Modeling of atmospheres of the brightest stars belonging to the Cyg OB2 association

OLGA MARYEVA, V.G. KLOCHKOVA, E.L. CHENTSOV

Special Astrophysical Observatory RAS; olga.maryeva@gmail.com

We present the results of modeling of the spectrum of the brightest stars belonging to the Cyg OB2 association – Cyg OB2 #7 (O3If$_*$) and Cyg OB2 #11 (O5Ifc). We determine the physical properties and chemical composition of their atmosphere using CMFGEN code. The atmosphere of Cyg OB2 #7 reveals an excess of nitrogen $X(N_*)/X(N_\odot) = 3.2$ and the carbon and oxygen deficiency $X(C_*)/X(C_\odot) = 0.08$, $X(O_*)/X(O_\odot) = 0.09$, while the atmosphere of Cyg OB2 #11 is enriched with carbon $X(C_*)/X(C_\odot) = 0.33$. The lines in Cyg OB2 #7 spectrum are divided into three groups which can not be described with a single model. The models describing each of these groups differ by the mass-loss rate and the velocity law. Thus, the numerical modeling suggests that the wind of the supergiant is heterogeneous.

Cyg OB2 stellar association has been discovered in the middle of 20th century and is still one of most often studied objects in the Galaxy. The association is rich with young hot stars, and its total mass is estimated to be 30 000 M$_\odot$. In this poster we present the results of our study of two supergiants from Cyg OB2 – Cyg OB2 #7 is one of the hottest stars in our Galaxy, classified as O3If$_*$ and Cyg OB2 #11 classified as Ofc.

In this study we combined spectral data obtained by the Hubble Space Telescope (spectrograph STIS), telescope Subaru (spectrograph IRCS), 6-m telescope of Special Astrophysical Observatory (spectrograph NES) and 1.5-m Russian-Turkish telescope (spectrograph TFOSC). The non-LTE CMFGEN code (Hillier & Miller, 1998) was used to determine the physical properties and chemical composition of the stellar atmospheres.

Cyg OB2 #7

The spectrum observed in the optical range is best described by the model with the following parameters: $L_* = 1 \pm 0.1 \cdot 10^6 L_\odot$, $T_{eff} = 43.4 \pm 1$kK, $\dot{M} = (1.5 \pm 0.5) \times 10^{-6} M_\odot/$. However, during the detailed study of spectral lines we encountered a problem of inability to describe all the optical lines using a single model. The lines in the optical range can be divided into three groups. The first group consists of absorbtion lines (Hβ, HeII λ5411, NIV $\lambda\lambda$5200, 5204 and UV-range). This group is well described by the Model 1 (Table 1). We fit winds lines (CIV $\lambda\lambda$5801, 5812, NIV $\lambda\lambda 7103 - 7129$) by Model 3. Model 3 differs from Model 1 by only $\dot{M}$. While Hα+HeII lines are better described by a model with a steep velocity law with β=1 (Model 2).

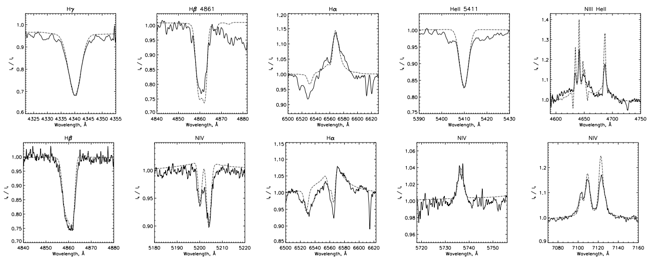

Fig. 1 *Comparison of the profiles of selected lines with the best model spectra. Top panel presents* Cyg OB2 #11 *, while bottom panel –* Cyg OB2 #7 *. The solid line shows the observed profile, and the dash-dot line – the model.*

The stars with stellar winds obtain axisymmetric shapes induced by rotation. Rotation can lead to an accumulation of outflowing material in the equatorial plane and emergence of an outflowing disk, like in the B[e] supergiants. We believe that the presence in the spectrum of Cyg OB2 #7 of line groups, revealing different mass loss rates is related to the inhomogeneity of wind due to the rapid rotation (Vsini $= 105$ km/s). Cyg OB2 #7 is yet another hot star, which has revealed the dependence of wind density on latitude.

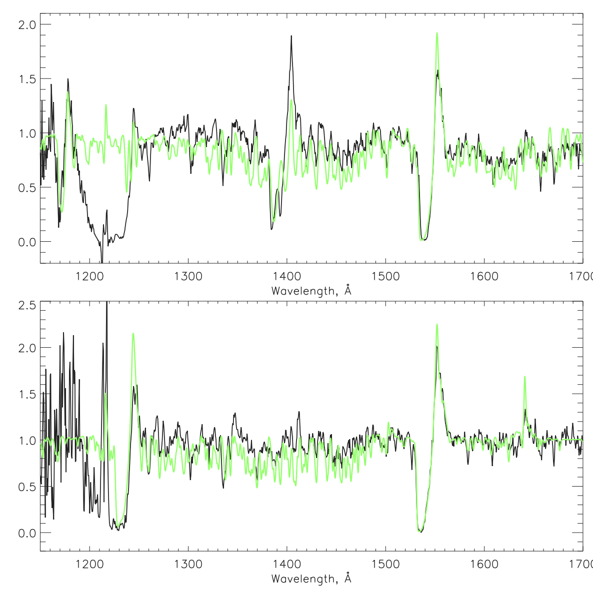

Fig. 2 *Comparison of the model spectrum (the green line) with the one obtained by the Hubble Space Telescope (the black line). Top panel shows the spectrum of* Cyg OB2 #11 *, bottom panel –* Cyg OB2 #7

Cyg OB2 #11

Cyg OB2 #11 one of eighteen Galactic O-stars classified as Ofc category. The star is located in the outer part of the Cyg OB2 association. A recent study by Kobulnicky et al. (2007) has shown that Cyg OB2 #11 is a single-lined spectroscopic binary (SB1 type). Therefore, we decided to model Cyg OB2 #11 as an isolated object. We determined the effective temperature using the lines of He II λ4541.59, 5411.52 Å and He I λ4471.5, 5875.66 Å, as well as the lines of nitrogen NIII $\lambda\lambda$4634.0, 4640.6 Å and weak absorptions of NIV $\lambda\lambda$5200.60, 5204.28 Å. To accurately determine the luminosity of the object, the magnitude of Cyg OB2 #11 were calculated in the V band from the model spectra and compared with observations. In order to obtain the magnitudes for the model spectra, we recomputed the fluxes for the distance to the Cyg OB2 association. Distance to the association Cyg OB2 is 1.5 kpc (Mel'nik & Dambis, 2009), magnitude is $V = 10.08\,^{\rm m}$ and interstellar reddening towards Cyg OB2 #11 is $A_v = 5.4$ (Kiminki et al., 2007). Table 1 shows the parameters of the atmosphere of the object.

Table 1 *Atmospheric parameters of* Cyg OB2 #7 and Cyg OB2 #11 derived in this work.

	T_*, kK	R_*, $R_\odot$	T_{eff}, kK	$R_{2/3}$, $R_\odot$	L_*, 10^6 $L_\odot$	$\dot{M}_{cl}$, M$_\odot$/year	V_∞, km/s	β
Model1 (Hβ)	**45**	**16.4**	**43.2**	**17.7**	**1**	$2 \cdot 10^{-6}$	**3250**	**2**
Model2 (Hα)	**45**	**16.4**	**44.4**	**17**	**1**	$3 \cdot 10^{-6}$	**3250**	**1**
Model3 (NIV, CIV)	**45**	**16.4**	**43.7**	**17.4**	**1**	$7 \cdot 10^{-7}$	**3250**	**2**
Cyg OB2 #11	**35**	**20**	**34.6**	**21.6**	**0.65**	$1.2 \cdot 10^{-6}$	**2200**	**2**

Figure 3 shows the locations of Cyg OB2 #7 and #11 on the H-R diagram. The position of Cyg OB2 #11 on the H-R diagram corresponds to the mass of star about 50 M$_\odot$and age about 4 Myr. The atmosphere of the star is enriched in carbon ($X_C/X_{C_\odot} \simeq 1$), silicium ($X_{Si}/X_{Si_\odot} \simeq 2.15 \div 3$) and sulphur ($X_S/X_{S_\odot} \simeq 1.1$). Comparison of Cyg OB2 #11 parameters with other supergiants shows that the high abundance of carbon itself does not imply the OIfc class. Moreother, Ofc stars belonging to Cyg OB2 association are scattered in the H-R diagram. Probably the appearance of strong CIII $\lambda\lambda$4647, 4650, 4652 emission lines in the spectra of O-stars is linked to the occurrence of some physical process rather than the chemical composition or evolutionary status. These are only assumptions though, as we do not have enough statistics for reliable conclusions.

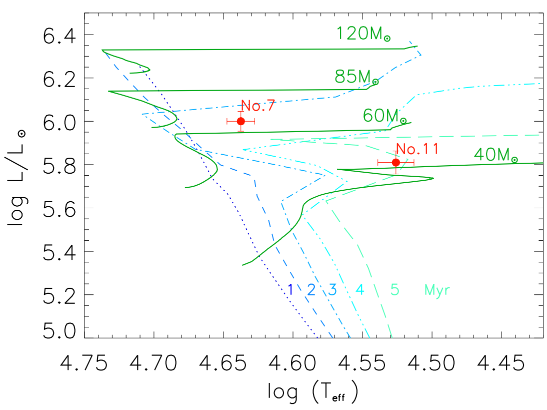

Fig. 3 *The locations of* Cyg OB2 #7 *and* Cyg OB2 #11 *in the Hertzsprung-Russell diagram. The solid horizontal lines represent the mass tracks. The vertical solid lines represent stellar isochrones. The evolution tracks and the stellar isochrones are taken from the Geneva library.*

References

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