ProReg-SD

an auxiliary python program for spectral disentangling

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Abstract. The Spectra disentangling technique is one of the tools available for spectroscopic analysis of multiple stellar systems, allowing a simultaneous determination of orbital elements and individual spectra of its components. The spectra reconstructed from this technique are purely mathematical and represent very well real stars of same spectral type, being able to analyze them as isolated stars. The literature points out different advises being taken before its application, in order to ensure satisfactory results. From this perspective, the ProReg-SD python program was created in order to prepare the input composite spectra dataset taking into account these recommendations. The program was developed using the PYTHON language. By means of graphics output, the user can interactively choose spectral regions for analysis (which contain information about the orbital motion of the component stars) and what kind of output file desired (for the KOREL or FDBinary disentangling spectral codes, both available in the literature).

Resumo. O Desembaraçamento Espectral é uma das técnicas disponíveis para análise espectroscópica de sistemas estelares múltiplos, permitindo a determinação simuntânea dos elementos da órbita e os espectros individuais de suas componentes. Os espectros reconstruídos a partir desta técnica são puramente matemáticos e representam muito bem espectros de estrelas reais de mesmo tipo espectral, podendo ser analisados como estrelas isoladas. A literatura aponta diferentes conselhos antes de sua aplicação para obtenção de bons resultados. Nesta perspectiva, o programa ProReg-SD foi criado, com o intuito de preparar o conjunto de espectros de entrada, levando em consideração estas recomendações. O programa foi desenvolvido na linguagem PYTHON. Usando saídas gráficas, o usuário pode interativamente escolher regiões espectrais para análise (contendo informação sobre o movimento orbital das estrelas componentes) e qual o tipo de aqruivo de saída desejado (para os códigos de Desembaraçamento Espectral existentes na literatura: KOREL e FDBinary)

Keywords. (Stars:) binaries (including multiple): close – (Stars:) binaries: spectroscopic – Techniques: spectroscopic

1. Introduction

More than 50% of the stars in the sky are composed as binary or multiple systems (Kepler 2004). Information on the physical properties (mass and radius) and stellar evolution (such as temperature, chemical composition, and gravity) can be obtained through the spectroscopy, where the light of stars is analyzed in terms of wavelength, and the photometry, which uses luminosity integrated into a wavelength range. The spectra disentangling is a spectroscopic technique which separates the individual spectrum of each component star of a multiple system, permitting us to analyze them as an isolated star. In an interactively way, orbital elements of a system are also determined (period, eccentricity, time of periastron passage, maximum radial velocity amplitude and mass ratio of components).

The physical model for the observed normalized composite spectra (y_j) is based in a weighted sum of the components star spectrum, (x_k), observed at the time j :

$$y_j(\ln\lambda) = \sum_{k=1}^{k} l_{kj}x_k(\ln\lambda - v_{kj}/c) \qquad (1)$$

where, l_{kj} is the light contribution and v_{kj} is the radial velocity of the k component in the time j.

The composite spectra are sampled in logarithmic wavelength scale, according to the Doppler shift of the x_k component in the time j, as below:

$$\frac{v_{kj}}{c} = \frac{\Delta\lambda}{\lambda_0} \simeq \Delta\ln\lambda \qquad (2)$$

There are two codes available in the literature which perform spectra disentangling: the KOREL and FDBinary codes. The KOREL code was developed by P. Hadrava (1997, 1997) and may analyze up to 5 stars components in a hierarchical system. The FDBinary code was developed by S. Ilijic (2004, 2004a), and analyze up to 3 components in a hierarchical system.

Hensberge et al. (2008) claimed that the spectra disentangling technique highlights smalls mistakes committed during the data reduction process emphasizing the need for a good planning of observations and careful data processing. Besides, a trust interval (corresponding to two times the sum of the radial velocities amplitude of the components) should be added in the corners of the spectral regions choose for analyzing, in order to get reliable results when using Spectra Disentangling.

Based on the Hensberge et al. (2008) and Torres (2002; 2008) works, a program written in the PYTHON language was developed, with a free license, which provides the input composite spectra data to be used in the Spectra Disentangling codes (KOREL and FDBinary). Through graphics outputs, the user may interactively choose perfects spectral regions to get orbital parameters and individual component spectra of a multiple system. In other words, choose a spectral region that contains information about the orbital motion of components stars (radial velocities), and consequently a good determination of fundamental stellar parameters (mass, radius, effective temperature, gravity, and stellar chemical composition) which will permit a detailed and reliable study on stellar evolution physics process.

The ProReg-SD code requires that the observed composite spectra have already undergone the reduction data process and are normalized in flux.
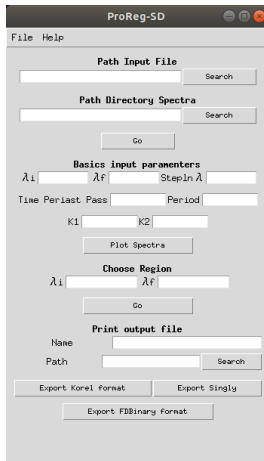
FIGURE 1. Main interface.

FIGURE 2. PrepReg-SD graphics output. Left: mean spectrum (upper panel) and variance of the observed spectra (bottom panel); Right: observed composite spectra.

2. Methodology

The PrepReg-SD program was developed in PYTHON because it has an open license, presents a clear syntax and is an object-oriented programming language. There are numerous libraries that can be used easily, reducing a PYTHON code in a few lines only. In order to make any subsequent change flexible in this code, it was split into two parts:

1. a routine which contains the graphics interface commands and the PYPLOT library (which allow handling the spectra: zoom in zoom out, move sideways, save an image and so on), called here as interface.py;
2. a routine which performs all mathematical calculations, as determination of the orbital phase, determination of the average spectrum and its variance, the determination of wavelengths (in logarithmic scale), and the pixel step in velocity scale (required by the Spectra Disentangling technique), called here as function.py.

3. Results

The Fig. 1 shows the main interface where users will inform a file containnig spectra's names which will be used, its HJD observations date and its signal to noise ratio; location of the observed composite spectra; initial and final wavelength (λ_i and λ_f) and step (in ln λ); time of periastron passage, period, maximum radial velocity amplitude of components stars, K_1 and K_2. The user may want to plot graphs with all observed composite spectra ordering in orbital phase (Fig. 2: right one) and a average/variance spectrum plot (Fig. 2: left one). This last one will help the user find spectral regions for his analysis, preferring those which shows mountains patterns as shown in Fig. 2 (left one), around 6100 to 6105 Å and 6120 to 6130 Å, corresponding to components orbital motion of a multiple system.

An interval equal to $2(K_1 + K_2)$ will be automatically added at the ends (corners) of the region chosen by the user (λ_i and λ_f). These corners should also contain intensities with values close to one, to avoid the appearance of spurious patterns supperposed on the continuum of the reconstructed components spectra (Hensberge et al. 2008).

Finally, the composite spectra output file may be written as required by the KOREL or FDBinary codes. Besides, users may choose its name and location where they will be saved (Fig. 1).
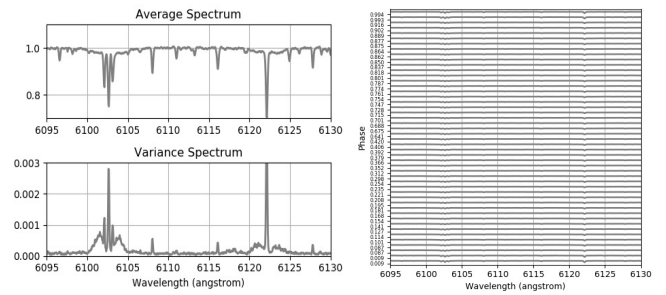
4. Conclusion

The ProReg-SD code proposes an easy and safe way of choosing spectral regions to those who want to use the Spectra Disentangling technique for stellar spectroscopic analysis.

The program has a possibility to deal with échelle observed spectra, "traveling" in all spectral interval and choosing regions to obtain good results.

We present here a first version, which will be improved before becoming public to the astronomical community. It is necessary to include in the code an interpolation of the observed composite spectra (in the case of using spectra of different spectral resolution) and to improve the visibility of the spectral lines in order to see the movement of the spectral lines due to the orbital motion (see Fig. 2).

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