DUPLICITY AND EVOLUTION STATUS OF THE EARLY-TYPE Be STAR V622 Per, THE MEMBER OF THE χ Per OPEN STAR CLUSTER

S.L. Malchenko[1], A.E. Tarasov[2,1], K. Yakut[3,4]

[1] Tavrida National University
95007 Vernadskogo avenue 4, Simferopol, Crimea, Ukraine, *svetlana_mal@ukr.net*

[2] Crimean Astrophysical Observatory
98409, Naychny, Crimea, Ukraine, *tarasov@cra.crimea.ua, aetarasov@mail.ru*

[3] University of Ege, Faculty of Science, Department of Astronomy and Space Science
35100, Bornova, Izmir, Turkey

[4] Institut voor Sterrenkunde, Katholieke Universiteit Leuven,
Leuven, Belgium

ABSTRACT. On high-resolution spectra, obtained in the Hα region and medium resolution spectra obtained in the region 4420-4960Å together with radial velocities, which was taken from other published sources we analyzed the radial velocities and calculate orbital parameters of the massive binary system V622 Per. It is shown that the system has an orbital period 5.2 days and is a post mass transfer binary. Temperature of components and an inclination angle of the system were obtained from light curve analysis of the ellipsoidal variability. Luminosity ration of components was found of about 4:1. T_{eff} and $log\, g$ for each of components was estimated. It is shown that primary, less massive but brighter star is an evolved object that has lost a large part of the mass during its evolution. Estimations of the primary chemical composition showed a noticeable enrichment of products of the CNO cycles such as He/H reach 0.18, the nitrogen is in excess of about 0.5 dex, the carbon has lower abundances (by 2-3 dex lower) and the oxygen has 1 dex lower than solar abundance. The possible evolution of the binary with the known age 17 Myear is discussed.

Key words: Stars: binaries: spectroscopic - stars: individual: V622 Per; Galaxy: cluster: χ Per.

1. Introduction

Presence of massive interacting binaries in open stellar clusters is the useful tool for understanding short-lived phases of their evolution. Such stars are rare and each of them requires detail analyses.

Close binaries are powerful tools for testing the stellar structure and evolution models, since the fundamental properties of the components (e.g masses, radii, luminosities) can be accurately determined from the observation. These systems in young open clusters provide a way of finding the age, distance, accurate masses, radii and chemical composition, and show the way of making a good discriminating test of the physical ingredients of theoretical models.

During the studying of the hot B stars in young open clusters h/χ Per we found and analyzed the binary system V622 Per/ BD +56°578/ Oo 2371 (Oosterhoff, 1937). The star may be a good indicator of verifying the theory of the evolution.

Early spectral type of the star B2III Strom et al. 2005, relatively short orbital period $\sim 5.2^d$ (Krzesinśki & Pigulski 1997), presence of emission details in the spectrum and unusual chemical composition of the atmosphere (Vranken et al. 2000) mean that the star is an interacting binary with unknown evolutional status, but locate in the open stellar cluster χ Per of the known age.

2. Observations and data reduction

Spectroscopic observations of V622 Per took place over four years from 1997 to 2000 as a part of studying emission spectrum of the Be stars in the young double open cluster h and χ Per (NGC 869 and NGC 884). We used the Coudé focus of the 2.6-m telescope of the Crimean Astrophysical Observatory. The spectral resolution was about 30000. The signal-to-noise ratio was $\sim$100. A total of 8 spectra was obtained in the Hα line and one in the region of the HeI $\lambda\,6678$ Å line.

Additionally, as a part of program of studying B and

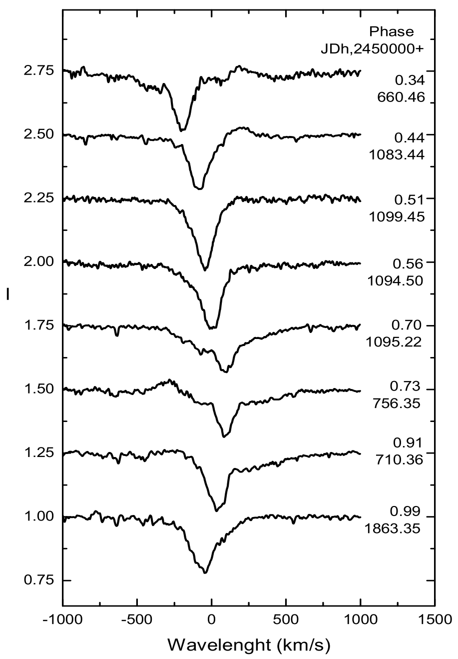

Figure 1: Hα line profiles of V622 Per. On the left side of each spectrum JD and phase of the orbital period is presented. Intensities of each next spectrum are shifted by 0.25.

Be stars in the open stellar clusters, two medium 2.5Å resolutions of spectra were obtained in the Nesmith focus of the same telescope. They cover spectral region between 4420-4960 Å. The signal-to-noise ratio of these spectra was about 100.

The Hα line has complex and it is variable in the time domain (Fig.1). The most pronounced component is a sharp absorption line with large amplitude of RV variation. Signatures of the broad absorption component are also seen on the most part of our spectra. Additionally, some faint emission line is presented in the red or blue wings of the line, but some spectra have no noticeable emission or they are hidden inside of the absorption profile. Gaussian fitting by three functions were used to deblend the Hα line profile.

The He I λ 6678 Å line profile can be seen in Fig.2. It has a single-component line profile without noticeable emission and some faint signatures of the additional absorption component in the blue wing of the line. Radial velocity was measured by fitting of two Gaussian functions with r.m.s. errors 1 and 5 km s^{-1}respectively for strong and hidden components of the line.

The observed blue region of the spectra is presented in Fig.4. The Hβ line profile has no signs of the emission component on the both of our spectra. The weak absorption from the secondary is seen in the blue wing of the line. Radial velocities for the primary component, obtained by individual lines deblending and by cross-correlation methods, have the same radial veloc-

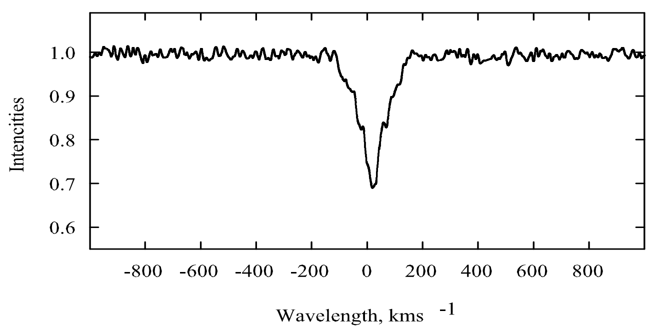

Figure 2: Line profile of the He I λ 6678 Å line, obtained at JDh = 2451094.577

ities.

As it shows at Fig.4, the red wing of the Hβ line has broad depression. It was found on all the spectra of other members of h/χ Per cluster, but absent in the spectra of the standard stars from the list Lybimkov et al. (2000). It is associated with the interstellar absorption band with unknown identification (Herbig 1975) and it has a very broad, asymmetric feature. According to Herbig (1975) wings of the line extend shortward edge to at least 4870 Å and longward to 4909 Å . The deepest point is about 4882 Å .

3. Radial velocities analysis and orbital solution

According to the rich BV photometry from Krzesinśki & Pigulski (1997), V622 Per is an ellipsoidal double system with the orbital period $P_{orb} = 5.2132 \pm 0.003^d$. The large fraction of our RV measurements were obtained from the emission Hα line. Practically the same velocities of the He I and sharp component of the Hα lines, is obtained in the same night, and "in phase" variability of the radial velocities, which is obtained from the Nesmith spectra, allow us to conclude that the sharp component of the Hα line mostly appears in the photosphere of the bright star and can be used with some caution in solving orbit of V622 Per.

To confirm the value of orbital period derived from Krzesinśki & Pigulski (1997), we used our RV measurements together with the data, which was obtained by Liu et al. (1989, 1991). Periodogram analyses based on nonparametric statistics were used for searching possible orbital period from radial velocities observations. Only one significant period, close to the value proposed in the work Krzesinśki & Pigulski (1997), was found.

In order to solve spectroscopic orbit we used the FOTEL code (Hadrava 1990). Obtained orbit solution is presented in the Table 1 and its graphical equivalent is present in Fig.3. As it seen from orbital solution, V622 Per is an evolved massive system with the less

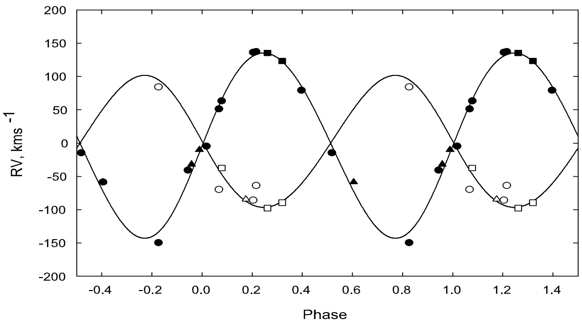

Figure 3: Radial velocity variability with the phase of orbital period. The filled symbols – orbital velocities of the primary component, open symbols – RVs of the secondary component. Filled circles – sharp component of the Hα and the He I λ 6678 Å lines. Circles – RVs derived from the Hα line profile; squares – RVs, obtained from the two Nesmith spectra and the He I λ 6678 Å line; triangles – RVs estimations from Liu et al. (1989, 1991) open triangle – ommited observation Liu et al. (1991)

Table 1: Orbital parameters of V622 Per based on radial velocity variability

Element	Orbital solution
P (days)	5.21429±0.00008
$T_{conj.1}$	2450661.4±0.2
K_1 (km s^{-1})	139±6
K_2 (km s^{-1})	99±11
q	1.40±0.13
e	0.05±0.04
ω°	236±36
γ_1 (km s^{-1})	-44±3
γ_2 (km s^{-1})	12±11
f_M (M$_\odot$)	1.46
$M_1 sin^3 i$ (M$_\odot$)	3.0
$M_2 sin^3 i$ (M$_\odot$)	4.3
$a_1 sin\, i$ ($R_\odot$)	14.3
$a_2 sin\, i$ ($R_\odot$)	10.2
No. of spectra	11 spectrograms and 3 velocities by Liu (1989, 1990)

massive, but more bright primary component. It has near circular orbit and low value of mass exchange.

We also used the rich BV photometry from Krzesinśki & Pigulski (1997) to perform light curve analysis. According to the light curve analysis V622 Per is an ellipsoidal double system, with colder primary component (T_1=21000K) and hotter secondary (T_2=24000K). The inclination angle of the system i=43.7^0 ± 2.9.

4. Physical parameters and chemical composition of the components

Radial velocities and photometrical variability due to ellipsoidality of the components allowed us to obtain most of the main physical parameters of the double system with exception of the radius of the components. The next step of our analysis was to constrain a model of atmosphere of the components with the goal to estimate chemical composition at least more luminous star.

Temperatures T_{eff} of the components were found from the light curve analysis. Next pair of parameters $log\, g_1$ and $log\, g_2$ of the components can be found from the equivalent width of the Hβ line, but only in assumption that gravity one of the components is taken elsewhere. We should accept that the less luminous component is still an undeveloped star which position on H-R diagram is close to the main sequence with $log\, g$=4.0. Then, using luminosity ratio of the components 4:1 and photometry index [c1] and β (took from Fabregat et al. (1996) and Capilla and Fabregat (2002)), we found that observed EW of the Hβ line satisfied approximation with $log\, g_1$=3.0 ± 0.5 .

Since we had only one high resolution observation of the photosphere line He I λ 6678 Å this line of the secondary was heavy blended with the primary one, we were only able to estimate their rotational velocities. We obtained $V_1 sin\, i$=60±10km s^{-1} and $V_2 sin\, i$=80±20km s^{-1} for the primary and secondary components respectively. Rotation velocity of the secondary seems to be close to synchronization with the orbital velocity that is in agreement with the relatively short, less than 1 Myear, time of synchronization after an active mass transfer (Langer et al.2003)

The last step of our analyses was to determine the abundance of the elements of CNO cycle. We used the LTE line blanketing model Kurucz (1993) for solar abundances with the line formation problem solved by Tsymbal (1996) in the program SynthV for finding the basic parameters of the atmosphere of the cold component of V622 Per and the estimation of the chemical composition.

The synthetic spectra were calculate with the parameters of atmosphere each of the component taken from our data (T_1 = 21000K, $log\, g_1$=3.0, T_2 = 24000K $log\, g_2$=4.0, $V sin\, i$=60km s^{-1}, V_{turb}=10km s^{-1}). From analysis of synthetic spectrum we have found that CNO abundances of V622Per are far from solar. Nitrogen lines demonstrate overabundance in comparing to the normal solar abundance. The oxygen abundance is noticeable lower to compare to solar. And even on height-resolution spectra in the Hα region we can not see the presence of the C II doublet at the λ6578 Å and λ6582 Å . The deficiency of the carbon is presented in the atmosphere of the both of components and should be et least 2-3 dex.

The quality of our data allowed us to obtain only estimations of the chemical composition. Abundance of helium He/H is 0.18, excess of the nitrogen is near

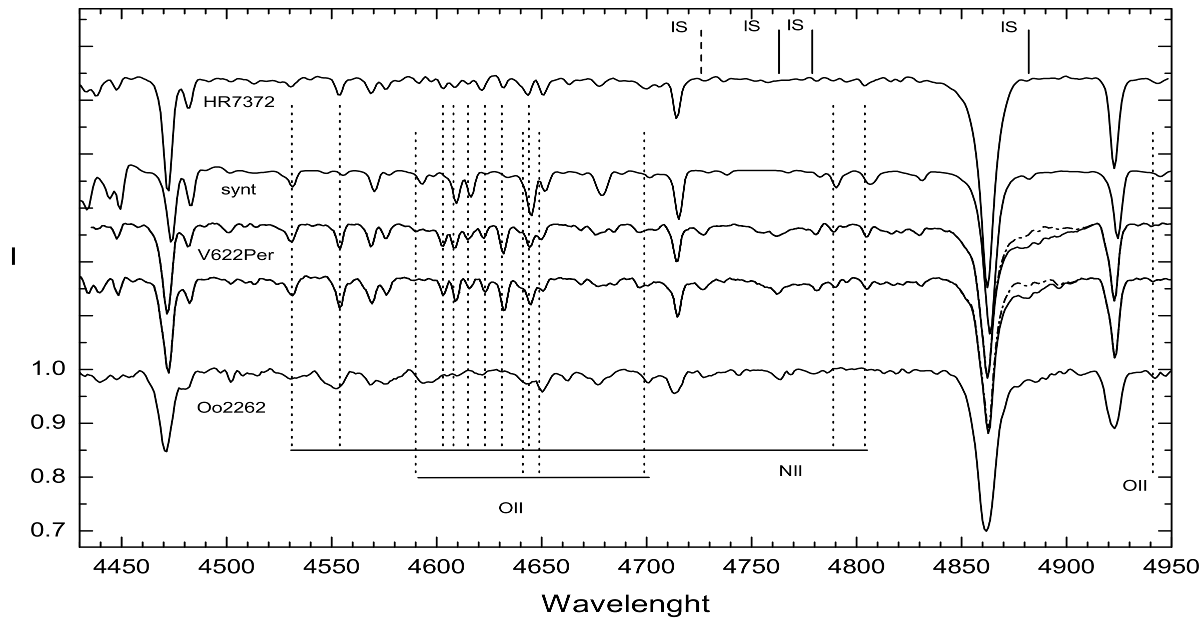

Figure 4: Medium resolution spectra of V622 Per, obtained in the spectral region 4420-4960 Å together with the spectra of two comparison stars HR6787 from list Lybimkov (2000) and member of h/χ Per cluster Oo2262. The calculated synthetic spectrum is also shown. Positions of stellar spectral lines with estimated abundances is present together with interstellar lines (IS). The dashed lines in the region of the blue wing of the Hβ line are removed interstellar band.

0.5 dex and deficiency of the oxygen is about 1 dex in comparison to solar abundances.

5. Evolution status of the system

From our data we can conclude that the less massive component is evolved, it has left the TAMS which is in good agreement with those reported in literature, the more massive one is located between the ZAMS and TAMS. As it seen from our analysis, V622 Per is Algol type massive interacting binary with the masses of the component $M_1 = 9.0 M_\odot$ and $M_2 = 12.8 M_\odot$. The less massive evolved the primary leave of main sequence and it is on the way to the red gianr stars. Presence product of the CNO cycle in the atmosphere of the primary means that it has lost noticeable part of its outer layers and the part of its possible seen on surface of the secondary component.

The chemical composition of V622Per is similar with the composition of β Lyr - is well know massive interacting binary with P_{orb}= 12.9 days. Balachandran et al. (1986) obtained large He enrichment, extreme nitrogen overabundant and very under abundant the oxygen and the carbon. Carbon lines are the same as in case of V622 Per were not found in the atmosphere of the primary component.

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