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Spectroscopic solution for the oEA star RZ Cas using the SHELLSPEC code

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Abstract

Reinvestigations of the short-period oEA star RZ Cas by using the "SHELLSPEC" code confirm most of the system parameters obtained by Lehmann & Mkrtichian (2008). Results from spectra obtained in 2001 point to a transient phase of rapid mass transfer and to the existence of dense circumprimary matter of disk-like structure, while results from spectra obtained in 2006 show that the system was in a quiet state during this period and can be modelled very well by two stars of which the secondary component fills its Roche lobe. The brightness distribution over the surface of the secondary can be described by a gravity darkening law that assumes two different exponents for hemispheres of different stars.

Individual Objects: RZ Cas

Introduction

RZ Cas is one of the best investigated oEA stars (i.e. Algol-type systems where the mass-accreting primary shows δ Scuti-like oscillations; Mkrtichian et al. 2002, 2004) of which extended photometric (Mkrtichian et al. 2007; Rodriguez et al. 2004) and spectroscopic (Lehmann & Mkrtichian 2004, 2008) investigations exist. As a result, the following facts were established: RZ Cas is a short-period Algol-type system (P = 1.1952595 d; A3 V/K0 IV spectral type) that shows an orbital period change of the order of seconds within decades, a very pronounced Rossiter effect during primary minimum and amplitude modulation of nrp (non-radial pulsation) modes with an orbital phase in which a strong enhancement of the amplitudes during the primary eclipse can be seen (so-called spatial filtration effect). A different asymmetry of the Rossiter effect and different strengths of the nrp-amplitude modulation in different epochs of observations have been observed.

Spectroscopic modelling and results

We obtained high-resolution spectra with the Coude-Echelle-Spectrograph at the 2-m telescope at the Thüringer Landessternwarte Tautenburg in 12 runs in 2001 (951 spectra) and in 8 runs in 2006 (512 spectra). Based on these spectra, we reinvestigated the RZ Cas system by using the modern code "SHELLSPEC" (Budaj & Richards 2004; Budaj et al. 2005) for the synthesis of composite line profiles from binary systems. The program computes the Roche geometry of the secondary; effects like gravity darkening for the secondary, accretion disk and gas stream are also taken into account. Composite spectra can be obtained for

all orbital phases, including eclipse mapping. Starting values for atmospheric parameters for both components like abundances, T_{eff} and $v\sin i$ have been obtained from the analysis of the disentangled spectra derived with the KOREL program (Hadrava 2004) while the starting values for the system parameters like radii and masses of the components, orbital inclination and separation were taken from the Wilson-Devinney solution and from the radial velocity analysis (Lehmann & Mkrtichian 2004, 2008). After the masses, T_{eff}, $v\sin i$ and limb darkening coefficients for both components were fine-tuned by using SHELLSPEC, we tried to adjust the gravity darkening exponent for the secondary using the spectra from 2006. We found that the brightness distribution over the surface of the secondary can be described very well if we apply a gravity darkening law with two different exponents for the two hemispheres of the secondary pointing towards ($\beta = 0.5$) and away ($\beta = 0.1$) from the primary. The obtained ultra-large value of $\beta = 0.5$ cannot be interpreted in terms of gravity darkening. Their interpretation is that it reflects the existence of a large dark spot on the surface of the secondary near to Lagrangian point one. This is in line with findings by Unno et al. (1994), where authors reported about an ultra-large gravity darkening exponent of 0.53 for the secondary of RZ Cas. The interpretation was that as a result of mass-outflow from the secondary, spots on the front and back sides of the secondary towards the primary are formed.

In a next step, the model obtained from the 2006 spectra was applied to the spectra taken in 2001 without changing any of the parameters. Results showed a strong attenuation of the primary line profile for most orbital phases, pointing to the existence of dense circumprimary matter of a disk-like structure. This result confirms the hypothesis of a transient phase of rapid mass transfer during the 2001 observational period as given by Lehmann & Mkrtichian (2004, 2008). Finally, we did a very first attempt to include a disk-like circumprimary matter in our model and found that the system in 2001 can be better described in this way, but we have to assume a complex angular density distribution of the disk.

Conclusions

RZ Cas shows different behaviour in 2001 and 2006 observation periods. Whereas in 2006 the observed line profiles can be very well modelled by two stars only, the more complex model with a dense disk of circumprimary matter should be applied to the spectra from 2001. We found that this disk must have a complex angular density distribution. In a further step, we want to model the system by using 3D-hydrodynamical simulations of the mass-transfer to improve our solution.

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