SPECTROSCOPIC MONITORING OF NOVA VULPECULAE 2007 (V458 Vul)

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ABSTRACT. We present results of the spectroscopic monitoring of the peculiar nova V458 Vul during eleven months. At the early decline of the brightness the nova transformed from Fe II to the He/N type. The profiles of the HI and the HeI lines showed the variability connected with the rebrightening. At the final decline of the brightness the nova displays a fast variability (within a day) of the forbidden iron line profiles. The spectral features of V458 Vul allow classifying it as a hybrid "neon" nova.

From the AAVSO light curve we obtained some photometric parameters, the mass of 458 Vul and the distance to the object. The nova showed a fast decline of the brightness (t_2=7, t_3=18 days). It reached M_v= -9.0 mag at the maximum of the brightness. The distance to the nova is in the range d=10.1-12.8 kpc. The reddening E(B-V)=0.59 towards the star is derived using the colour index of the nova at the maximum and the Balmer decrements. The white dwarf mass was derived about 1.1–1.2 $M_\odot$

Key words: Stars: binary: novae; stars: individual: V458 Vul.

1. Introduction

Nova Vulpeculae 2007 was discovered by Hiroshi Abe on 2007 August 8.54 UT (Nakano, 2007). A progenitor B=18.2 was found by Henden & Munari (2007). The nova was named V458 Vul (Samus, 2007). After the rapid decline during a day more then by one magnitudes, the nova underwent two abrupt increasing of brightness about 1.5 mag. The spectra acquired near the maximum showed the Balmer and the FeII (multiplet 42) lines in a emission with the P Cyg profile and the HeI lines in the absorption. The nova was classified as FeII type (Williams, 1991; Williams, 1992). After the rapid decline of the brightness the nova spectrum changed towards the He/N type. Therefore it was classified by us as a hybrid nova (Tarasova, 2007).

In the time of the principal and the second maxima the Balmer, the FeII and the HeI lines had the P Cyg type profiles. Just after the decline of the brightness the intensity and the profiles of the Balmer and the HeI lines changed: the HeI profiles became a saddle shape and the Balmer lines were seen as a complex P Cyg profile. After the rebrightening the profiles of the HI and the He I lines demonstrated an almost flat topped form. The early spectral evolution of V458 Vul was described by Tarasova (2007) and Poggiani (2008). In this work we analysed the subsequent spectral evolution of the V458 Vul and also derived the distance to the nova, the reddening and the Balmer decrement.

2. Spectral evolution

2.1. Observations

The spectral observation was carried out at the Crimean Astrophysical Observatory with the 2.6m Shajn telescope. The low resolution spectra with the dispersion of 2 Å/pix, were observed in the wavelength ranges 3700-6190 Å and 5600-7600 Å. The medium resolution spectrum, obtained on Aug 17^{th}, had the dispersion of 0.75 Å/pix and covers the spectral range 4200-5300 Å. In Fig.1 we presented all our spectral observation.

2.2. Early decline phase: 9^{th}–25^{th} day after the outburst

17.8, 18.8 Aug 2007 (t=+9, 10). The broad emission HI, FeII (27, 28, 37, 38, 42, 49, 74 multiplets) lines and the HeI 5876, 6678, 7065 lines dominate in the nova spectrum . The expansion velocity (FWHM) is about $2700\,\mathrm{km\,s^{-1}}$ for the HI and about $3100\,\mathrm{km\,s^{-1}}$ for the HeI lines.

21.8 Aug 2007 (t=+13). The spectra have been obtained after second rebrightening. Spectra show that V458 Vul evolved towards the He/N class. The N III 4640 and the He II 4686 lines form the broad blend centered at 4670 Å. The line profiles differ noticeably from the previous observation. The HI, FeII lines have a complex P Cyg type profile, while the HeI line profiles have an asymmetric saddle shaped form. The flux of the Balmer lines sharply decreased, while the

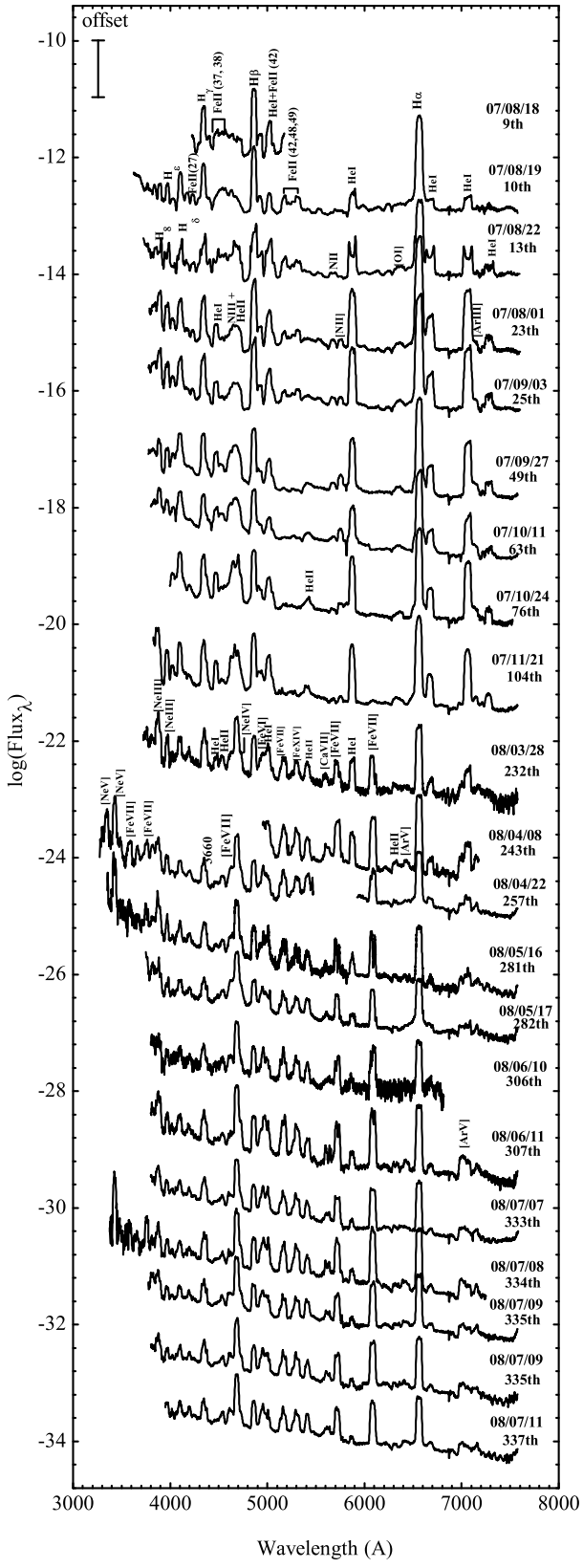

Figure 1: Dereddened spectra of V458 Vul. Fluxes are given in logarithmic scale to show the less intence lines. The spectra are separated vertically by the constant offset.

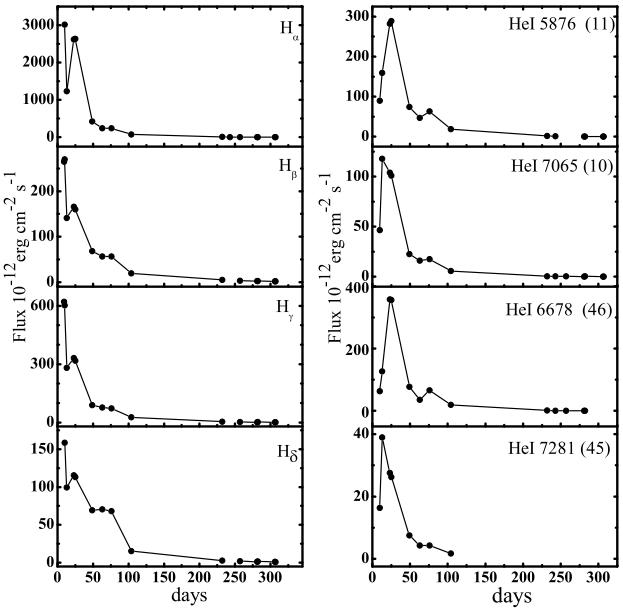

Figure 2: The variability of the HI and HeI line fluxes.

flux of the HeI lines either continues to increase (HeI 5876 (11 multiplet), 7065 (10 multiplet)) or reaches the maximum (HeI 6678 (46 multiplet), 7281 (45 multiplet)) (Fig.2). The noticeable increasing of the velocity of the HI and the HeI lines occurs after the rebrightening. The distance between emission peak of the HI lines is about 3300 km s^{-1}, of the HeI lines is about 3500 km s^{-1}. The line profiles exhibit the complex structure indicating at the asymmetric outburst. The profiles of the various potential ionization lines are diverse.

31.8 Aug, 2.8 Sept 2007 (t=+23, 25). The FeII lines faded, while the HI and the HeI lines intensified. The HeI lines (with exception for the H_α lines) dominate in the nova spectrum. The width (FWHM) of the HI, HeI lines diminished and became about 2700 km s^{-1}, 3000 km s^{-1} respectively.

2.3. Transition phase: 49^{th}–104^{th} day after the outburst

27.4 Sept, 10.8, 23.7 Oct 2007, 20.6 Nov (t=+49, +63, +76, +104). The reduction of the flux in the HI and the HeI lines by one order of a value is observed. The FeII lines disappeared, but the HeII lines became stronger. The width (FWHM) of the HI lines was not changed, but the HeI lines decreased by one third. The HI and HeI lines have the weak P Cyg components on the 49^{th} day and on the 63^{th} day after outburst. They disappeared on the 76^{th} day. The brightness on the light curve oscillated at this time and besides the nova was detected as a supersoft X-ray source (SSS) by Swift XRT on Oktober 17 (Drake, 2008). On of the explanation of that is a outflow of the matter from

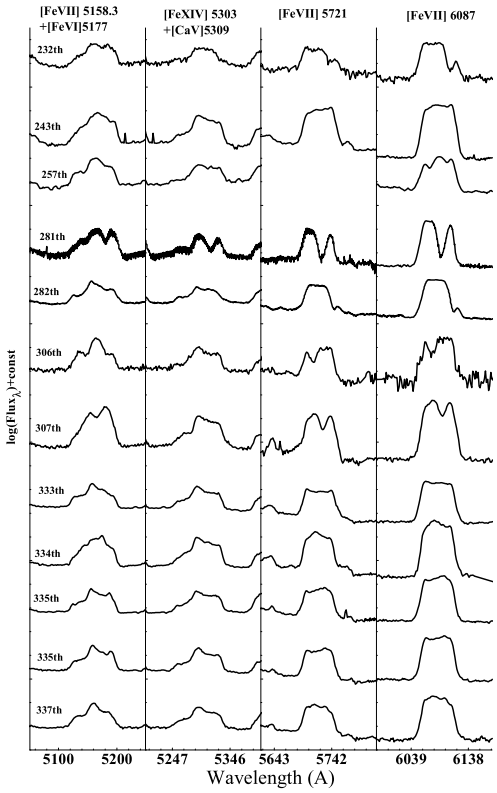

Figure 3: The profile variability of the [FeVII] 5159, 5721, 6086 and [FeXIV] 5303 lines

a surface of the white dwarf. It is provided by the continued thermonuclear reactions on a white dwarf surface.

2.4. Nebular phase: 232th–337th day after the outburst

28.1 Mar, 8.1, 22.0 Apr, 16.0, 17.0 May, 11.0 Jun, 7.0, 7.9, 8.8, 10.9 Jul (t=+232, 243, 257, 282, 307, 333, 334, 335, 337). The spectrum is rich with the [FeVII] (3586, 3759, 5159, 5721, 6086) lines and the HeII (4542, 4686, 5412, 6311) lines. There are [FeXIV] 5303, [CaVII] 5619, [ArV] 6435 and 7006, [NeIII] 3869, 3968, [NeV] 3426, 3346 lines. The [NeV] 3346, 3426 lines stand out against the other lines in the spectra. The strength of these lines qualifies V458 Vul as a "neon" nova. The profiles of the high ionization forbidden iron lines demonstrate a fast variability. The noticeable changes occur within a day (see Fig. 3).

3. Light curve

The light curve has been constructed using the observation of the AAVSO group (Henden, 2007) and the observation published in the IAU Circulars. The light curve of V458 Vul is shown in Fig.4. The striking features of the light curve of V458 Vul are the presence

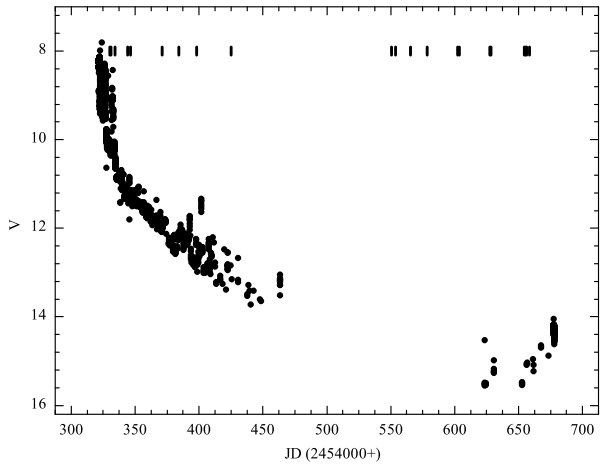

Figure 4: Light curve of V458 Vul based on the AAVSO data. The vertical bars indicate the time of our spectral observations.

of two strong post maximum peaks with the amplitude of about 1.5 mag. The duration of the first and the second peaks is about 3 and 4 days, respectively, and the time between them is about 3 days. The oscillations of a brightness are also seen during the transition phase. The light curve indicates that the maximum V_{max}=8.14 was reached on JD_{max}=2454321.9. A smooth fit of the light curve gives the following: i) the magnitude on the 15th day after the maximum is V_{15}=10.87; ii) the time of the decline through 2 mag is t_2=7 days; iii) the time of the decline through 3 mag is t_3=18 days. Thus V458 Vul is a fast nova according to Payne-Gaposchkin classification (Payne-Gaposchkin, 1957).

The absolute magnitude of the nova at the maximum was estimated using the various $M_{V,max}$, t_n (n=2,3) - relations (Schmidt 1957; de Vaucouleurs 1978; Cohen 1988; DellaValle 1985; Downes & Duerbeck 2000). The absolute magnitude ranges from M_v=–8.8 to M_v=–9.2.

4. Reddening, distance and mass

The reddening towards the nova is calculated using the colour index of a nova at the maximum and 2 mag below the maximum (Van Den Berg & Younger 1987). We defined $(B\text{-}V)_{max}$=0.76 and $(B\text{-}V)_{t_2}$=0.65 from the photometric data of AAVSO group (Henden, 2007). This leads to E(B-V)=0.53 mag and E(B-V)=0.65 mag, respectively.

The reddening was derived also using the flux of the H_α/H_β ratio (Fig.5). During our observations the H_α/H_β ratio varied between 3.3 and 15. The theoretical H_α/H_β ratio was found to be in the range of 2.8-3.0. To calculate the reddening we took the Balmer decrement close to the theoretical. The color excess E(B-V) calculated from the H_α/H_β ratio is 0.42. The average

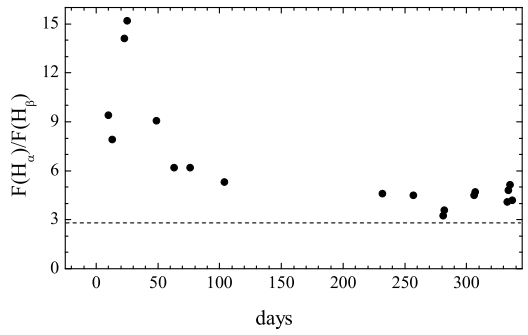

Figure 5: H_α/H_β ratio versus time after maximum (in days)

reddening E(B-V) was found to be 0.59.

The mass of a white dwarf M_{wd} in a nova is given by Livio(1992):

$$M_B^{max} \sim M_V^{max} = -8.3 - 10 \lg \frac{M_{wd}}{M_\odot} \qquad (1)$$

The white dwarf mass is about 1.1-1.2 $M_\odot$. Using the relation:

$$m_v - M_v = 5 \lg d - 5 + A_v \qquad (2)$$

and the absolute magnitude on the 15^{th} day after the initial maximum (Buscombe & de Vaucouleurs 1955; Cohen 1985a; van den Berg & Younger 1987; Capaccioli et al. 1989; Downes & Duerbeck 2000) we estimated the distance to a nova in the range d=10.1–12.8 kpc.

5. Conclusions

The spectral evolution of the V458 Vul allows to classified it as a hybrid "neon" nova according to Williams classification. The general picture of the spectrum evolution is similar to that of V2214 Oph (Nova 1988) (Williams, 1991). But in contrast to Nova Oph 1988 the spectra of V458 Vul exhibit a dramatic change in the early decline phase of the brightness connected with the rebrightening and a fast variability of the forbidden lines on the final decline.

We calculated the fluxes and the widths (FWHM) of the HI and HeI lines and showed that in the time of the rebrightening change not only the profile but also the flux and the width of this lines. At the same time the flux of the HeI lines increased and the HI lines diminished. The width (FWHM) of the HI and the HeI lines rised in the time of the rebrightening and then declined at the following phases.

We revealed the fast variability (within days) of the forbidden iron profiles of the high ionization potential lines during the nebular stage. We believe, that the cause of this variability can be a variable flux of a radiation triggered by the continued thermonuclear reactions on a surface of the white dwarf. Indeed the nova was detected as a supersoft X-ray source (SSS) by Swift XRT in this time (Drake, 2008).

Using the light curve of the V458 Vul we get the parameters t_2=7 d and t_3=18 d and conclude that it is a fast nova according to Payne-Gaposchkin (1957) classification. We estimated the absolute magnitude at the maximum with the various MMRD relations. We believe that the values of M_v range from -8.8 to -9.2. The reddening E(B-V)=0.59 is derived using the colour index of a nova at the maximum and 2 mag below the maximum and the H_α/H_β ratio. The nova distance is in the range d=10.1-12.8 kpc. The white dwarf mass is about 1.1-1.2 $M_\odot$.

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References

van den Berg S., Younger P.F.: 1987, *Astron. Astrophys. Supl. Ser.*, **70**, 125.
Buscombe W., de Vaucouleurs G.: 1955, *Obs*, **75**, 170.
Capaccioli M., et al.: 1989, *Astrophys. J.*, **97**, 1622.
Cohen J.G.: 1985, *Astron. J.*, **292**, 90.
Cohen J.G.: 1988, *ASP Conf. Ser.*, **4**, 114.
Della Valle M., Livio M.: 1995, *Astrophys. J.*, **452**, 704.
Drake J.J. et. al: 2007, *ATel* 1246.
Drake J.J. et. al: 2008, *ATel* 1603.
Downes R.A., Duerbeck H.W.: 2000, *Astron. J.*, **120**, 2007.
Henden A.A.: 2007, Observations from the AAVSO, priv. comm.
Henden A., Munari U.: 2007, *Inform.Bul.Var.Stars*, 5803.
Livio M.: 1992, *Astrophys. J.*, **393**, 516.
Nakano S.: 2007, *CBET*, 1027.
Payne-Gaposchkin C.: 1957, *Science*, **126**, 1350.
Poggiani R.: 2008, *Astrophys. Space Since*, **4**, 77.
Samus N.N.: 2007, *IAUS*, 8863.
Schmidt T.Z.: 1957, *Z. Astrophys*, **41**, 182.
Tarasova T.N.: 2007, *Inform. Bul. Var. Stars*, 5807.
de Vaucouleurs G.: 1978, *Astron. J.*, **223**, 351.
Williams R.E., Hamuy M., Phillips M.M. et al.: 1991, *Astrophys. J.*, **376**, 721.
Williams R.E.: 1992 *Astron. J.*, **104**, 725.