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# New insights from early spectra of the bright Nova Vela 1999

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Nova Vela 1999 (V382 Vel) went into outburst in 1999, reaching a maximum of $V \sim 3$ mag on 22 May. It was observed spectroscopically with the 1.9 m telescope at the South African Astronomical Observatory two days after maximum. Three sets of spectra, covering the full visual range, were collected at UT 16h47, 19h23 and 22h02 respectively. The evolution of Nova Vela 1999 was studied extensively by a number of research teams during the months (and years) after maximum in wavebands ranging from the infrared to x-rays. Observing modes covered by these investigations include spectroscopy and high-speed photometry. Noting that these previous studies are entirely based on spectra obtained no earlier than 5 days after maximum, we revisit our data secured closer to the time of outburst, and we explore whether new insights may be gained into the properties of Nova Vela 1999, previously described as a fast, Neon-class nova. We identify emission lines, determining components, relative line strengths and line profiles. This paper presents the outcome of this investigation.

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## 1. Introduction

On 22 May 1999 an extremely bright ($V = 3.1$) nova was spotted in the constellation of Vela, which within hours peaked at a magnitude of $V = 2.7$ [1]. This made it the brightest nova observed since Nova Cygni 1975, and one of the most prominent of the last 100 years. The nova, referred to as Nova Vela 1999, but also identified as V382 Velorum, thereafter faded relatively fast ($t_2 \sim 5$ days, $t_3 \sim 10$ days) [2]. Its steady decline was monitored over the coming few years, and by mid-2001 its magnitude was $V \sim 13$, i.e. a luminosity decline by a factor of $10^4$ since the peak of the outburst [3].

Given its remarkable brightness, only comparatively few studies of this nova outburst were ever published. Della Valle et al. [2] published a spectroscopic study spanning the period 28 May 1999 (6 days after maximum) to Oct 2000. Spectra obtained during the nebular phase (roughly 100-900 days after maximum) were analysed by Augusto & Diaz [4]. The third major spectroscopic study of Nova Vela 1999, albeit only in the UV, is that of Shore et al. [5]. While some of the circulars published soon after discovery mention spectroscopic observations made around the nova's maximum [1] [6], none of these spectra were ever published. Fig. 1 illustrates Nova Vela 1999's light curve, and pinpoints the times when spectra of the nova were collected.

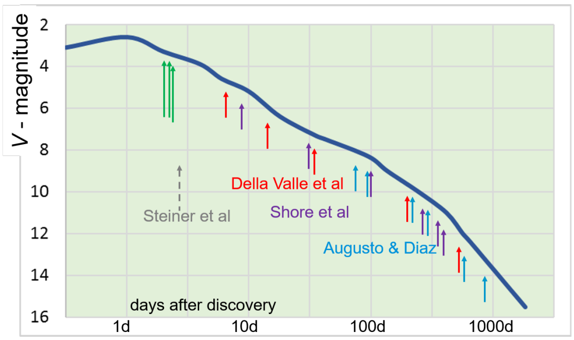


**Figure 1:** The Nova Vela 1999 light curve, with $t$ representing the time after first discovery on 22 May 1999. Also indicated are arrows pointing out the times when spectra were recorded by Steiner et al. (grey) [6], Della Valle et al. (red) [2], Augusto & Diaz (blue) [4], Shore et al. (violet) [5] and this study (green).

More information about the nova has come to light through photometric observation, as well as work done in other wavebands. The orbital period of the system was determined to be 3.795 h by Woudt et al. [7], while Balman et al. found this period to be 3.507 h [8]. This discrepancy is merely noted here. A series of x-ray studies found, amongst other things, a decrease in the opacity (consistent with an expanding shell) and shocks associated with particle interactions as a result of the nova ejecta colliding with other parts of the shell [9] [10] [11].

## 2. Observations

Spectroscopic observations were carried out using the CCD spectrograph on the SAAO 1.9 m telescope. One set of spectra consisted of ten 2-s integrations. Even with the extremely short integration time, it was necessary to carry out the spectroscopy through a 4 mag neutral density filter.

PoS(HEASA2019)020

A 100 s Ar spectrum was recorded for wavelength calibration purposes both at the start and the end of the sequence. The flux calibration was effected through observations of the spectrophotometric standard star CoD $-32°9927$. As these spectra were required to be taken through the same neutral density filter, this required a long integration of 900s.

The spectroscopic observation sequence was repeated three times during the night 24 May 1999. The first of these was during twilight, at 16h47 UT. The second set of spectra was recorded about 2.6 hours later, at 19h23 UT. The final set of spectra was obtained at 22h02 UT, after which the nova was too low in the sky to be accessible.

## 3. Analysis of the spectrum two days after maximum

### 3.1 General characteristics

The three sets of spectra analysed here appear very similar, and the general characteristics can be displayed in the form of the averaged spectrum illustrated in Fig. 2. It shows a rich emission line spectrum dominated by hydrogen Balmer-line and Fe II, sometimes with hints of a P Cygni profile. In addition, emission lines corresponding to He I were present as well, and some emission features might possibly be associated with Na I and Al II.

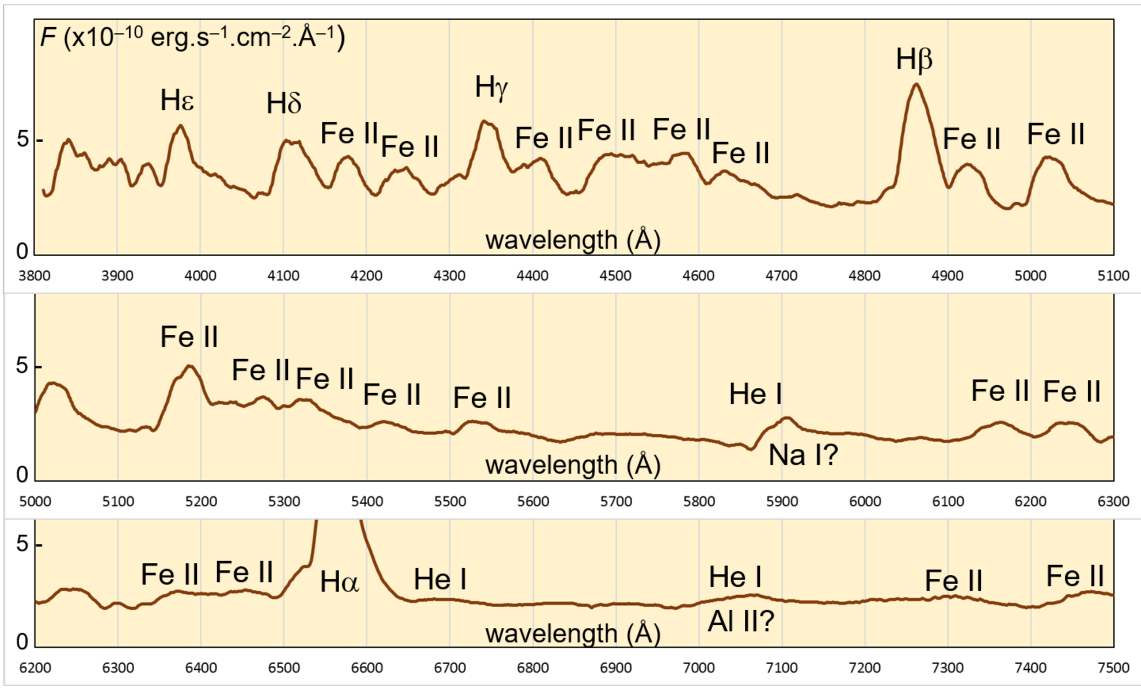


**Figure 2:** The averaged spectrum of Nova Vela 1999 for the night of 24 May 1999. The most important lines are labeled.

Nova Vela 1999 was classified as a neon nova [4] based on the presence of neon emission during the nebular phase. Strong Fe II emission was reported in the earliest spectrum of Della Valle et al. [2]. Our spectrum confirms the prominent iron emission lines at the time of the nova's luminosity peak. The iron lines disappeared almost totally in spectra from a month later [2], where many helium and nitrogen emission lines are now visible. This makes Nova Vela 1999 a hybrid between the "Fe II" and "He/N" type neon novas [12]. Another example of that category is Nova LMC 1988 No. 2, where a spectrum taken 2 days after maximum displays considerable similarities to our spectrum presented here [13]. In Fig. 2 we identify the line at ∼4570Å with Fe II, and ∼5900Å & ∼7050Å with He I, rather than Mg I, Na I and Al II proposed for emission at those respective wavelength by Della Valle et al. [2] in a spectrum recorded five days later. We claim this based on the lines in question having strengths consistent with other iron and helium lines visible in the spectrum, although identifications corresponding to other elements cannot be ruled out.

The profiles of the H$\alpha$ to H$\delta$ lines have been displayed in Fig. 3. Attempts to fit these with a combination of Gaussian components did not prove very successful. While the Balmer line profiles will to some degree be affected by some of the adjacent emission features, mostly due to Fe II, there are some peculirities in the hydrogen line profiles that seem to be common to the entire Balmer series. These are: i) An absorption dip at about 1600 km.s$^{-1}$ that is likely to be caused by a shell expanding at that velocity – the characteristic mechanism responsible for P Cygni profiles, ii) a redshifted emission peak corresponding to a recession velocity of 1250 km.s$^{-1}$, that becomes more prominent as one goes to the higher order Balmer lines, and iii) a red excess in the region 2500-3000 km.s$^{-1}$.

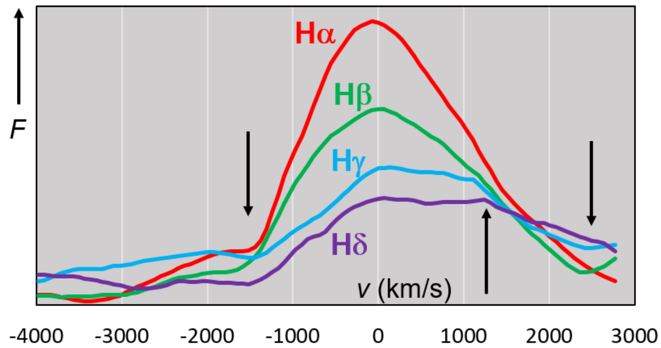


**Figure 3:** Profiles of the first four hydrogen Balmer emission lines in terms of velocities relative to the H$\beta$ peak. The features highlighted by the arrows are discussed in the text.

The observed width of the Balmer lines is of the same order of magnitude as that found in later spectra [2], although there is no obvious sign yet of the double-peaked profile, with a stronger blue peak, found in those epochs. However, as will be shown next, double-peaked profiles are already developing.

### 3.2 Spectral evolution over a 5-hour period

Despite the similarity of all spectra obtained on the night, there was spectral evolution over the five hour period. This can be seen when plotting the ratio of the 19h23 UT and 16h47 UT spectra, and especially for the ratio of the 22h02 UT and 16h47 UT spectra. These are illustrated in Fig. 4.

We note the similarity between the profile of the spectral ratio plot at H$\alpha$ and H$\beta$ with later epoch double-peak profiles of these lines shown by Della Valle et al. [2].



PoS(HEASA2019)020

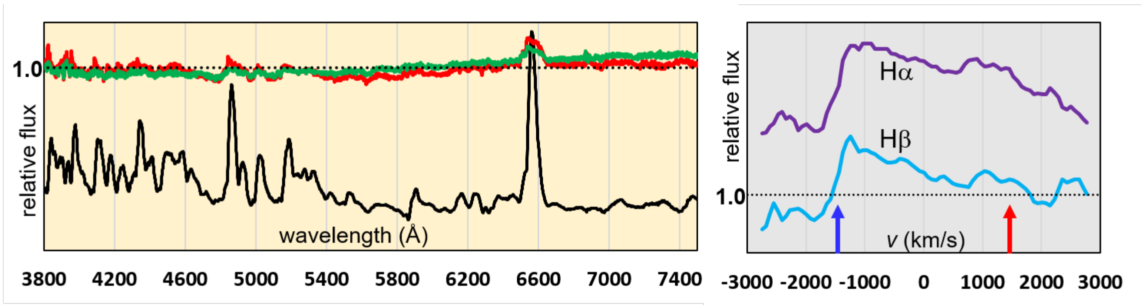


**Figure 4:** The left panel illustrates the ratio of (in green) the 19h23 UT to the 16h47 UT spectrum, and (in red) the 22h02 UT to the 16h47 UT spectrum over the entire optical range. The (scaled-down) actual nova spectrum (in black) is included for comparison. The right panel compares the 22h02-to-16h47 flux ratios near H$\alpha$ and H$\beta$, in terms of gas velocity. The arrows indicate the positions of the blue and red peak in the Della Valle et al. spectrum [2].

## 4. Comparison with the recently discovered nova shell

A shell with a 9.9 arcsec diameter has recently been identified by Takeda and Diaz, imaged with an [OIII]5007Å narrow-band filter [14]. This image was recorded 5781 days after maximum.

A further recent development has been the publication of the vast database of stellar distances determined through parallax measurements made by the GAIA satellite [15]. This includes a distance measure for V382 Vel of 1.79 kpc, which translates to $5.5 \times 10^{16}$ km. Even though our target is a binary star, implying a higher degree of uncertainty in parallax-derived distances, we expect this to be a reasonable estimate of the actual distance to the system. Given the observed 4.95 arcsec radial expansion of the shell, and utilising the geometric construction lined out in Fig. 5, this implies that the shell's radius equates to $1.32 \times 10^{12}$ km. Combining this with the time $t$ since the outburst of 5781 days = $4.995 \times 10^{8}$ s, this means that the average expansion velocity of the gas forming the shell will be $v = \Delta s/t \sim 2600$ km.s$^{-1}$.


**Figure 5:** Relationship between the angular shell radius, expansion velocity and distance.

This is consistent with the maximum expansion velocities of 2500-3000 km.s$^{-1}$ observed in our spectra for the Balmer lines, as well as shell expansion velocities identified for later epochs in some of the previously published papers.

## 5. Conclusion

We have presented our analysis of some of the earliest spectra available of Nova Vela 1999. While earlier spectroscopic data of this nova exist, these have not been evaluated in depth, and only verbal descriptions of these spectra have ever been published. Our spectra illustrate the earliest evolution of the nova shell, and the expansion velocities we measured are consistent with the size of the nova emission line shell recently confirmed by direct imaging.

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