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SpectraView 1.0 – 2D visualization of stellar spectra

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Abstract.

This article presents a 2D visualization of stellar spectra, obtained in Rozhen NAO.The aim is to convert one-dimensional arrays into two-dimensional images with the possibility of adjusting the degree of gray. This allows us to visualize the curves of the radial velocities and to determine their half-amplitudes even more precisely. The results of the observed stars NSVS 254037 and TYC3621-711 are presented.

Keywords: *Variable stars, Spectra, Programs*

Introduction

The article presents a program for 2D visualization of star spectra obtained in Rozhen NAO. The aim is to convert one-dimensional arrays into two-dimensional images with the possibility of adjusting the degree of gray. This allows us to visualize the curves of the radial velocities and to determine their half-amplitudes even more precisely. As known in astronomy, spectral observations are the only source of information on the masses of the stars. The relation of the masses and the relative masses of the components, important for the system, are derived from the radial velocity curves analysis. Based on them and having system parameters derived from photometric observations, it is possible to determine the main physical characteristics of the system and those of the individual components in particular. The program, object of the present work, aims to facilitate the analysis of the obtained radial velocity curves. The program has been tested on the observations of the stars NSVS 254037 and TYC3621-711.

Observations

The observations were conducted with the 2-m telescope at Rozhen NAO, using a CCD Photometrics AT200 camera with the SITe SI003AB 1024×1024 pixels chip mounted on the Coude-spectrograph (grating B&L632/14.7◦). The exposure time was 15 min when the spectra with S/N ratios of

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35-50 for NSVS 254037 and 55-65 for TYC3621-711 were obtained. The NSVS 254037 star was observed on 2014 Nov 11 and the TYC3621-711 star - on 2015 Aug 31.

The spectra cover a spectral range of around the H□ line (6500 - 6710 A) and have a resolution of 0.19 °A/pixel. The spectra were processed using the standard reduction procedures (bias subtraction, flat-field division and wavelength calibration with Th-Ar comparison source exposures) using the PCIPS program [3]. The 40 Peg star was used as a standard for the radial velocities.

The Ephemerides for phasing both stars were determined by Velimir Popov from his photometric observations. For NSVS 254037: MinI = 2456965.3900 + 0.317412 × E; for TYC3621-711: MinI = 2457284.6441 + 0.326997 × E.

Part of the one-dimensional spectra of the two stars is presented on Figure 1.

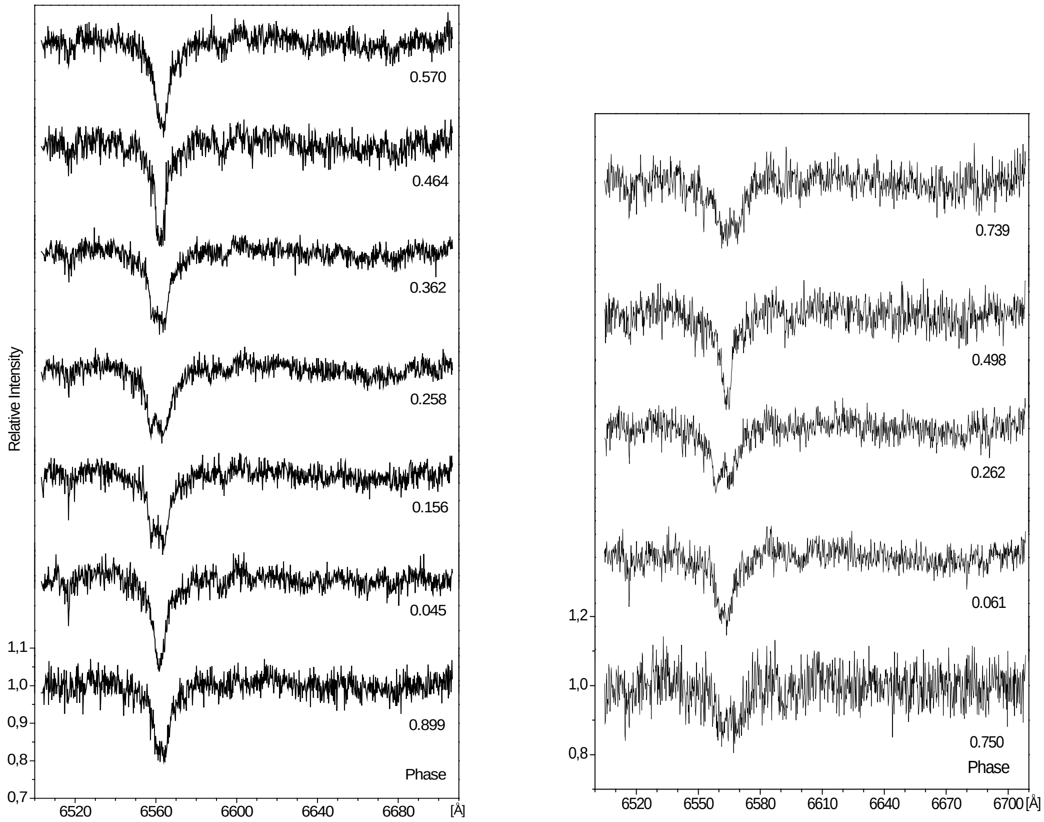

Figure 1. Star spectra of TYC3621-711 (on the left) and NSVS 254037 (on the right)

Results

The spectrum conversion procedure consists of several steps. First, the input data must be in a separate directory in (*.DAT) text format, with file names corresponding to the observation phase eg. file with spectrum obtained at phase 0.567 is named 567.DAT. The period and exposure time of the received stellar spectra are set in the program to determine what part of the period each spectrum is. The time when a single spectrum is obtained is the time in the middle of exposure and the phase is determined by it. So in the program this phase is taken as the middle of the presented spectrum. In the converted file the phase is plotted on the abscissa, and on the ordinate – the radial velocity in km/s^2. The zero value of the ordinate is set in the program and, in our case, is the value of the H□ line in angstroms (6562.82 [A]). Thus, for each point of the one-dimensional spectrum, the displacement (dL□) is calculated and converted in km/s^2. To

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save time, the Y axis is limited in the range of -400 km/s^2 to +400 km/s^2. This interval is also set as an input parameter.

The key moment of the conversion is to compare the corresponding level of gray to the corresponding intensity value. For best visibility, background and contrast vary. Figure 2 presents the converted files with two different values of the background level.

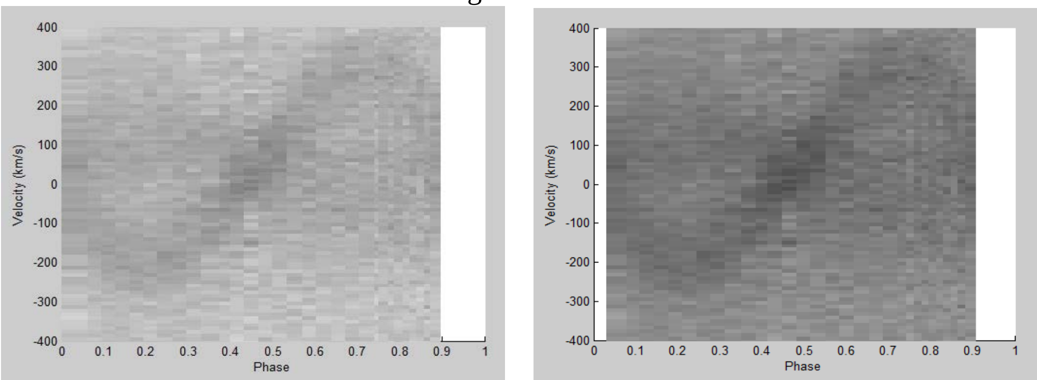

Figure 2. Two different values of the background level (with higher value on the right)

After setting the background level, the contrast is varied until a clearer picture of the radial velocity curves of the two components is obtained.

Figure 3 shows the converted files with a different contrast value.

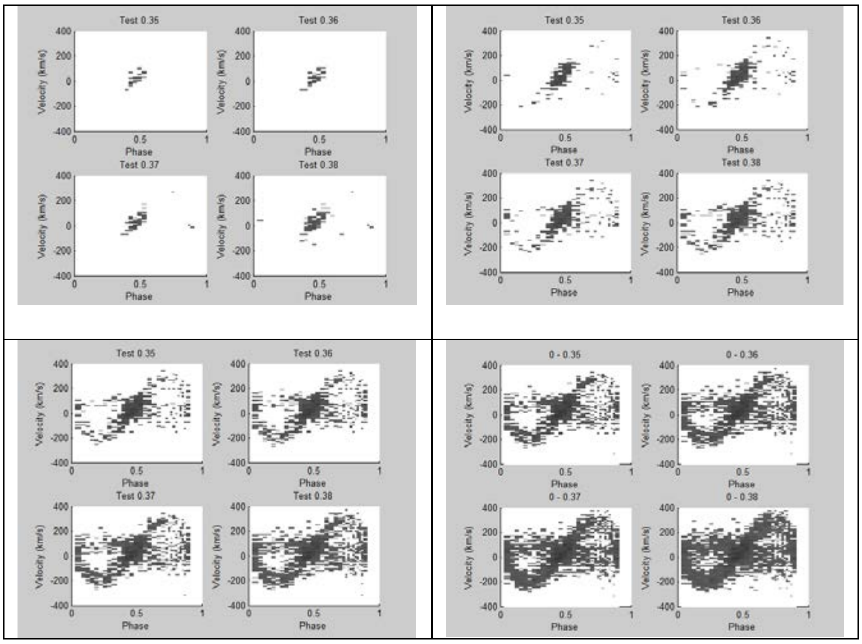

Figure 3. Different contrast values

The obtained converted images of the radial velocity curves of the two stars are presented on Figure 4.

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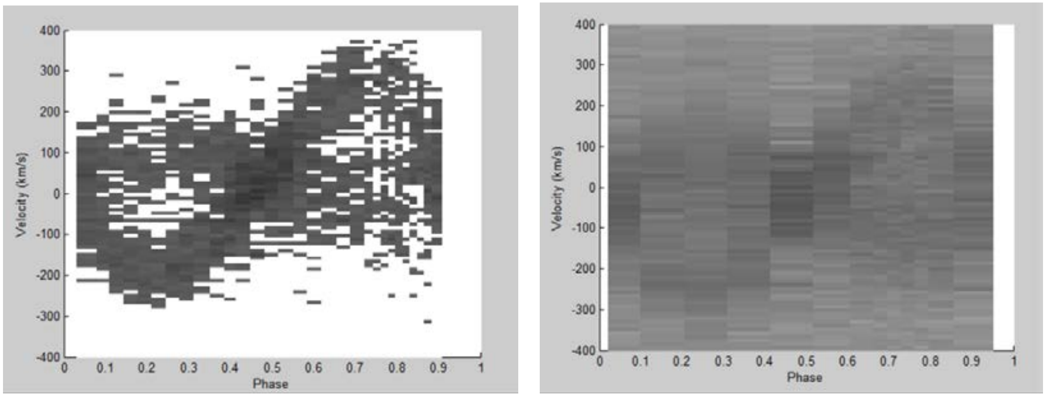

Figure 4. NSVS 254037 on the left, TYC3621-711 on the right

The next step is to find the half-widths of the radial velocity curves. For this purpose, a fitting procedure is used in the VelFit program [1], [2]. Using the least squares method, the two radial velocity curves are fitted by a sinusoid, which means we assume circular star orbits. The fit quality is determined by the obtained correlation coefficients for the two fits. The system's own velocity is obtained as the arithmetic average of the beginning of the two sinusoids. The results are presented in Table 1.

Table 1. Results from the fitting procedure for the two stars

Parameter	**NSVS 254037**	**TYC3621-711**
V_1sini	236.36 +- 7.73 [km/s]	200.39 +- 6.82 [km/s]
V_2sini	88.22 +- 5.82 [km/s]	68.25 +- 4.94 [km/s]
Q	2.6793 (0.373)	2.9360 (0.341)
average γ	28.38 +- 8.31 [km/s]	-33.92 +- 7.49 [km/s]
correlation coefficient 1	-0.984926	-0.988746
correlation coefficient 2	0.951715	0.957026

The programming language this program is written on is MatLab. MatLab is a software program, designed for scientific and technical calculations and the graphical representation of their results. With the help of its additional components, the system enables matrix calculations, numerical analysis, statistical analysis, calculations in the area of mathematics, physics, chemistry, etc. The MatLab's name comes from MATrix LABoratory, which comes from the product's purpose of working with datasets - vectors, matrices, multi-dimensional arrays, and more. MatLab has a built-in high-level programming language that allows the system to run in two modes – calculator mode and programming mode. This enables each user to create their programs and programming tools through the special language tools of the product, but it also has the capability to run programs written on FORTRAN, C and other programming languages.

In order to calculate all the calculations as well as to graphically visualize the results we used the Chemserver server of Shumen University, which offers additional resources needed to run the program.

Discussion

The conducted attempt to visualize the spectral data in two-dimensional scale shows good results. The work on visualizing the fitting function is in progress. Due to the demanding amount of computer time to process this code on MatLab, we consider writing this code in another language. The next step is the inclusion of a 3D model of the stars and the possibility of fitting elliptical orbits.

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