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LETTER

Letter to the Editor

EROS variable stars: discovery of a slow nova in the SMC*

The EROS collaboration

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Abstract. We report the discovery of a slow nova found in the core of the Small Magellanic Cloud by the EROS microlensing survey. Nova SMC 1994 is a classical nova with a DQ Her type lightcurve characterized by a deep minimum. Low amplitude variations occuring on time-scales of hours and days are also detected at maximum light. Spectra collected during the nebular phase indicate that Nova SMC 1994 is similar to Galactic novae of the same class. Large helium enhancement in the shell is found and O and N enrichments are suspected.

Key words: surveys – stars: novae, cataclysmic variables – galaxies: Magellanic Clouds

1. Introduction

Until recently, rather few photometric data on variable stars were available for the Magellanic Clouds. But this situation has changed owing to the long timebase microlensing survey programs, which have led to major results on variables in these neighbouring galaxies (see Ferlet et al., 1997).

Until now, very few novae have been detected in the Small Magellanic Cloud (SMC): 8 are known to date (including Nova SMC 1994), the last one being Nova SMC 1996 of the MACHO project (1997, IAUC 6713). None of them has been carefully studied, whereas detailed comparison of such objects with Galactic novae are important for our understanding of the physics of these extragalactic candles. In the next section, we present the collected photometric and spectroscopic observations. These data are discussed in Sect. 3 and Nova SMC 1994 is then compared to Galactic novae.

2. Observations

2.1. EROS photometry

CCD photometry was obtained for ∼150 000 stars at ∼6 000 epochs in a field of 0.5 square degree in the core of the SMC. The observations spanned over 600 days, between August 1993 and March 1995. Data were taken in two broad bandpass filters (B_{E2}, R_{E2}) centered respectively on 4 900 Å and 6 700 Å. We have systematically searched the EROS data base for microlensing (Renault et al., 1996), and variable stars (Beaulieu & Sasselov, 1997). Among the hundreds of variable stars detected, we have discovered a new nova for which a finding chart is given in Fig. 1.

The collected light curve for Nova SMC 1994 is shown in Fig. 2. It was too faint to be detected in 1993 before its outburst and was detected around its maximum of brightness for about 25 days in June-July 1994. Low amplitude brightness variations were observed at that epoch (see Fig. 3). We checked that these variations are real by comparison with the light curve of other stars with similar brightness in the field. Two timecales are present in the data: one of the order of 4 days, on which is superimposed a rather shorter one (few hours). However, no clear periods were found with a Fourier analysis. The nova then experienced a huge and sudden decline to become more than 6 magnitudes fainter and substantially bluer. It then experienced a

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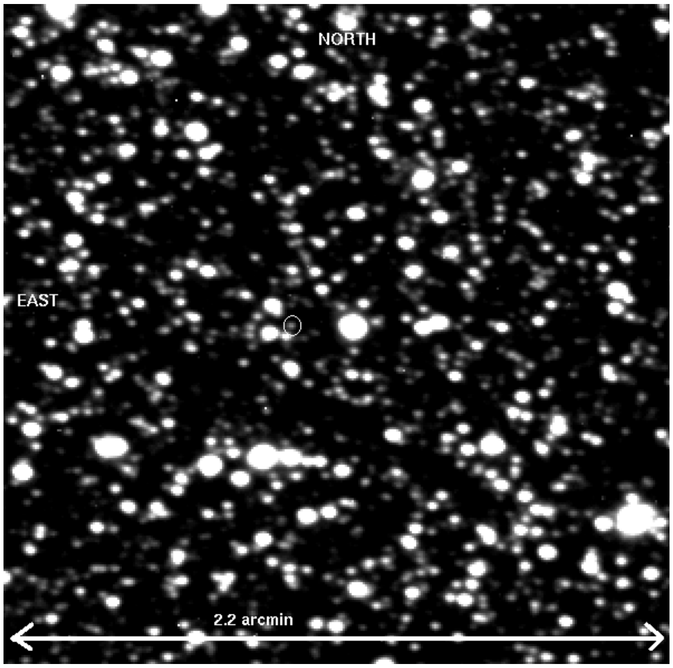

Fig. 1. Finding chart of Nova SMC 1994 : $\alpha(2\,000) = 00^{\rm h}51^{\rm m}29.8^{\rm s}$, $\delta(2\,000)$ = -73°19′54″The image was obtained when the star was faint. The field is 2 arcmin along each axis, north is up and west is left.

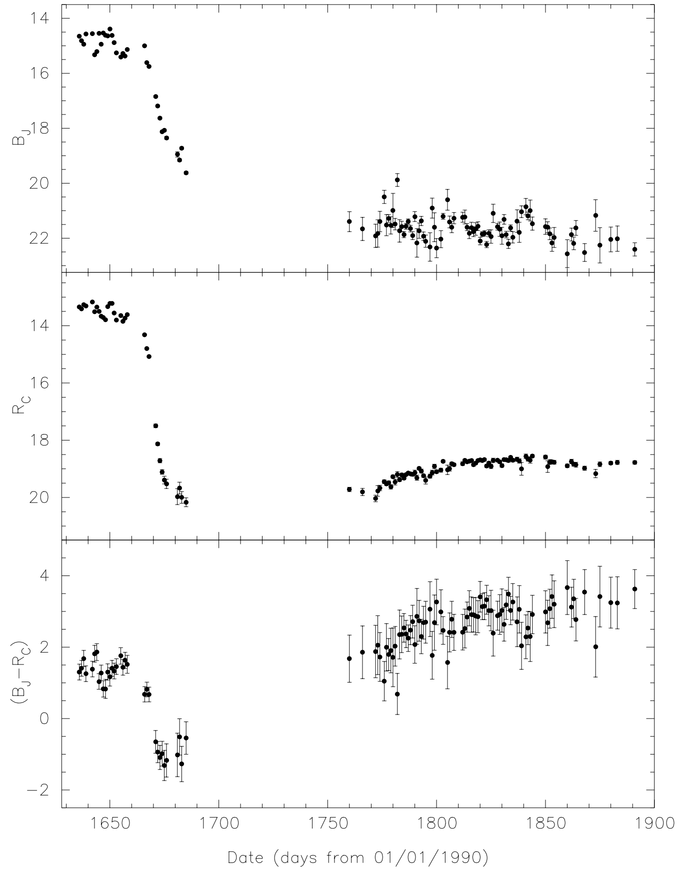

Fig. 2. Light curves and colour of Nova SMC 1994 in the Johnson-Cousins system. The EROS filters are broad band filters. A linear color equation transformation has been derived to link this system to the Johnson-Cousins standard system. We caution the reader about possible systematic effects in adopting these colour equations when the target is a star with extreme colours. For reasons of clarity, only the nightly averages of the individual observations (913 points in B_{E2} and 1259 in R_{E2}) are plotted. The object was too faint ($B_{\rm J} > 22$) to be detected before maximum between days 1288-1313 (250 measurements in B_{E2}) and at minimum between days 1680-1760 (1 100 measurements in B_{E2}).

very deep minimum (actually too faint to be detected) for more than two months, and afterwards declined much more slowly while becoming redder and redder. As with most classical novae, Nova SMC 1994 then remained brighter than its preoutburst magnitude until our last observation in January, 1997.

2.2. Additional observations

Low resolution spectra (3600–5200 Å; resolution $\sim$ 4 Å) were obtained in 1996 June and July (i.e. two years after the outburst) with the SAAO 1.9m telescope and Reticon photon-counting system. The nova was very faint and only broad emission lines of [O III] 4 959, 5 007 Å were detected as well as weak Hα blended by [N II] in July.

On August 1996, a sequence of images were obtained at the ESO/Dutch telescope on La Silla. With exposure times around 40 min., Nova SMC 1994 only shows up in V ($V_J = 19.22 \pm 0.02$), $R_{\rm C}$ and through the [O III] and Hα filters. Nothing was detected in $B_{\rm J}$, $I_{\rm C}$ and Hβ.

Spectroscopy was also obtained with EFOSC1+grism B300 on the ESO-3.6m telescope on January 11, 1997. The projected width of the 1.5 ″slit leads to a resolution of about 15 Å. The observations were reduced in a standard way using the MIDAS package and the wavelength calibration was checked using sky emission lines. The Doppler shift of each line (measured with a rather large uncertainty, around $\sim 100\ {\rm km\,s^{-1}}$) is however consistent with the velocity of the SMC. The star was still very faint and its spectrum (shown in Fig. 4) was similar to those obtained 6 months previously at the SAAO. However, the better signal-to-noise ratio allowed us to detect several more emission lines (see Table 1). Furthermore, the nova still appeared as a point-source and no extended Hα emission, which would indicate a H II region, was detected.

3. Discussion

3.1. Light-curve

This moderately faint nova with low-amplitudes variations in the post-eruption phase and a deep minimum during its decline can be classified as a *slow nova* of type Ca (see Duerbeck, 1981). These novae, similar to DQ Her, are known to form a thick circumstellar dust shell. The reddening due to this dust is clearly seen in Fig. 2 after the deep minimum.

Since Nova SMC 1994 was detected after its outburst, the exact date of its maximum is unknown. We can only derive lower limits of the rates of decline (time employed for a brightness

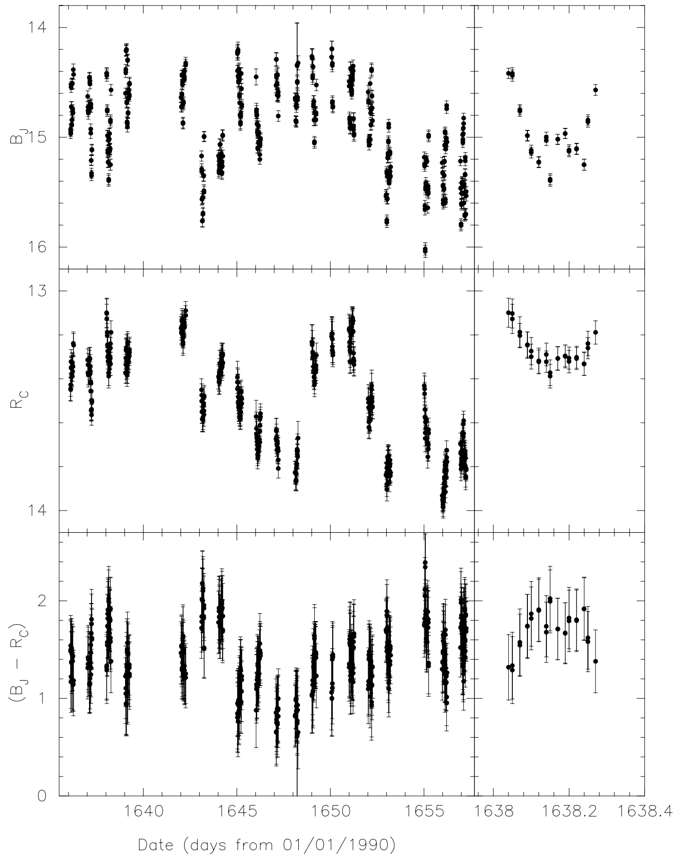

Fig. 3. EROS light curves of Nova SMC 1994 around its maximum of brightness. An enhancement of the shortest timescale is shown in the right panel.

decrease of 2 and 3 magnitudes respectively) after maximum in B: t(2) $>$ 33 and t(3) $>$ 37 days (these estimates are wrong if the maximum occured before discovery). The decay was faster in R (as already noticed for Galactic novae by van den Bergh & Younger, 1987).

To estimate the reddening, we have used the fact that expanding photospheres of novae are similar to supergiants with $T_{\rm eff}$ ∼6 000 K (Duerbeck, 1992). Using updated MARCS models (Asplund et al., 1997) for SMC metallicity, such supergiants have (B-R)∼0.9 leading to an extinction A_B ∼1.5 (the observed (B-R)=1.5 would require $T_{\rm eff}$ ∼5 000 K without reddening). During outburst, the nova therefore seems to have had M_B ∼-6.1 when assuming a distance modulus of 19.1 for this part of the SMC. With this extinction, the luminosity is consistent with an Eddington-limited nova (Duerbeck 1981); otherwise it would have been significantly underluminous. The line ratios presented in Table 1 have been de-reddened using the extinction law of Cardelli et al. (1989) and A_B.

3.2. Physical properties of the ejected envelope

All of our spectra show Nova SMC 1994 in its nebular phase. Since the strongest lines are the [O III] 4 959, 5 007 transitions,

Table 1. Emission lines from the ESO-3.6 spectrum. The line identifications are in Å, the estimated intensity of Hβ is 10^{-17} erg s^{-1} cm^{-2}Å^{-1} and the line-widths are expressed in $\rm km\,s^{-1}$. All fluxes expressed relative to Hβ = 100.

Line Identification		Flux Observed	Flux Dereddened	FWHM
Hγ	4 340	500.	610.	500.
[O III]	4 363	500.	600.	700.
He II	4 686	200.	210.	900.
Hβ	4 861	100.	100.	1100.
[O III]	4 959	1800.	1740.	1400.
[O III]	5 007	5400.	5140.	1200.
[N II]	5 754	120.	90.	
He I	5 876	20.	15.	
[O I]	6 300	130.	90.	1150.
[O I]	6 364	60.	40.	900.
[N II]+Hα	6 548	470.	320.	
[N II]+Hα	6 583	800.	550.	

we propose that the spectrum of this nova be classed as a Notype, following the Tololo system (Williams et al., 1994).

From the nebular emission lines, the physical conditions in the shell can be estimated. First, the expansion velocity provided by the FWHM of [O III] and [O I] lines, Hβ and He II 4 686 is about 500 $\rm km\,s^{-1}$. Unfortunately, neither the [S II] 6 717, 6 731 nor the [O II] 3 729, 3 726 lines were detected to allow derivation of the electron density ($N_{\rm e}$). However, [O III] 4 363 is much weaker than the two other [O III] lines, indicating a rather low $N_{\rm e}$ in the emitting region. [O I] and He I emissions are also consistent with low gas density i.e. around 10^6 cm^{-3} (Scott et al., 1995). From the [O III] lines ratio and $N_{\rm e} = 10^6$ cm^{-3}, we found an electron temperature $T_{\rm e} \sim 14\,100$ K; a value of $N_{\rm e} = 10^7$ cm^{-3} leads to $T_{\rm e} \sim 7\,600$ K. Assuming a theoretical ratio Hα/Hβ = 2.9 (case B around 10 000 K), the maximum flux of [N II] 6 548 and 6 583 relative to Hβ can be crudely estimated to 30 and 220, respectively ($F_{\rm H\beta}$ = 100). The intensity ratio of the three [N II] lines (formed in a different region from the [O III] lines) then leads to a slightly cooler electron temperature. However, following the discussion of Williams (1994) on the [O I] 6 300, 6 363 Å line ratio which is rather weak in Nova SMC 1994 (2.25 instead of 3 in the optically thin case), the shell ejected by the nova could be composed of dense, optically thick globules in these transitions. Our temperature estimates are thus only indicative. Furthermore, uncertainties in the flux measurements and the reddening should be considered (note, for instance, the large and non-case B Hγ/Hδ ratio).

The abundance of helium relative to hydrogen was estimated as in Saizar et al. (1991, including correction for collisional excitation of He I) from the relative line strengths of He I 5 876 and He II 4 686 to Hβ. We found He/H ≈ 0.3 by number (rather insensitive to the adopted T_e and N_e, following Saizar et al., 1991). This rather uncommon He/H ratio is three times larger than the cosmic abundance and is, actually, very close to the He-enrichment found in the moderately fast nova QV Vul (t(3) $\approx$

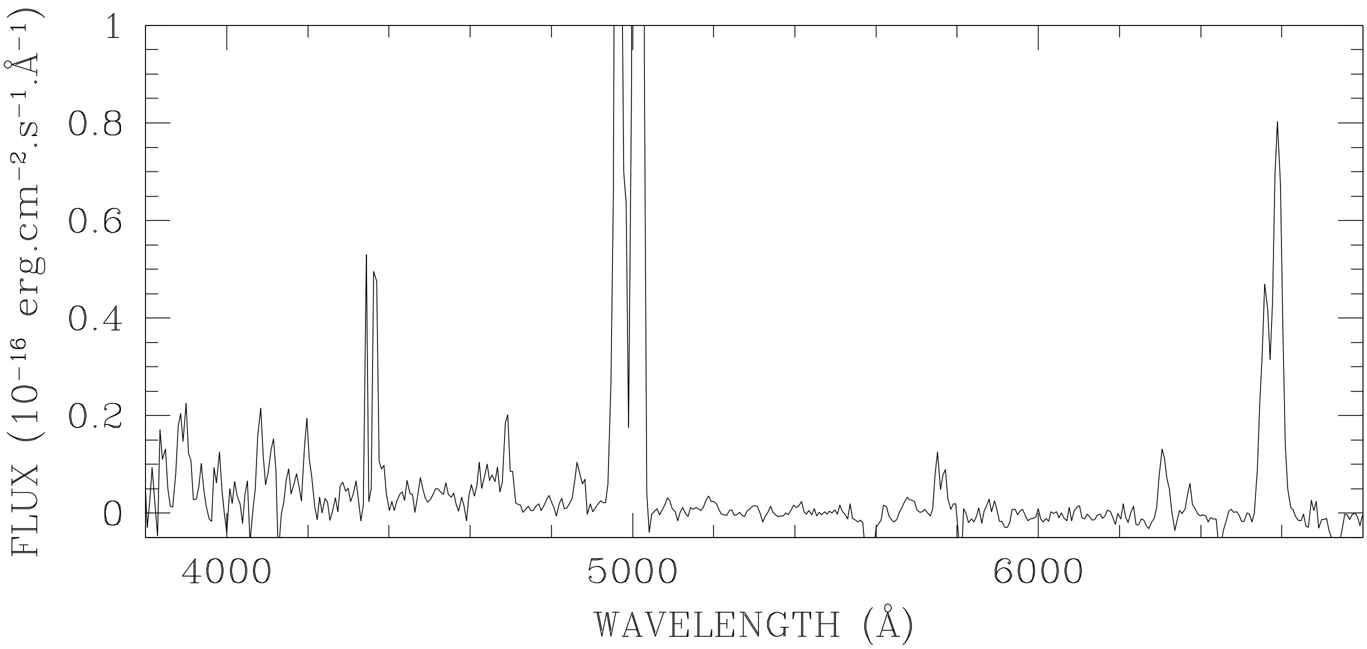

Fig. 4. Spectrum of Nova SMC 1994 in January 1997. The continuum was estimated to be less than $2 \cdot 10^{-18}$ erg s^{-1} cm^{-2}Å^{-1}.

50 d.; Scott et al., 1994). By comparing the [O III] and [N II] line intensities in Nova SMC 1994 with those observed by Saizar et al. (1991), overabundances of O and N are also suspected. All these abundances estimates are consistent with thermonuclear runaway models of Galactic slow novae.

Finally, the physical properties of Nova SMC 1994 are consistent with those of other Galactic novae (see Rafanelli et al., 1995 for instance). Its spectrum could be compared to those observed for FH Ser (a nova belonging to the same class from the light curve classification) a couple of years after its maximum (Rosino et al., 1986) with, however, stronger [O III] and He II emissions. The spectrum of QV Vul taken more than 5 years after outburst (Scott et al., 1994) is also very similar while revealing a slightly hotter and more teneous shell. The estimated abundances are also consistent. We therefore can conclude that the main characteristics of Nova SMC 1994 are consistent with the average properties of Galactic novae of similar type.

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