Large Magellanic Cloud Novae 13 Days After Peak Brightness

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Abstract If two novae, one fast and one slow, were to go off simultaneously in a distant galaxy, the fast one would be the brighter of the two. But this means that at some point in time after peak brightness, the two novae, fading at different rates, would become equal in brightness. From a study of recent novae in the Large Magellanic Cloud (LMC), we find that 13 days is, on the average, that interval of time, and the average absolute magnitude then is $M_V = -6.32 \pm 0.17$. This result is markedly different from that obtained for galactic novae.

1. Introduction

In an important early paper on classical novae, Buscombe and de Vaucouleurs (1955) concluded that "the most favorable period for using novae as distance indicators is about 2 weeks after maximum when the mean absolute magnitude is $M_{15} = -5.2 \pm 0.1$ (p.e.)." Combining studies of galactic novae and novae in M31, they take 15 days as the "best" interval of time and from these data they derive a distance modulus for the Magellanic Clouds of 18.6 ± 0.3 (m.e.).

A number of later authors (e.g., see Downes and Duerbeck 2000 and references therein) have used this same time interval and have determined an improved value for M_{15} but no one, to our knowledge, has attempted to confirm or to improve upon this time interval, and none has used novae in the Magellanic Clouds for this purpose. We do note, however, that Capaccioli *et al.* (1990) considered 21 novae in the LMC, and from the 10 most reliable objects, derived $M_{15} = -5.69 \pm 0.14$.

There are, of course, distinct advantages for using Magellanic Cloud novae to improve the above values: all the novae in each of the two clouds are effectively at the same distance, the distance moduli of the clouds are now known with considerable certainty, and the interstellar extinction is small and generally well known.

We have re-evaluated both the optimum time interval and M_{15} using Large Magellanic Cloud data (the SMC novae are not so well observed), and below, we will compare these results determined with novae in the Galaxy.

2. Data

Since the Capaccioli *et al.* (1990) paper, some 13 novae have been discovered in the LMC (see Table 1). Light curves for seven of these appear in the *Information*

Bulletin on Variable Stars (*IBVS*; Liller *et al.* 2004); Nova LMC (NLMC) 1991 has been carefully studied by Della Valle (1991); NLMC 2001 may not be a true nova (Liller 2002); and the recent recurrent NLMC 2004 (= YY Dor = NLMC 1937) will be discussed herewith.

Despite the rarity of having a recurrent nova appear in the LMC (only two are known), NLMC 2004 was observed for only a few days after maximum. However, since its fragmentary light curve resembles that of YY Dor, we have combined the data of these two novae, thereby giving a somewhat better set of data. A further problem, which exists to some degree for most of the recently observed novae, is that sometimes there is a clear difference in magnitudes between, for example, those measured visually or in the standard *V* band, and those measured with detectors sensitive to the spectral region near the frequently strong H-alpha and the red [N II] lines. In the case of NLMC 2004 the difference appears to be nearly one magnitude.

In Table 1 we list data for the LMC novae that have occurred since 1988, the year of the last novae considered by Capaccioli *et al.* Following these authors, we tabulate in successive columns the nova designation, the estimated visual magnitude at maximum, the estimated visual magnitude 15 days after maximum, the smoothed rate of fading in magnitudes per day, the quality of the data (Very Good, Good, Fair, Poor), and references.

The MACHO observations were made with broadband red and blue systems, while OGLE-II used primarily an I system. Corrections to *V* are not obvious. Also, the magnitudes near maxima of NLMC 1996 and 1997 and possibly that of NLMC1999 are indeterminate because the images were saturated. Also for NLMC 1997, the date of maximum is uncertain by nearly 13 days.

3. Results

We have considered two different sets of data; novae in the LMC and galactic novae. For the well-observed novae in each set, we took the magnitude 15 days after maximum, and then added or subtracted the daily rate of change of brightness times *x* days to derive the magnitude at other time intervals. Because novae frequently show irregular variations in brightness during the declining stages, this procedure will smooth out these often not-well-observed fluctuations. We then averaged the magnitudes in each set at each time interval and calculated the standard deviation (s.d.) of these values. Finally, we plotted these s.d.s against the time interval and noted where the minimum occurs. This time interval should then be the optimum for using novae as distance indicators.

For the LMC we have taken the 15 well-observed novae listed by Buscombe and de Vaucouleurs (1955) and by Capaccioli *et al.* (1990), and added the G-quality novae listed in Table 1. We have omitted NLMC 1935 since it appeared well outside the boundary of the LMC, and NLMC 1948 since Subramaniam and Anupama (2002) note that it lies in a region of reddened stars. Capaccioli *et al.* have made corrections to the photographic (blue) magnitudes to put all on a *V* scale, and we have used only visual and *V* observations to derive the values of M_{15} listed in Table 1.

For the Galaxy we considered the 28 galactic novae studied by Downes and Duerbeck (2000), who derived improved distances by using expanding nova shell images. As they make no distinction on the basis of quality, we have used all 28 novae listed. They have calculated absolute magnitudes, and they, too, adjust all magnitudes to the standard *V* system.

The plots of s.d. versus time interval after maximum for the two sets of data are presented in Figure 1, and as can be seen, there is a clear shift in the two curves in the sense that LMC novae have the least spread in magnitude two days earlier than those in the Galaxy. The recent LMC novae show a minimum s.d. approximately 10 days after maximum, and that has lowered the implied result of Buscombe and de Vaucouleurs. Because the recent novae are, in general, better observed than the older novae, these data should be of higher quality. Therefore, we are confident that the shift is real.

It should be noted that only one of the two recurrent novae in the LMC is included, namely YY Dor, discussed in the previous section. If it were omitted for being "different," the final result would change only marginally, moving the minimum of the LMC curve from 13 to 12 days.

After 13 days the LMC novae have an average $V = 12.58 \pm 0.16$, and if, following van den Bergh (2000), we take values for the LMC of $(m-M)_0 = 18.50 \pm 0.05$ and $E(B-V) = 0.13$, we find the average absolute magnitude to be $M_V = -6.32 \pm 0.17$. This value corresponds well with that for galactic novae 15 days after maximum, namely -6.05 ± 0.14.

4. Discussion

Why there should be a difference between the data from the LMC and from the Galaxy is not clear. Interstellar absorption is always a source of uncertainty when dealing with galactic novae since they are usually distant and often close to the galactic plane. While the determination of the date of maximum and the rate of fading will not be affected, the value of the absolute magnitude may suffer. Also, one possible selection effect is that the earlier novae were usually discovered by chance, while the recent LMC novae and some of the galactic novae were found as a result of dedicated surveys. Therefore, the exact time of maximum is typically less well known for the old novae, as will be the critical time interval. Finally, the Editor has pointed out that this difference may somehow be related to the well-established fact that average metal abundance in the LMC is somewhat lower than in the Milky Way.

An anonymous referee expressed some surprise that the minimum dispersion is lower for galactic novae than for LMC events, noting the uncertain distances to galactic novae and the near-uniform distance of LMC novae. We do not feel that the small difference in minimum magnitude deviations, viz. 0.027, is significant given the relatively small number of data points, but we certainly believe that this result speaks well for the quality of the results published by Downes and Duerbeck.

How reliable a distance indicator is the nova magnitude 13 or 15 days after maximum? It should be noted that while the standard deviations of the mean absolute magnitudes are barely more than a tenth of a magnitude, the uncertainty of the magnitude of a newly discovered nova is larger by a factor of the square root of the number of novae considered, namely 3.9 and 5.3 times larger for the LMC and for the Galaxy, respectively. Therefore, calculating the distance to an individual nova will be riskier than calculating the distance to, for example, a nearby galaxy in which a large number of novae have been observed.

Three galactic novae have spectra with notable emission from O, Ne, and Mg, and we note that the values of M_{15} for these novae show a very small spread; the formal value of s.d. is 0.055. It will be interesting to see if further ONeMg novae follow the same pattern. Furthermore, it may be that other subsets of novae show similar smaller spreads in M_{15}.

5. Conclusions

Because of the greater suitability of the Magellanic Clouds for the purpose of evaluation of the characteristics of nova light curves, we believe that our finding that novae are best used as distance indicators 13 days after maximum is significant, and that rather than the 15-day interval used by earlier investigators, the new interval should be used henceforth. We find the average absolute magnitude of novae at that time to be $M_V = -6.32 \pm 0.17$.

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Table 1. Recent novae in the LMC

LMC Nova	m_{max}	M_{15}	v_d	*Quality*	*Reference*
1990a	9.7	14.7	0.59	G	1
1990b	10.2	<15.2	0.59:	P	1
1991	8.8	12.2	0.33	G	
1992	10.2	13.1	0.27	G	1
1995	10.2	12.5	0.18	G	1
1996	<12.4	15.6:	0.22	P	3
1997	<12.7	—	0.05:	P	3
1999	13.5:	14.3:	0.12	F	4
2000	10.1	11.9	0.12	G	1, 5
2001	< 9.7	—	>3.0	VP	6
2002	10.1	11.5	0.10	G	1
2003	11.0	13.1	0.25	G	1
2004	10.9:	13.1	0.17	F	7, 8

References: (1) Liller et al. *2004, (2) Della Valle 1991, (3) the MACHO Project, (4) Cieslinski* et al. *2003 (OGLE-II), (5) P. Kilmartin, 2002, private communication (OGLE-II), (6) Liller 2002, (7) Buscombe and de Vaucouleurs 1955, (8) Liller 2004, Bond* et al. *2004, and our own observations.*

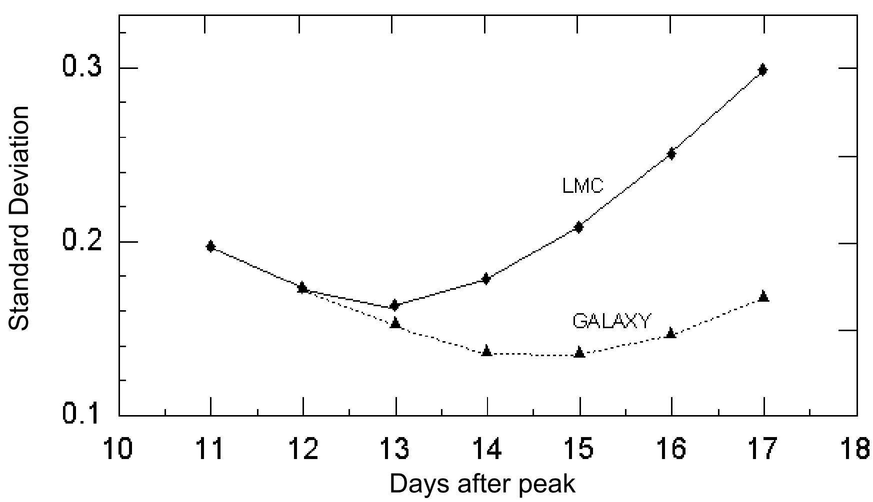

Figure 1. The standard deviations of the magnitudes of well-observed novae in the LMC and in the Galaxy various days after maxima.