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Eclipsing and density effects on the spectral behavior of Beta Lyrae binary system in the UV

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ABSTRACT

We analyze both long and short high resolution ultraviolet spectrum of Beta Lyrae eclipsing binary system observed with the International Ultraviolet Explorer (IUE) between 1980 and 1989. The main spectral features are P Cygni profiles originating from different environments of Beta Lyrae. A set of 23 Mg II k&h spectral lines at 2800 Å, originating from the extended envelope [Hack, M., 1980. IAUS, 88, 271H], have been identified and measured to determine their fluxes and widths. We found that there is spectral variability for these physical parameters with phase, similar to that found for the light curve [Kondo, Y., McCluskey, G.E., Jeffery, M.M.S., Ronald, S.P., Carolina, P.S. McCluskey, Joel, A.E., 1994. ApJ, 421, 787], which we attribute to the eclipse effects [Ak, H., Chadima, P., Harmanec, P., Demircan, O., Yang, S., Koubský, P., Škoda, P., Šlechta, M., Wolf, M., Božić, H., 2007. A&A, 463, 233], in addition to the changes of density and temperature of the region from which these lines are coming, as a result of the variability of mass loss from the primary star to the secondary [Hoffman, J.L., Nordsieck, K.H., Fox, G.K., 1998. AJ, 115, 1576; Linnell, A.P., Hubeny, I., Harmanec, P., 1998. ApJ, 509, 379]. Also we present a study of Fe II spectral line at 2600 Å, originating from the atmosphere of the primary star [Hack, M., 1980. IAUS, 88, 271H]. We found spectral variability of line fluxes and line widths with phase similar to that found for Mg II k&h lines. Finally we present a study of Si IV spectral line at 1394 Å, originating from the extended envelope [Hack, M., 1980. IAUS, 88, 271H]. A set of 52 Si IV spectral line at 1394 Å have been identified and measured to determine their fluxes and widths. Also we found spectral variability of these physical parameters with phase similar to that found for Mg II k&h and Fe II spectral lines.

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1. Introduction

Beta Lyrae is the pro-totype for a close eclipsing variable binary star system. The Beta Lyrae system has evolved non conservatively during its 32 million year lifetime (DeGreve and Linnell, 1994). The two stars of this binary are in a circular orbit with a separation of 55–60 $R_{\odot}$. The orbital period is approximately 12.9 days, but the period is slowly increasing at a rate of 19 yr^{-1}. The Beta Lyrae system thought to be composed of a B8 II star Sahade (1980), the primary, filling its critical Roche lope and losing mass to the secondary star. The mass gaining star is embedded in an optically thick accretion disk and is not directly visible. Although the embedded source had been considered as a possible compact object (Devinney, 1971; Wilson, 1971), it is probably a main sequence B0 star (Hubeny and Plavec, 1991). The system is very complex, having bipolar jet – like structures (Harmanec et al., 1996; Hoffman et al., 1998), thick accretion disc, and a scattering envelope above the disc (Ak et al., 2007), and a substantial kilo – Gauss magnetic field (Leone et al., 2003). Reviews of the literature are given in (Harmanec et al., 1996; Harmanec, 2002). The system is probably at a distance of 370 pc (Dobias and Plavec, 1985), while DeGreve and Linnell (1994) found that Beta Lyrae system is located at a distance of 270 pc.

Evidence that mass transfer has occurred is found in the observed depletion of Carbon and Oxygen relative to Nitrogen in the absorption spectrum of the primary (Balachandron et al., 1986). The high rate of mass transfer between the two stars ($\sim 10^{-5}$ $M_{\odot}$ yr^{-1}) creates a rare geometry for the system (Gray and Ignace, 2008). An analysis of the P Cygni profiles based on the assumption that they are formed in a wind ejected by the primary component yielded a value for the mass loss $M = 2 \times 10^{-7}$ $M_{\odot}$ yr^{-1} (Mazzali, 1987), a value typical of luminous giants (Mazzali, 1986). The mass transfer rate is not well established. The reason for this is that it can only be measured indirectly from the observed properties of the system. First, one may use the observed increase of the orbital period. This determination, however, is hampered by ignorance of the degree to which the mass transfer process is conservative. Assuming the mass transfer to be conservative (Harmanec and Scholz, 1993) determined a mass transfer rate of about 20×10^{-6} $M_{\odot}$ yr^{-1}. Another possibility is to use evolutionary considerations (DeGreve and Linnell, 1994) found

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a value of $28 \times 10^{-6}\ M_\odot\ yr^{-1}$. The evolutionary calculation finds that the mass transfer is not conservative.

In Beta Lyrae, therefore, unlike classical Algols, the two components are still strongly interacting. It is not unlikely that Beta Lyrae and the other stars showing similar characteristics (Plavec, 1980) represent an earlier stage than Algols in the evolution of semidetached binaries.

The system shows a rich emission spectrum, particularly in the UV, where many resonance lines of moderately highly ionized atoms are observed. Most of the emission lines appear to be combinations of two components (Sahade, 1980): one which is produced by rotation and is associated with the secondary, and the other, very much stronger, showing in high dispersion a P Cygni profile, some of these emission lines originate in different layers of the systems extended gaseous envelope (Hack et al., 1976).

Despite numerous and ongoing modeling attempts (Wilson, 1974; Linnell and Hubeny, 1996; Bisikalo et al., 2000; Linnell, 2002; Nazarenko and Glazunova, 2003, 2006a,b), no model is yet capable of matching the observed light curves from the IR through the UV.

In this paper our main purpose is to study the effect of both eclipsing and density variations on the spectral variability of some spectral lines originating from different environments from Beta Lyrae system by using considerable sample of observations taken by IUE between 1980 and 1989.

We discuss the spectral observations and the data reduction in Section 2. The results and the discussions are presented in Section 3 and its implications concerning the spectral behavior of Beta Lyrae system and the reasons behind this variability. In Section 4, a discussion of the physical meaning of the observed ratio of Mg II k&h emission lines is made. Finally, concluding remarks about this work are presented in Section 5.

2. Observations and data reductions

2.1. IUE LWP high resolution spectra with Mg II emission lines at 2800 Å

The IUE high resolution long wavelength spectra have been retrieved from the IUE Newly Extracted Spectra (INES) system through its principle center at http://ines.vilspa.esa.es. A Full description of the INES system for high resolution data is given in (Cassatella et al., 2000; Gonzales-Reistra et al., 2000). We note that for accurate spectroscopic analysis, the low dispersion data must be taken with the large aperture. Most LWP data of this type had been overexposed and are not suitable for our aims, so no LWP low dispersion spectra were included in this study. The observational data were processed using the standard ESO MIDAS package for the processing of spectra. We referenced the spectra to the phase of the binary using the ephemeris of (Ak et al., 2007). We analyzed 23 high resolution IUE spectra with large aperture of Beta Lyrae system. The spectra were inspected individually in the Mg II k&h region to identify and reject noisy and overexposed or underexposed data. Representative example for Mg II k&h emission lines is given in Fig. 1. These lines are arise from extended envelope, also it is appear that there are additional absorption and emission components on the blue sides of the Mg II k&h emission lines, the absorption component is Fe I, while the emission component is Mn I. The combined effects of both absorption and emission components is small and has been taken into consideration in calculating the line fluxes and line widths of the Mg II k&h emission lines, in addition to this we take into account the uncertainties of the measurements. Also we noticed that for Beta Lyrae eclipsing binary system, the eclipsing phenomena affecting the values of physical parameters (line fluxes and line widths).

2.2. Mg II k&h emission lines in velocity space

In Fig. 2 we display the observed Mg II k&h line profiles. The k line is shown as a solid line, and the h line is represented by a dotted line. The spectra are shown in a velocity space. The date, time and phase of each observation is indicated in the figure, from these plots we deduced the following:

(a) The emission profiles in Mg II k&h emission lines extends up to 300 km s^{-1}, and redshifted as in the figure.
(b) The integrated flux area for the k emission line is greater than the integrated flux area for the h emission line.
(c) In the blue sides of the Mg II profiles, there are emission and absorption components, the absorption component is Fe I approximately at 0 velocity, while the emission component is Mn I extends to -150 km s^{-1}.
(d) Approximately there is coincidence for the integrated area of flux for both absorption and emission components on the blue sides of Mg II lines.

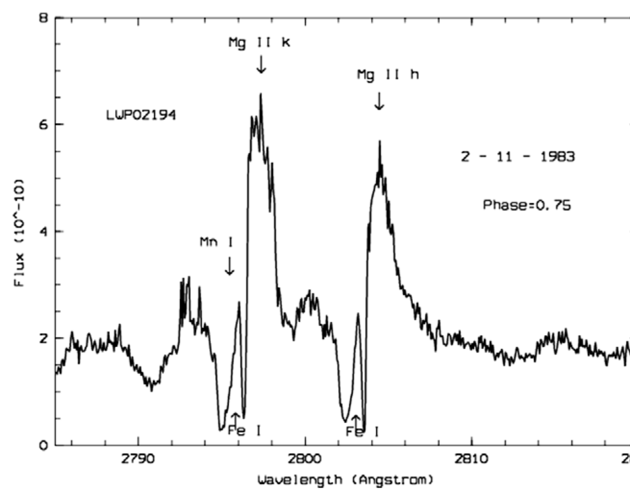

Fig. 1. IUE spectrum of Mg II k&h emission lines at phase 0.7. (The flux is plotted in units of erg $cm^{-2}\ s^{-1}\ Å^{-1}$.)

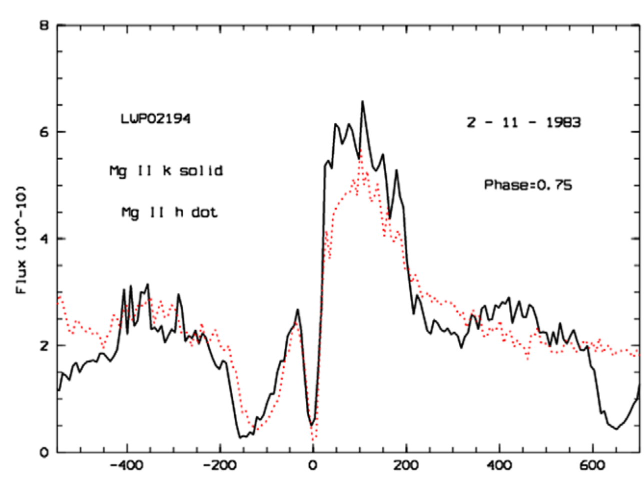

Fig. 2. IUE Spectrum of the Mg II k&h profiles in velocity space at phase 0.75. The Mg II k&h lines show good agreement in their profiles. (The flux is plotted in units of erg $cm^{-2}\ s^{-1}\ Å^{-1}$.)

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