. In addition, the bolometric light curves show that, during the early outburst, LMC 1988#1 and LMC 1991 were significantly brighter than the Eddington luminosity for a 1.4 $M_\odot$ white dwarf.

We are now involved in ground-based optical and infrared spectroscopic follow up of surveys for novae in M31. Once these combined studies are well underway, we plan to expand our investigations to other galaxies in the Local Group. Gradually, as larger aperture ground-based telescopes become available (such as the new single mirror 6.5 m MMT), we will extend our surveys and spectroscopic follow up to M81 and M87 since novae have been found in both these galaxies. Local Group and more distant novae are prime targets for satellite studies at wavelengths blocked by the Earth's atmosphere.

References

Ferland, G. J. 1996, Department of Physics & Astronomy Internal Report (University of Kentucky)
James, F., & Roos M. 1993, MINUIT, CERN Program Library D506
Schmidt, Th. 1957, Z. Astrophys., 41, 182