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Modeling of accretion disk-originated features in the high resolution spectra of U Sge

Ö. Taşpınar, H. Bakış and V. Bakış

Department of Space Sciences and Technologies, Akdeniz University, 07058 Antalya, Turkey, (E-mail: ozlemtaspinar@akdeniz.edu.tr)

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Abstract. U Sge (HD 181182) belongs to the group of short period Algol-type binaries with a period of 3.38 days. One hundred and eleven high-resolution spectra of U Sge, which are known to exhibit H_α emission, were obtained at (TÜBİTAK) National Observatory in Turkey. The emission and absorption structures of the system have been analysed. The astrophysical parameters of the system have been obtained by means of analysing the spectral and photometric data. Accordingly, the primary component is a B7-8 spectral type main-sequence star, while the secondary component is a G2 spectral type giant. The cool secondary component has filled its Roche lobe and is transferring material through the L_1 point onto the hot primary component. The effects of both components and the transferring material were detected in the H_α lines. In order to determine these effects, the SHELLSPEC code, which uses an LTE approximation, has been used. The circumstellar structure around U Sge is due to a very low density disk, transferring material, a hot spot where the transferring material from the secondary impacts onto the primary and the magnetic activity from secondary itself. Moreover, all of these effects on the system are highly variable in just a few orbital cycles.

Key words: binary stars – mass transfer – accretion disk

1. Introduction

U Sagittae is the brightest eclipsing binary of the Algol-type with a total primary eclipse. It has been actively studied by photometry as well as by spectroscopy. Observations of U Sge have revealed the presence of variable circumstellar gas in the system. In this study, we determined the physical parameters of the system and the components. We then investigated the variability on H_α spectra and physical properties of the accretion regions in the U Sge using the SHELLSPEC code (Budaj and Richards, 2004).

2. Observations and Analysis of Data

The spectroscopic observations of U Sge were carried out with the Coudè-Èchelle Spectrograph ($R \sim 40000$) at the RTT150 telescope of (TÜBİTAK) National Observatory. The spectra were reduced by using the IRAF software. The Strömgren b-band ($\lambda_{max} = 4670$ Å) photometry was taken by McNamara and Feltz (1976).

The SHELLSPEC code requires the synthetic spectrum of the components in order to model the circumstellar material. We computed the model atmospheres for the spectrum of the secondary component, where the primary component is totally eclipsed, using the ATLAS9 code written by Kurucz (1993). Synthetic spectra of the secondary component were produced for 17 different èchelle orders at this phase using the SYNTHE code. In this way, model atmosphere parameters of the secondary component were determined.

The spectra of U Sge were analysed with the Fourier spectra disentangling code KOREL (Hadrava, 1995). The light contributions of the components used in the disentangling procedure were taken from the light curve solution which was performed by using the WD code (Wilson and Devinney, 1971). The atmospheric model parameters of the primary component were obtained by fitting synthetic spectrum on He I and Mg II lines of the primary component.

3. Modeling of the Circumstellar Matter

The free parameters for modeling of accretion disk are thickness, inner and outer radius, temperature and density. The models were generated by altering these parameters. The results of the H_α modeling are shown in Fig. 1. It is seen that the distribution of circumstellar matter is highly variable in different epochs at the same phase (see the top panel of Fig. 1).

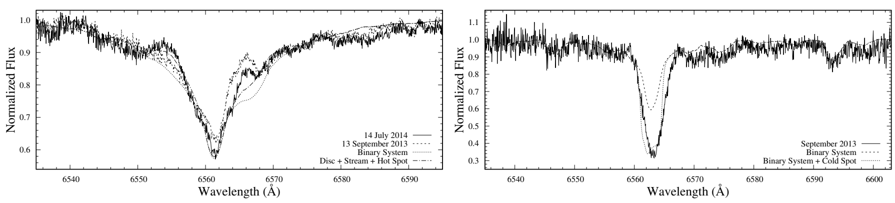

Figure 1. Variability of the circumstellar matter in different epochs at the same phase (ϕ= 0.25) (*top*) and two different models for ϕ= 0.003 (*bottom*).

At the orbital phase ϕ=0.003, the synthetic H_α spectral line calculated for the secondary component is shallower than the observed H_α line implying an excess absorption (see bottom panel of Fig. 1).

This extra absorption may indicate a presence of additional matter in front of the star along our line of sight or chromospheric activity of the secondary star. A model of a cold low density absorbing gas, which is shown as a cold spot in Fig. 1 (bottom panel), around the secondary component as a consequence of the chromospheric activity fits the observed spectrum.

Table 1. Physical parameters of the component stars and the disk.

Parameter (unit)	Value
Stellar parameters	
$T_{eff1,2}$ (effective temperature, K)	12250 ± 50, 5500 ± 50
$\log g_{1,2}$ (surface gravity, cgs)	4.00 ± 0.06, 3.25 ± 0.09
$v \sin i_{1,2}$ (rotation velocity, km/s)	70 ± 5, 80 ± 5
Disk parameters	
a (thickness, $R_\odot$)	0.82 ± 0.02
R_{in} (inner radius, $R_\odot$)	6.20 ± 0.20
R_{out} (outer radius, $R_\odot$)	9.50 ± 0.40
ρ (density, cgs)	$10^{-14} \leqq \rho \leqq 10^{-12}$
$T_{\rm disk}$ (disk temperature, K)	8000 ± 500

4. Conclusions

By modeling the circumstellar matter, we obtained physical parameters of the accretion disk which are given in Table 1. In this study a total of 111 spectra of U Sge were obtained in 14 observing nights between September 2013 and August 2014. The features of the H_α spectra were found to be highly variable in the course of the observing period. As Albright and Richards (1995) suggessted, we also confirmed that circumstellar features in H_α spectra are stable over timescales of days, but vary significantly over timescales of weeks. Investigation of the U Sge system in this study may be important with regards to understanding the mass transfer process in active Algol-type binary systems.

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