IN BETWEEN $\beta$ LYRAE AND ALGOL: THE CASE OF V356 Sgr

D. DOMINIS$^1$, P. MIMICA$^2$, K. PAVLOVSKI$^3$ and E. TAMAJO$^3$

$^1$Institut für Astrophysik, Universität Potsdam, Germany; E-mail: dijana@astro.physik.uni-potsdam.de
$^2$Max-Planck Institut für Astrophysik, Garching, Germany
$^3$Department of Physics, University of Zagreb, Croatia

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Abstract. The eclipsing binary system V356 Sgr is of considerable interest, since it is probably at the very end of its mass transfer phase, i.e. between $\beta$ Lyrae and Algol. Hence, the binary provides an opportunity to directly examine the exposed core of a star for signatures of nuclear burning, and to test stellar evolution models. The system is composed of an early B star accreting matter from a Roche-lobe filling A2 II star. Recently, with progress in the UV spectral region, significant revision of previous values for absolute parameters has been made. Therefore, we find it justified and important to present a new photometric solution. Our model is compared to an early disk model, and is discussed in the framework of mass transfer processes in this binary system.

Keywords: binary stars, accretion disk, V356 Sgr

1. Introduction

V356 Sgr (HD 173787, $V_{\text{max}} = 6.8$ mag, $P = 8.93$ d) is an unusual binary system. This was recognized by Popper (1955) in an admirable study in which he had analyzed both spectrographic and photometric observations. Lines of both components are visible in the spectra. During primary minimum he found the spectrum to be of type A2 II. Because lines of the hotter component of spectral type B2 or B3 are considerably broadened by rotation, its RV curve was less precise than the RV curve of the sharp-lined A component. There are a number of anomalies in the light curves, so that Popper was not able to fit a model with methods of the 50s.

A major improvement in the model of the V356 Sgr system has been achieved by Wilson and Caldwell (1978), who have calculated synthetic light curves with a model in which the hotter and more massive component is hidden by an opaque and thick circumstellar disk.

While the effect of the disk eclipse by the secondary will be slight, since the disk emits only a small fraction of total light, the eclipse of the secondary by the disk should be appreciable. Thus the secondary eclipse should be wider than the primary eclipse, and it should also be deeper than it would be without an eclipse by the disk. With this disk model some of the anomalies in the light curves were explained.
Our work on the new photometric solution has been motivated by: (i) Important revision of some fundamental quantities for the components of V356 Sgr made by Polidan and co-workers (c.f. Polidan 1989, Roby et al. (1996), (ii) Brief note by Wilson and Woodward (1995) who challenged the earlier opaque disk model by Wilson and Caldwell in favour of an only rotationally distorted primary component in a double contact configuration, and (iii) Importance of abundance studies for interacting binaries, which need reliable fundamental stellar data for understanding the chemical evolution of close binary systems, and in particular, mass-transfer processes in these binaries (c.f. Tomkin and Lambert 1994).

2. Modeling and Optimization

The models of the binary system considered in the present calculations are: (1) a ‘disk model’, in which a cool component, mass-losing star, is filling its critical equipotential surface. A mass-gaining component is detached from its Roche lobe and is surrounded by an optically thick accretion disk, and (2) a ‘rotation model’, in which a hot component is rotationally distorted. Its surface is defined by the equipotential surface of a single star rotating as a solid body. Two parameters define its shape: the polar radius and flattening coefficient.

The optimal solution was reached by simultaneously adjusting a set of parameters to obtain the best agreement between theoretical model, and observed data (Popper’s 1995 $UBV$ observations). Light curves are calculated with the code described by Pavlovski and Króž (1985), while an optimization algorithm based on the laws of natural selection has been used after Charbonneau (1995), who coded a general purpose optimization subroutine PIKAIA.

3. Results and Conclusion

The ‘disk model’ solution was found to fit the measurements better than the ‘rotation model’, both in detail and globally with smaller residuals (Figure 1). In general, our new photometric solution with an accretion disk, which surrounds the hotter component, corroborates recent results of on-going work by Polidan and co-workers, in particular a lower mass ratio $q \sim 0.27$, effective temperature of the hotter, partially hidden, component $T_{B,\text{eff}} \sim 23000$ K, and its high rotational velocity close to the centrifugal break-up limit. Recently, from IUE high-resolution UV spectra of V356 Sgr, Fraser et al. (1997) revised Popper’s mass ratio to $q = 0.25$. Also, from the same set of observations, Roby et al. (1996) derived effective temperatures for both components, which are, in particular for the hotter component, in substantial discordance with the temperature obtained earlier by Wilson and Caldwell in their photometric study.

Parameters derived in the present study (Table I) position the star on the borderline where a stable accretion disk could be formed around the mass-gaining star