OBSERVATIONS OF NOVAE IN M51, M87, AND M101: A PRELIMINARY REPORT

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Abstract. We report preliminary results from a new program of observations of novae in nearby galaxies. The principal goal of the program is to explore the population of nova progenitors through observations of galaxies having a wide range of Hubble types. Here we present preliminary results from observations of the spiral systems M51 and M101, and the giant elliptical, M87. Based on available data, we find no evidence that the luminosity specific nova rate varies across the Hubble sequence.

1. Introduction

Establishing the stellar population of close binaries is important to our understanding of how binary star formation and evolution may depend on the underlying stellar population. The study of novae is well suited for this purpose because their eruptions enable them to be readily identified, not only in the Galaxy, but, more importantly, in external galaxies as well. Despite its importance, the stellar population of novae is poorly understood. Galactic data appear to be consistent with novae belonging to an old disk population (Patterson 1984). However, it is clear that the Galactic data are of limited usefulness in establishing the population of novae because these data are heavily biased by selection effects, principally interstellar absorption. It seems clear that our best opportunity to explore the population of novae is to study their spatial distribution in nearby galaxies.

Novae have been observed in M31 since the pioneering work of Hubble in the early years of this century. In recent years novae have been studied in several additional galaxies. Among these galaxies are late-type systems

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such as the Magellanic Clouds (Graham 1979) and M33 (Della Valle et al. 1994). A testament to the current state of confusion concerning the population of novae is evidenced by comparing the summaries of nova rates in extragalactic systems recently published by Ciardullo et al. (1990a), and by Della Valle et al. (1994). These two groups come to very different conclusions regarding the population of novae despite reviewing the same data in some cases. Ciardullo et al. conclude that the luminosity specific nova rate is essentially independent of the underlying stellar population, while Della Valle et al. argue that disk dominated stellar systems such as M33 and the LMC are more prolific nova producers. In an attempt to resolve the confusion, we have decided to undertake a study of novae in several additional galaxies, including the massive disk-dominated systems M51 and M101. These galaxies have the advantage that their absolute nova rates should be significantly higher than their low mass counterparts M33 and the LMC, making an estimation of their luminosity specific nova rates more accurate and reliable. In this paper, we report preliminary results of observations of M51, M87, and M101.

2. Observations and results

Observations were obtained in 1994 May and 1995 April using the Kitt Peak National Observatory 4 m Mayall telescope. A 2048 × 2048 CCD detector was used at prime focus, yielding a field-of-view of $\sim 16 \times 16$ arcmin^2. The field-of-view was sufficient to cover essentially all of M51 and M87, and most of M101. Following Ciardullo et al. (1987), we imaged the galaxies in Hα and in the continuum (broad-band R). Total integration times were approximately 1 h for M51 and M101, and approximately 3 h for M87, with the precise integration times being set by the seeing and our desire to reach a limiting absolute magnitude in Hα of -7.5 (the Hα magnitude scale is defined in Ciardullo et al. (1987)). Observations of spectrophotometric standard stars revealed limiting Hα apparent magnitudes of 23.1, 23.5, and 23.0 for M51, M87, and M101. Adopting μ_o=31.03 and μ_o=28.65 for M87 and M101 (de Vaucouleurs 1993), and estimating μ_o=29.1 for M51, we reached limiting absolute magnitudes of -6.0, -7.5, and -5.7, for M51, M87, and M101, respectively.

For the spiral galaxies M51 and M101, novae were identified by blinking Hα images from 1994 and 1995. In the case of M87, we took advantage of the fact that novae can be identified by single epoch observations, as they are the only bright Hα sources thought to be present with the possible exception of low excitation planetary nebulae. The planetary nebulae were identified by their strong OIII λ5007 emission as part of another project (Ciardullo & Jacoby 1996), and were excluded from our sample. During the

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first two seasons of observation, a total of 6 novae were found in M51, with another 6 identified in M101. In the case of M87, 14 novae were discovered during a single epoch of observation in 1995 April.

To estimate the global nova rate of the galaxy, the observed nova rate must first be corrected for incompleteness caused by a bright and spatially varying background, for the fraction of the total galactic luminosity sampled, and extinction internal to the galaxy. We were insensitive to novae within a radius of 23 arcsec from the nucleus of M87 because of the high surface brightness. Based on the surface photometry of Cohen (1986), we estimate that our observations cover 78% of M87's luminosity. In the case of M51 and M101, the completeness is harder to quantify. Here we assume no correction for incompleteness due the background luminosity, but, in the case of M101 we estimate that our 16×16 arcmin^2 field excludes 10% of the galactic light. Extinction along the line of sight to these three galaxies is small, and has been neglected. Furthermore, we assume no significant absorption internal to M87, however, in the case of M51 and M101, the internal extinction is patchy and can be significant. Here we assume that the extinction internal to M51 and M101 is sufficient to obscure novae on the back sides of these galaxies. Thus, we apply correction factors of 50% to both our M51 and M101 observations. We acknowledge that the correction factors for the spiral systems are large and uncertain, and thus our initial estimates for the global nova rates for these galaxies will be more uncertain than that for M87.

Finally, to estimate the nova rate from multi-epoch observations, it is necessary to determine the effective survey time. As shown by Ciardullo et al. (1990b) the effective survey time can be estimated from the limiting absolute magnitude of the survey. From a fit of the time (τ_c) M31 novae remain brighter than a specified absolute magnitude in Hα (M_c), they found: $\log \tau_c = 0.48M_c + 0.56$. Here we depart slightly from Ciardullo et al. and adopt a non-linear fit to the same M31 data: $\log \tau_c = -0.0958 - 0.907M_c - 0.0843M_c^2$. The latter relationship gives a better estimate of the limited nova lifetime at faint magnitudes. For the single epoch of observation of M87, we find a global control time of 90 d. For two epochs covering M51 and M101, we find control times of 410 d and 436 d, respectively. These effective survey times in conjunction with the correction factors determined above lead to global nova rates of approximately 11 ± 4 novae per year for both the M51 and M101 systems, and 73 ± 19 for the giant elliptical galaxy, M87. We stress that the error estimates reflect only the Poission statistics of the number of novae detected, and do not reflect the uncertainties in the correction factors for incompleteness. These factors are particularly large for the spiral systems.

To compare nova rates from different galaxies it is necessary to normalize the observed nova rate by the luminosity of the galaxy. Since nova systems are composed of low-mass, low-luminosity stars, it seems most appropriate to normalize by the infrared luminosity of the galaxy. The luminosity at optical wavelengths is dominated by radiation from a relatively small number of young, massive, and very luminous Population I stars. For consistency with the previous studies of Ciardullo et al. (1990a) and Della Valle et al. (1994) we compute the luminosity specific nova rate, ρ_k, defined as the number of novae per year per 10^{10} $L_\odot$ in the infrared K band. The K magnitudes were computed in a consistent manner using the integrated B-band luminosities and the $B-V$ colors from the *RC3* (de Vaucouleurs et al. 1991), and the $V-K$ colors from the Hubble means of Aaronson (1978). Using the distances given earlier, we find $\rho_k = 1.20 \pm 0.55$, $\rho_k = 1.55 \pm 0.48$, and $\rho_k = 1.63 \pm 0.73$ for M51, M87, and M101, respectively.

3. Conclusions

In our initial analysis, we find no significant difference between the luminosity specific nova rates for the three galaxies studied. Furthermore, the nova rates appear to be consistent with those determined for other galaxies with measured nova rates. We conclude, therefore, in agreement with the results of Ciardullo et al. (1990a), that the present evidence does not support the contention that luminosity specific nova rates vary significantly across the Hubble sequence. The only caveat is that our preliminary nova rates for the spiral systems M51 and M101 are relatively uncertain and could be somewhat higher if we have underestimated the effects of internal extinction in these galaxies. Further work is in progress to improve our estimate the nova rates in these late-type galaxies.

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