Serb. Astron. J. № 174 (2007), 77 - 81 **UDC 520.84 : 524.384**
DOI: 10.2298/SAJ0774077C Preliminary report

IDENTIFICATION OF PHASE-INDEPENDENT SPECTRAL LINES IN CLOSE BINARY V455 CYG: I. TELLURIC LINES

A. Cséki[1], I. Vince[1], O. Latković[1] and I. I. Antokhin[2]

[1]*Astronomical Observatory, Volgina 7, 11160 Belgrade 74, Serbia*

[2]*Sternberg Astronomical Institute*
Universitetski pr. 13, Moscow 119992, Russia

(Received: March 23, 2007; Accepted: April 10, 2007)

SUMMARY: Spectroscopic observations of close binary star V455 Cygni reveal many lines that originate in interstellar and circumstellar medium and the atmosphere of the Earth; we found over two hundred such spectral features, and in this paper we present the list of telluric lines we identified through comparison with HITRAN database of molecular lines. The lines that remain unidentified or show peculiar behavior will be discussed in the second part of the paper.

Key words. Line: identification: binaries: spectroscopic – Stars: individual: V455 Cyg

1. INTRODUCTION

The close eclipsing binary V455 Cygni is a Hα emission-line star (coordinates $\alpha = 20^h26^m20^s.92$, $\delta = +39^o40^{'}10^{''}.1$, FK5 2000.0/2000.0) in the region of the emission/absorption nebulae around P Cyg. V455 Cygni belongs to the OB-association Cyg OB9 (Zakirov and Eshankulova 2004), which is located at the distance of about 500 pc (Garibdzhanyan 1984).

The preliminary results of our analysis of spectroscopic and photometric data suggest that V455 Cygni is a semi detached system in the stage of mass exchange, with the hotter star having an accretion disc, and the cooler star filling its Roche-lobe and streaming gas to its companion (Đurašević at al. 2007). The system is classified as B spectral type, so we can expect an extended envelope around it. Furthermore, due to the increased density of interstellar gas in the P Cyg region, spectra of V455 Cygni have strong interstellar absorption components in some resonant spectral lines (such as D1 and D2 sodium lines, or h and k ionized magnesium lines). Therefore, the spectra of this star are a mixture of lines from all these different sources; and for successful separation and examination of these sources we first need to identify the spectral lines, and determine their origin.

Another reason for making an effort at identification of telluric lines in particular is that some of the mentioned interstellar and circumstellar features have very similar profiles as the spectral lines that originate in the Earth's atmosphere; telluric lines also have a pronounced influence on profiles of important lines (in the vicinity of Na I D1 and D2 lines, Hα region, in infrared A and B bands and so forth). Identification of telluric lines, effectively eliminating them from further study, is thus essential for proper analysis of V455 Cygni's spectra.

2. OBSERVATIONS AND REDUCTION

The spectra were obtained with echelle spectrograph ($R \approx 10000$) linked to the 1.25 m telescope of the Crimean observatory of the Sternberg Astronomical Institute in September 2004. The spectral range covered by the spectrograph was approximately 4200 to 7100 Å. Nine spectra were obtained in the course of two weeks, covering different phases. The data were processed in the usual way: bias frames subtracted, the influence of cosmic particles filtered out, orders found/approximated/extracted, wavelength calibration done using calibration spectra of a line lamp, orders combined. The resulting one-dimensional spectra were divided by the response curve of the spectrograph. The spectra were re-binned to the wavelength bin size of 0.25 Å. Finally, the continuum was approximated by a spline function to produce normalized spectra. The processing was performed using the MIDAS package.

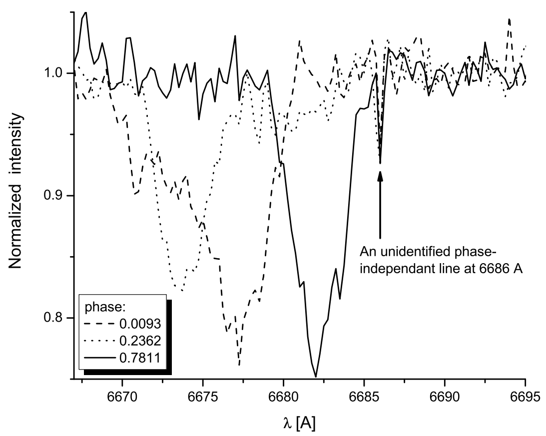

Fig. 1. *Spectra of V455 Cygni in three different phases. We see a typical example of wavelength shifting of He I line at 6678.15 Å due to system's orbital motion; the small line in the right clearly does not originate in the binary.*

3. LINE IDENTIFICATION

Since V455 Cygni is a single-lined spectroscopic binary, spectral lines originating in stellar atmospheres (or in the accretion disk, the gas stream and other elements comprising this complex system) clearly show wavelength shifts corresponding to orbital motion. Therefore, by overlapping spectra at different phases it is possible to separate such "stellar" lines from the lines that are created "outside" the system, in the interstellar and circumstellar medium and in the Earth's atmosphere, as their wavelengths will not change with orbital phase. The preliminary inspection of V455 Cygni's spectra revealed a large number of these phase-independent features. Fig. 1 shows an excerpt of our spectra in phases near 0, 0.25 and 0.75; while the wavelength shift of the strong, broadened stellar line is obvious, the narrow (so far unidentified) line shows no change in position.

The identification procedure was as follows. The spectra from all the phases were overlapped in a new version of our program for spectral analysis, ISAAC (Latković, Čeki and Vince 2003), so the phase-independent features were fairly easy to distinguish. After making a complete list of all such lines, we tried to identify each one using the HITRAN database (Rothman et al. 2005) of molecular lines and the atlas of solar spectrum (Moore, Minnaert, and Houtgast 1966). We created an artificial spectrum out of the entries in the HITRAN database by normalizing the line intensities to a maximum local to the range of observed spectra, and then overlapped it with the observations (see Fig. 2).

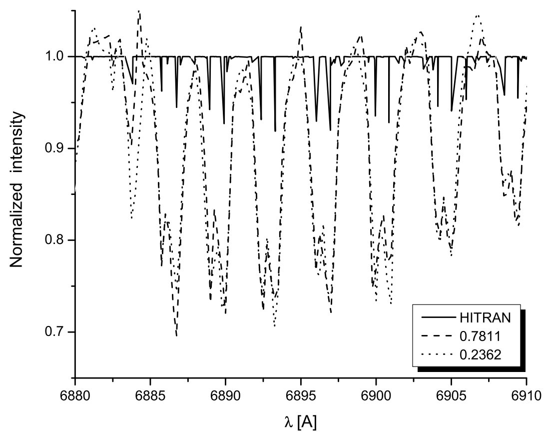

Fig. 2. *Spectra of V455 Cygni in two of the three phases from Fig. 1, overlapped with the "spectrum" composed of HITRAN molecular lines.*

Most of the lines that do not "participate" in the system's orbital motion are telluric lines. The lines are shown in Table 1, with wavelengths, intensities and absorbing molecules; all the data presented here are taken from the HITRAN database. The intensities are given in $\frac{\mathrm{cm}^{-1}}{\mathrm{molecul \cdot cm}^{-2}}$. Entries in the table are grouped so as to emphasize that many lines could not be resolved in our observations, as they constitute composite profiles. Every one of 122 segments of the table represents one line in the observed spectra, and every one of 197 rows a line in the HITRAN database.

Table 1. Telluric lines identified in spectra of V455 Cygni. Every segment represents one observed profile composed in some cases of several unresolved molecular lines. The line intensity is given in $\frac{cm^{-1}}{molecul \cdot cm^{-2}}$

λ[Å]	Line intensity	Species
5883.891	1.133×10^{-24}	H_2O
5885.969	2.013×10^{-24}	H_2O
5886.330	6.558×10^{-25}	H_2O
5887.214	1.702×10^{-24}	H_2O
5887.652	1.291×10^{-24}	H_2O
5891.148	3.394×10^{-25}	H_2O
5891.492	5.658×10^{-25}	H_2O
5891.649	1.993×10^{-24}	H_2O
5892.387	1.382×10^{-24}	H_2O
5893.034	7.899×10^{-25}	H_2O
5893.496	6.052×10^{-25}	H_2O
5898.151	2.014×10^{-24}	H_2O
5899.001	8.305×10^{-25}	H_2O
5899.910	1.149×10^{-24}	H_2O
5900.030	1.920×10^{-24}	H_2O
5901.240	4.171×10^{-25}	H_2O
5901.457	2.690×10^{-24}	H_2O
5903.528	6.277×10^{-25}	H_2O
5905.113	2.852×10^{-25}	H_2O
5905.282	4.376×10^{-25}	H_2O
5905.364	2.374×10^{-25}	H_2O
5907.255	4.611×10^{-25}	H_2O
5907.352	2.242×10^{-25}	H_2O
5907.831	6.618×10^{-25}	H_2O
5908.198	5.907×10^{-25}	H_2O
5908.989	1.479×10^{-24}	H_2O
5912.987	1.189×10^{-24}	H_2O
5918.395	1.708×10^{-25}	H_2O
5918.395	1.053×10^{-24}	H_2O
5918.449	8.279×10^{-25}	H_2O
5919.045	2.155×10^{-24}	H_2O
5919.638	2.743×10^{-24}	H_2O
5922.360	3.405×10^{-25}	H_2O
5922.505	1.218×10^{-24}	H_2O
5922.707	3.446×10^{-25}	H_2O
5923.638	1.022×10^{-24}	H_2O
5923.737	3.682×10^{-25}	H_2O
5923.822	1.390×10^{-24}	H_2O
5924.265	1.790×10^{-24}	H_2O
5928.283	1.154×10^{-24}	H_2O
5932.084	1.975×10^{-24}	H_2O
5932.774	1.109×10^{-24}	H_2O
5941.076	2.526×10^{-24}	H_2O
5941.622	1.786×10^{-24}	H_2O
5942.400	6.630×10^{-25}	H_2O
5942.423	6.918×10^{-25}	H_2O
5942.558	2.266×10^{-24}	H_2O
5945.643	7.862×10^{-25}	H_2O
5945.999	2.177×10^{-24}	H_2O

λ[Å]	Line intensity	Species
5946.842	9.927×10^{-25}	H_2O
5947.048	1.613×10^{-24}	H_2O
5949.165	1.858×10^{-24}	H_2O
5956.346	5.846×10^{-25}	H_2O
5957.874	1.651×10^{-24}	H_2O
5958.244	9.616×10^{-25}	H_2O
5958.620	1.272×10^{-24}	H_2O
5966.319	3.614×10^{-25}	H_2O
5966.656	1.038×10^{-24}	H_2O
5967.825	1.274×10^{-24}	H_2O
5968.268	1.461×10^{-24}	H_2O
5971.341	9.867×10^{-25}	H_2O
5976.998	8.277×10^{-25}	H_2O
5990.607	2.427×10^{-25}	H_2O
5990.842	6.347×10^{-25}	H_2O
6285.802	5.418×10^{-25}	H_2O
6469.348	5.188×10^{-25}	H_2O
6469.630	8.863×10^{-25}	H_2O
6469.985	5.664×10^{-25}	H_2O
6472.457	9.475×10^{-25}	H_2O
6473.164	1.200×10^{-24}	H_2O
6475.043	1.479×10^{-24}	H_2O
6475.193	1.673×10^{-24}	H_2O
6475.807	2.949×10^{-24}	H_2O
6483.233	2.250×10^{-24}	H_2O
6483.759	8.076×10^{-25}	H_2O
6483.904	8.961×10^{-25}	H_2O
6490.782	2.397×10^{-24}	H_2O
6492.900	1.695×10^{-24}	H_2O
6492.921	2.171×10^{-25}	H_2O
6495.862	2.465×10^{-24}	H_2O
6497.474	3.190×10^{-25}	H_2O
6497.593	6.404×10^{-25}	H_2O
6504.202	5.184×10^{-25}	H_2O
6508.594	9.785×10^{-25}	H_2O
6511.998	6.952×10^{-25}	H_2O
6512.248	5.918×10^{-25}	H_2O
6514.723	2.694×10^{-24}	H_2O
6516.452	6.809×10^{-25}	H_2O
6516.539	1.959×10^{-24}	H_2O
6516.629	1.937×10^{-24}	H_2O
6518.005	9.266×10^{-25}	H_2O
6519.448	1.201×10^{-24}	H_2O
6523.836	1.516×10^{-24}	H_2O
6532.347	1.798×10^{-24}	H_2O
6543.897	2.763×10^{-24}	H_2O
6547.687	1.062×10^{-24}	H_2O
6548.614	1.989×10^{-24}	H_2O
6552.616	2.335×10^{-24}	H_2O

Table 1. Continued

λ[Å]	Line intensity	Species	λ[Å]	Line intensity	Species
6574.838	2.164×10^{-24}	H_2O	6939.610	3.569×10^{-24}	H_2O
6580.777	6.719×10^{-25}	H_2O	6940.180	5.513×10^{-24}	H_2O
6588.559	1.740×10^{-25}	H_2O	6942.148	3.971×10^{-24}	H_2O
6867.540	2.262×10^{-25}	O_2	6942.367	1.967×10^{-24}	H_2O
6868.907	4.201×10^{-25}	O_2	6943.797	5.187×10^{-24}	H_2O
6869.089	2.908×10^{-25}	O_2	6947.532	6.938×10^{-24}	H_2O
6869.890	3.779×10^{-25}	O_2	6947.629	1.409×10^{-24}	H_2O
6869.968	5.125×10^{-25}	O_2	6948.985	2.007×10^{-24}	H_2O
6870.941	4.535×10^{-25}	O_2	6949.080	2.291×10^{-24}	H_2O
6871.278	5.757×10^{-25}	O_2	6953.574	2.454×10^{-24}	H_2O
6872.242	4.977×10^{-25}	O_2	6953.763	1.115×10^{-24}	H_2O
6872.838	5.886×10^{-25}	O_2	6956.401	6.700×10^{-24}	H_2O
6873.791	4.910×10^{-25}	O_2	6956.506	3.394×10^{-24}	H_2O
6874.649	5.362×10^{-25}	O_2	6959.448	4.398×10^{-24}	H_2O
6875.588	4.208×10^{-25}	O_2	6961.257	6.211×10^{-24}	H_2O
6876.711	4.155×10^{-25}	O_2	6986.575	4.575×10^{-24}	H_2O
6877.633	2.865×10^{-25}	O_2	6988.980	5.950×10^{-24}	H_2O
6879.038	2.387×10^{-25}	O_2	6990.366	2.023×10^{-24}	H_2O
6879.926	1.025×10^{-25}	O_2	6992.816	6.384×10^{-25}	H_2O
6883.829	2.052×10^{-25}	O_2	6993.511	3.287×10^{-24}	H_2O
6885.751	2.603×10^{-25}	O_2	6994.104	2.502×10^{-24}	H_2O
6886.739	3.830×10^{-25}	O_2	6998.709	1.518×10^{-24}	H_2O
6888.943	4.001×10^{-25}	O_2	6998.961	4.523×10^{-24}	H_2O
6889.898	5.071×10^{-25}	O_2	7004.305	1.217×10^{-24}	H_2O
6892.367	4.763×10^{-25}	O_2	7004.749	3.704×10^{-24}	H_2O
6893.304	5.644×10^{-25}	O_2	7005.116	1.718×10^{-24}	H_2O
6896.034	4.884×10^{-25}	O_2	7005.354	4.729×10^{-25}	H_2O
6896.960	5.569×10^{-25}	O_2	7005.607	6.994×10^{-25}	H_2O
6899.949	4.485×10^{-25}	O_2	7009.865	1.180×10^{-24}	H_2O
6900.864	4.990×10^{-25}	O_2	7010.648	2.127×10^{-25}	H_2O
6904.113	3.760×10^{-25}	O_2	7010.733	2.174×10^{-25}	H_2O
6905.019	4.111×10^{-25}	O_2	7010.954	8.278×10^{-25}	H_2O
6908.528	2.907×10^{-25}	O_2	7011.229	7.527×10^{-25}	H_2O
6909.425	3.139×10^{-25}	O_2	7011.321	1.359×10^{-24}	H_2O
6913.194	2.087×10^{-25}	O_2	7011.349	7.926×10^{-25}	H_2O
6914.084	2.231×10^{-25}	O_2	7015.932	1.599×10^{-24}	H_2O
6918.115	1.397×10^{-25}	O_2	7016.450	5.517×10^{-24}	H_2O
6918.997	1.482×10^{-25}	O_2	7026.931	2.263×10^{-24}	H_2O
6929.095	1.402×10^{-24}	H_2O	7027.472	4.511×10^{-24}	H_2O
6929.302	2.680×10^{-24}	H_2O	7027.857	1.580×10^{-24}	H_2O
6929.832	1.697×10^{-24}	H_2O	7037.189	1.207×10^{-24}	H_2O
6929.930	5.480×10^{-25}	H_2O	7037.532	2.479×10^{-24}	H_2O
6931.312	1.275×10^{-24}	H_2O	7039.282	1.072×10^{-24}	H_2O
6931.758	1.091×10^{-24}	H_2O	7039.794	3.546×10^{-24}	H_2O
6933.594	1.377×10^{-24}	H_2O	7077.789	4.884×10^{-25}	H_2O
6933.808	2.771×10^{-24}	H_2O	7078.240	9.351×10^{-25}	H_2O
6935.420	2.722×10^{-25}	H_2O	7078.831	7.883×10^{-25}	H_2O
6935.814	6.906×10^{-25}	H_2O	7079.466	2.515×10^{-25}	H_2O
6937.694	4.327×10^{-24}	H_2O	7079.598	7.038×10^{-25}	H_2O
			7090.652	2.367×10^{-25}	H_2O

All the lines presented in this paper were found in both the HITRAN database and in the atlas of solar spectrum; we reason that the lines present in the HITRAN database and missing from the atlas are good candidates for interstellar and circumstellar lines. However, a number of well defined lines couldn't be identified in either source, and there are several lines found in the atlas, but not in the HITRAN database. Furthermore, some non-stellar lines exhibit changes of line profile depth through phases; while in telluric lines this effect might be a result of changing air-mass from one observation to another. Our analysis is not yet conclusive, and will be discussed in the forthcoming second part of this paper.

Acknowledgements – This work was supported by the Ministry of Science and Environmental Protection of the Republic of Serbia (Project: "Stellar and Solar Physics"; Contract No. 146003) and by the Russian Foundation for Basic Research (grant No 05-02-17489). Some basic data for V455 Cyg were taken from Centre de Données astronomiques de Strasbourg astronomical databases. Molecular data for line identification were taken from HITRAN database.

REFERENCES

Đurašević, Vince I., Antokhin, I., Khruzina, T., Zakirov, M.M. and Eshankulova, M.U. *in preparation.*

Garibdzhanyan, A.T., Gasparyan, K.G. and Oganesyan, R.Kh.: 1984, *Astrofizika*, **20, No. 2**, 245.

Latković, O., Čeki, A. and Vince, I.: 2003, *Publ. Astron. Obs. Belgrade*, **75**, 85.

Moore, C.E., Minnaert, M.G.J. and Houtgast, J.: 1966, The Solar Spectrum from 2935 to 8770 Å, National Bureau of Standards Monograph, **61**.

Rothman, L.S. et al.: 2005, *The HITRAN 2004 molecular spectroscopic database J. Quant. Spectrosc. Radiat. Transfer*, **96**, 139.

Zakirov, M.M. and Eshankulova M.U.: 2004, *Kinematika i Fizika Nebesnykh Tel*, **20, no. 4**, 313.

ИДЕНТИФИКАЦИЈА СПЕКТРАЛНИХ ЛИНИЈА КОЈЕ СЕ НЕ МЕЊАЈУ СА ФАЗОМ У ТЕСНОМ ДВОЈНОМ СИСТЕМУ V455 CYG: I. ТЕЛУРСКЕ ЛИНИЈЕ

A. Cséki[1], I. Vince[1], O. Latković[1] and I. Antokhin[2]

[1]*Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia*

[2]*Sternberg Astronomical Institute*
Universitetski pr. 13, Moscow 119992, Russia

УДК 520.84 : 524.384
Претходно саопштење

Спектроскопска посматрања тесног двојног система V455 Cygni откривају мноштво линија које потичу из међузвездане средине, околозвезданог омотача и Земљине атмосфере; пронашли смо преко две стотине оваквих линија и у овом раду представљамо списак телурских линија које смо идентификовали поређењем са HITRAN базом молекулских линија. О линијама које нисмо могли да идентификујемо и линијама које показују неуобичајено понашање биће речи у другом делу рада.