Astron. Astrophys. 252, L9–L12 (1991)

ASTRONOMY AND ASTROPHYSICS

Letter to the Editor

Nova LMC 1991: evidence for a super-bright nova population

M. Della Valle

European Southern Observatory, Casilla 19001, Santiago 19, Chile

Received September 3, accepted September 13, 1991

Abstract. We discuss the recent outburst of nova LMC 1991. By comparing its magnitude at maximum and rate of decline with those of 14 historical LMC novae, we show that nova LMC 1991 represents the first detection of a *super*-bright nova in the Large Magellanic Cloud. We have critically reviewed the photometric properties of the nova population in the Galaxy, M31, LMC and Virgo Cluster, and find that 9 objects deviate systematically from the Magnitude at Maximum *vs.* Rate of Decline relation by about one magnitude. This result may imply the existence of a distinct family of *super*-bright novae.

Key words: Novae — Distance Scale

1. Introduction

Since Zwicky's study (1936), it has been known that the rate of decline, defined as the average rate (mag day^{-1}) at which a nova drops 2 (or 3) magnitudes below maximum light, correlates well with the absolute magnitude at maximum. In recent years the use of this distance indicator has received a growing revival of interest for a number of reasons:

1. Novae at maximum are considerably more luminous that other classical standard candles (e.g. Cepheids), therefore the Magnitude Maximum *vs.* Rate of Decline (MMRD) relationship represents a powerful tool to determine extragalactic distances.
2. the discovery of nine novae in two elliptical galaxies of the Virgo Cluster (Pritchet and Van den Berg 1987), has shown that 4m-class telescopes coupled with CCD performances and superb seeing conditions, enable us to carry out systematic studies on novae populations in galaxies beyond the Local Group,
3. the endemic problems related to the calibration of the the zero point of MMRD has been recently overcome. The revised calibration of MMRD relationship (Capaccioli et al. 1989, hereafter CDDR89) has indeed been successfully tested on the nova population of M31 and LMC, and the derived distances are definitively consistent with the distances provided by other indicators,
4. the comparison of the properties of the nova population of the Galaxy, M31, and LMC (Capaccioli et al. 1991, hereafter CDDR91) shows that to the $\simeq$ 0.2 mag (1σ) level, the zero point of the MMRD does not depend on the Hubble type of the parent galaxy and thus may be an universal relation. Therefore novae constitute excellent standard candles.

Send offprint requests to: Massimo Della Valle

The recent outburst of Nova LMC 1991 (Liller 1991) apparently conspires against the previously well established 'state of the art'. When we apply the revised MMRD relationship, determined for galactic novae (CDDR89), to nova LMC 1991, we obtain a distance modulus to the LMC 'shorter' by about one magnitude than the commonly accepted value of (m–M)=18.5 (van den Bergh 1990). In this paper we show that this discrepancy is due to the fact that Nova LMC 1991 possibly belongs to an exiguous group of *super*-bright novae, systematically deviating from the classical MMRD relationship towards brighter magnitudes.

2. The Outburst of Nova LMC 1991

Nova LMC 1991 was discovered as a star of visual magnitude $m_v \sim 12.3$ by Liller (1991) on April 18. In Fig. 1, we report the lightcurve of the nova obtained from the photometric measurements reported in the IAU Circ. (5250, 5253, 5257, 5260) and two later points obtained on May 5 and June 20 with the 3.6m telescope at La Silla. The completeness of the observations, due to prompt announcement of discovery, and the unusual brightness at maximum light, makes this extragalactic nova an exceptional object to be studied. The epoch of the maximum can be easily inferred from the light curve. It took place on April 25 (JD 2448372) at a visual magnitude $m_v^{max} \simeq 9$. From the photometry obtained by Gilmore (1991) one day after maximum, we get a (B–V)=0.21. Assuming an average E(B-V)=0.09±0.03 for the novae in LMC (CDDR 1991) we derive a $(B\text{–}V)_o^{max} \simeq -0.05$, which is bluer than the $(B\text{–}V)_o^{max}$= 0.23, typical of novae at maximum (van den Bergh and Younger 1987). An optical spectrum (370-900 nm) obtained on May 6.15 with the 3.6m telescope (Della Valle and Leisy, 1991) shows that the nova has not reached the nebular phase yet. The spectrum is dominated by broadened Balmer emission lines, indicating high expansion velocities (FWHM $\sim$ 2500 km/s), and by the blend NIII+CIII, at 464.5 nm.

A close inspection of the early photometric evolution of the nova yields a rate of decline of v_d = 0.5 mag day^{-1}. Through the MMRD relationship of Galactic Novae (CDDR89)[1] we get an absolute magnitude at maximum of:

$M_V(max) = -7.89 - 0.81 \times \arctan\{[log(100 \times v_d) - 0.98]/0.19\} = -8.95$

After combining this value with m_v^{max}=9.0 and $A_V = 3.3 \times E(B-V)$, we derive the distance modulus of (m-M)=17.65 for the LMC. At first glance this result may argue against the use of novae as distance indicators, but, if we compare the MMRD relation for LMC novae (CDDR 1991, their Fig. 1) with the m_v^{max} and the rate of decline of nova LMC 1991, it is apparent that this nova is shifted by $\sim$ 1 magnitude above the mean relation. This is also illustrated in Fig. 2, where we have plotted the MMRD relationships for novae of M31 (filled circles) and LMC (filled squares), and LMC 1991 (open diamond) assuming $(m\text{-}M)_{M31}$ = 24.30 and $(m\text{-}M)_{LMC}$ = 18.50. To make proper allowance for the absorption, we have applied, following CCDR89 and CCDR91, the average corrections of E(B–V)=0.07 and E(B-V)=0.09 for each nova in M31 and in LMC respectively. The comparison of the absolute magnitude at maximum of nova LMC 1991 with the mean MMRD relation (solid line) confirms that this nova is about one magnitude brighter than we expect from its rate of decline, and that this object is the first *super*-bright nova detected in the LMC. With respect to the mean MMRD relation of Fig. 2 the global rms for M31 and LMC nova population is $\sigma(O-C)$ = 0.17 mag, therefore nova LMC 1991 deviates by more than 6σ.

The 8 data points which populate the region below the MMRD relationship can be accounted for, when we assume they should be novae affected by patchy absorption larger than the average correction which has been applied [*i.e.* A4 (Arp 1956), nova LMC 1951 (Buscombe and de Vaucouleurs, 1955) etc.]. For novae n.48 and n.79, Rosino (1973) suggested they likely were two outbursts of a recurrent nova.

3. Evidence for Super-Bright Novae in other Galaxies

3.1. Novae in M31

For historical reasons the most suitable hunting field is represented by the nova population in M31. The two extensive surveys carried out by Arp (1956) and Rosino (1964,1973,1989) have provided 172 objects. From these we have extracted a sub-sample of 90 objects with well sampled light curves and for which it has been possible determine the magnitude at maximum and the rate of decline. Rosino (1964) first noted that two novae in his sample (n. 28 and n. 36) strongly deviated from the mean relation (Fig. 2). The magnitudes at maximum of nova n.28 and n. 36 (open circles) are about 1 mag larger than we expect from the relative rate of decline. The analysis of the entire Rosino sample finds other three "peculiar objects": nova n.53, nova n.57 and possibly nova n.85. We note, in passing, that on the basis of four out five of these objects (n.28, n.36, n.53 and n.57), van den Bergh and Pritchet (1986) and CDDR91 suggested the possible existence of a small sub-class of novae. No peculiar objects has been detected in Arp's sample.

[1]The value of arctan is in radians

3.2. Novae in Virgo

Among the 7 objects discovered by Pritchet and van den Bergh (1987) in the Virgo Cluster one of them (nova n.2 in the W field of NGC 4472) seems to fit well the characteristics of a *super*-bright nova. In Fig. 2 we have reported this data point (open square) after having determined its absolute magnitude from a distance for Virgo of $(m\text{-}M)_{Virgo}$ = 31.45 (from the same authors).

3.3. Galactic Novae

In spite of the fact that more than 200 galactic novae have hitherto been discovered, the absolute magnitude at maximum has been measured (via nebular parallaxes) for only a twenty objects (Cohen and Rosenthal 1983; Cohen 1985). From Cohen's sample we have extracted, on the basis of their absolute magnitude at maximum and rate of decline, two possible candidates: nova Cyg 1975 and nova Aql 1943 (Fig. 2 open triangles). This choice is strongly supported by the comparison with five other *bright* galactic novae (filled triangles in Fig.2, CP Pup 1942, V603 Aql 1918, GK Per 1901, CP Lac 1936 and V446 Her 1960), which are confined into the 3σ strip.

4. Basic Data

On the basis of the previous summary we have selected the 9 objects listed in Tab. 1. We report here the parent galaxy (col. 1), the identification of the nova according to the original source (col. 2), the observed magnitude (col. 3), the expected magnitude computed with the corresponding MMRD relationships (col. 4), and finally the Δm=($mag_{exp} - mag_{obs}$) which measures the amount of the deviation from the mean relation in magnitudes (col. 5), and in rms units (col.6).

Table 1. Magnitudes of super-bright Novae

Galaxy	nova	mag_{obs}	mag_{exp}	Δm	$\Delta m(\sigma)$
M31	28	14.85	15.95	1.10	6.5
	57	14.95	16.00	1.05	6.2
	85	15.70	16.50	0.80	4.7
	53	16.95	17.78	0.83	4.9
	36	16.90	17.90	1.00	5.8
LMC	1991	9.00	10.06	1.06	6.2
Galaxy‡	V1500 Cyg	- 9.95	- 9.00	0.95	5.6
	V500 Aql	-10.35	- 8.06	2.29	13.5
Virgo	4472W n.2	21.24	22.68	1.44	8.5

‡The 'observed' magnitudes at maximum for the galactic novae have been derived from the nebular parallaxes

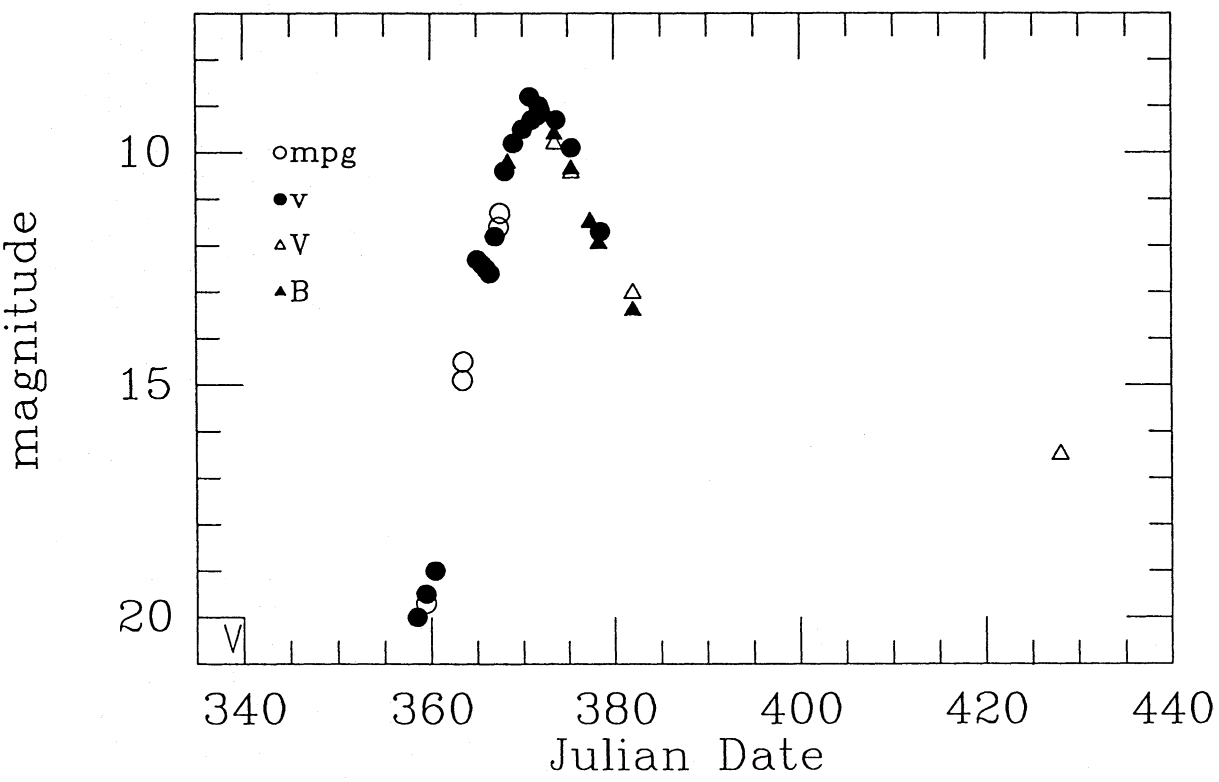

Fig. 1. Lightcurve of nova LMC 1991. Magnitudes derived from the IAU Circs. The two last points arise from observations obtained with the 3.6m telescope at La Silla.

In Tab. 2 we have summarized the number of objects that have been considered in the present study (col. 2), the number of the deviating objects (col. 3) and finally a rough estimate (col. 4) of the frequency of the *super*-bright outbursts in comparison with the 'normal' ones.

Table 2. Frequency of super-bright Novae

Galaxy	N	n	f
M31	90	5	0.06
LMC	15	1	0.07
Galaxy	19	2	0.11
Virgo	7	1	0.14

This table suggests that about $\leq 10\%$ of all the observed novae may be *super*-bright.

5. Discussion

We can summarize the main points of the paper as follows:

a) The analysis of the lightcurve of nova LMC 1991 has allowed us to derive its magnitude at maximum and rate of decline. The comparison between these parameters and the well established MMRD relation for LMC novae, shows that Nova LMC 1991 deviates toward the brighter magnitudes by more than one magnitude.

b) A critical review of the magnitude at maximum *vs.* rate of decline relationships for the most consistently investigated nova populations (Galaxy, LMC, M31, Virgo), shows that:

1. 90% of the novae of our sample is bounded inside a Δm strip of ± 0.5 mag (Fig. 2). Moreover novae in this area seem to follow the same MMRD relationship. This sketch is entirely consistent with the prediction (Shara 1982), that a dispersion of MMRD relation should be observed as a result of the intrinsic scatter in the white dwarf luminosity before the outburst. The contribution to the scatter of the photometric errors is indeed less than 20%.
2. at least one object in each sample (9 objects in all) deviates strongly from the respective MMRD relationships. In particular, the M31 and LMC objects (uncertainty on the photometry $\sim\leq 0.1$ mag), are systematically 1 magnitude brighter than what is expected from their rate of decline. For the object in Virgo and the two galactic ones, the respective errorbars are still consistent with the 1 magnitude deviation. This also may suggests the presence of a parallel MMRD relationship for the *super*-bright novae, although in the framework of the present statistic we can not make definitive conclusions.

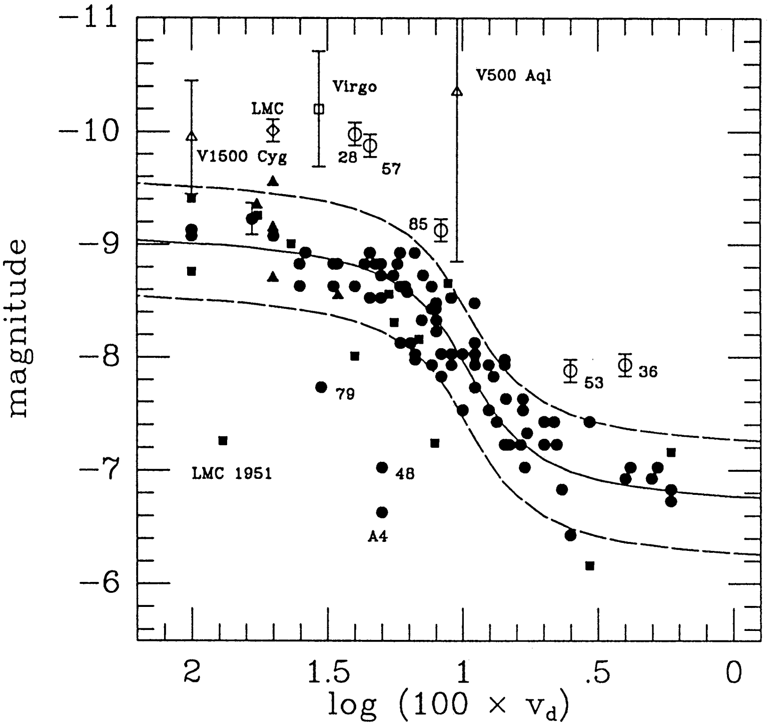

Fig. 2. Maximum magnitude *vs.* rate of decline relationship (MMRD) for the novae of M31 (filled circles) and LMC (filled squares). The magnitudes for each nova have been transformed to absolute magnitudes, assuming $(m-M)_{M31} = 24.30$ and $(m-M)_{LMC} = 18.50$ (van den Bergh 1990). Open circles represent the 5 deviating objects belonging to the M31 nova population. The open square is the Virgo nova after re-scaling the magnitude with $(m\text{-}M)_{VIRGO}$=31.45 (Pritchet and van den Bergh 1987). The open diamond is the LMC nova 1991. The open triangles are the two galactic candidates, V1500 1975 Cyg and V500 1943 Aql. The filled triangles are 5 *bright* and *very fast* galactic novae (Cohen 1985). Their position in the M_{max}–t_2 plane, confirms the realty of the brighter shoulder of MMRD relation for the Milky Way nova population as well. The dashed lines define the 3σ strip of the mean relation. The errorbar shown inside the 3σ strip, is representative of the typical error which affects the M31 and LMC data points. The points below the 3σ strip, correspond to heavily reddened novae. The n.48 and n.79 events may be two outbursts of a recurrent nova.

c) Though heavily limited by poor statistics, we can attempt an estimate of the frequency of *super*-bright outbursts in comparison with 'normal' events. It is apparent that the weight of this estimate is almost completely based on the 5 objects in M31, from which we obtain a frequency of $f \sim 0.06$. Nevertheless, it is interesting to note (see Tab. 2) that consistent figures arise from the LMC population and more marginally from the galactic one. We can assume an indicative final value of $(N_{super})/(N_{normal}) \approx 9/131 = 0.07$.

d) The results obtained in this paper impose some degree of caution in the use of novae as distance indicators, when the nova samples do not clearly permit a distinction between 'normal' and super-bright novae.

Acknowledgements. I'm indebted to J. Melnick for useful comments and to S. van den Bergh for reading the final version of the manuscript. I have also benefitted from discussion with L. Pasquini.

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