COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 5940

Konkoly Observatory
Budapest
26 May 2010

HU ISSN 0374 – 0676

THE HIGHLY ACTIVE LOW-MASS ECLIPSING BINARY BS UMa

WILS, PATRICK[1]; LAMPENS, PATRICIA[2]; VAN CAUTEREN, PAUL[1,3]; SOUTHWORTH, JOHN[4]

[1] Vereniging Voor Sterrenkunde, Belgium; e-mail: `patrickwils@yahoo.com`

[2] Koninklijke Sterrenwacht, Brussel, Belgium; email: `patricia.lampens@oma.be`

[3] Beersel Hills Observatory, Beersel, Belgium

[4] Keele University, Newcastle-under-Lyme, UK; email: `jkt@astro.keele.ac.uk`

BS UMa was found to be a short-period eclipsing binary by Meinunger and Wenzel (1968). They gave a period of 0.437016 days, but later on this turned out to be a spurious period. The correct period of 0.34951 days was given by Diethelm (2009). Lampens et al. (2010) noted that the given ephemeris is in fact that for the secondary minimum.

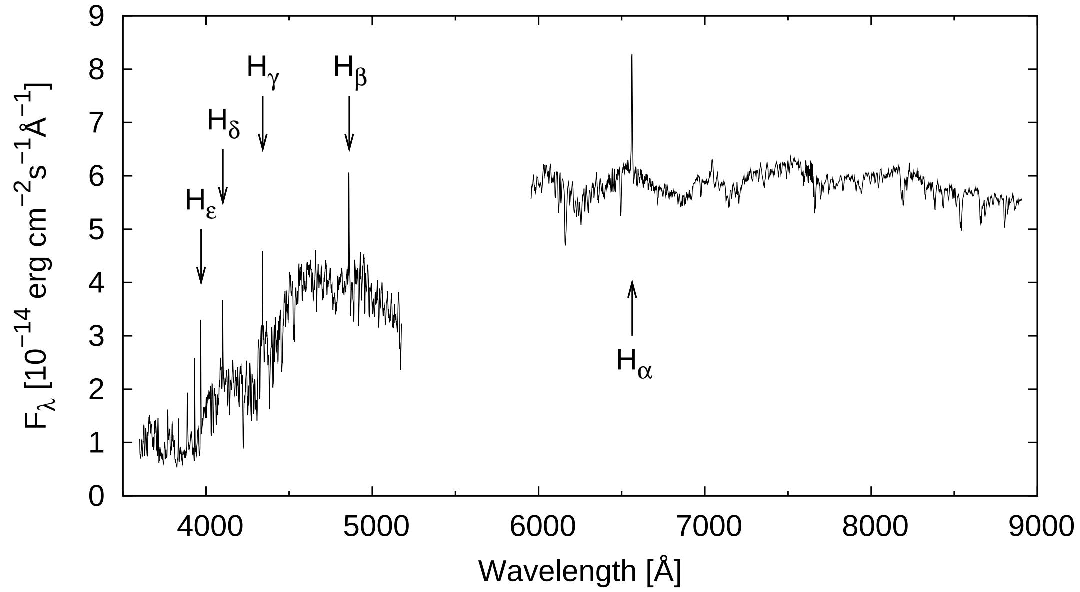

Figure 1. Spectrum of BS UMa taken on JD 2454512.5 with WHT/ISIS, total exposure time 1500 seconds. The spectrum was flux-calibrated with SP0946+139 and telluric lines were removed. For details of the data reduction method see Southworth et al. (2007a & 2007b).

From a simple black body fit to the available photometry in the literature (2MASS, SDSS, CMC, GALEX) and the low-resolution spectrum discussed below, a temperature of $T_1 = 3800 \pm 100K$ can be estimated for the brightest star in the BS UMa system, making it of late K to early M spectral type. Interstellar extinction has been neglected in this, as $E(B-V) = 0.018$ in the direction of the object (Schlegel et al., 1998). BS UMa is also known as the X-ray source 1RXS J112540.3+423449, indicating chromospheric activity.

Low-mass eclipsing binaries are of interest because they can provide the necessary physical parameters to test the evolutionary models for the low-mass main-sequence stars.

Until recently very few were known (see e.g. Dimitrov & Kjurkchieva, 2010). Therefore BS UMa was chosen as a target for further study.

A low-resolution spectrum was taken with the ISIS double-beam spectrograph on the William Herschel Telescope (WHT) at La Palma in February 2008 (see Fig. 1). It shows the Balmer lines in emission, another indication of chromospheric activity.

BS UMa was observed photometrically on 5 nights in April 2009 and on 4 nights in April 2010 at the Humain site of the Royal Observatory in Belgium. A 40-cm Newtonian was used, equipped with an SBIG ST-10XME CCD camera and B and V filters. GSC 3059-1349, with $V = 11.50 \pm 0.11$ and $B - V = 0.62 \pm 0.18$ (derived from Tycho photometry, Høg et al., 2000), was used as comparison star and GSC 3059-1419 as check star. Image processing and photometric analysis were done using Mira AP Pro from Mirametrics Inc. All the photometric data obtained for this study are available as electronic tables (`5940-t3.txt` and `5940-t4.txt`) from the IBVS website.

The light curve obtained during 2009 already showed small changes after three weeks. But as shown in Fig. 2, the light curve obtained in 2010 differs dramatically from the one obtained the year before. Consequently, BS UMa is a highly active system with rapidly changing spots significantly altering the shape of the light curve.

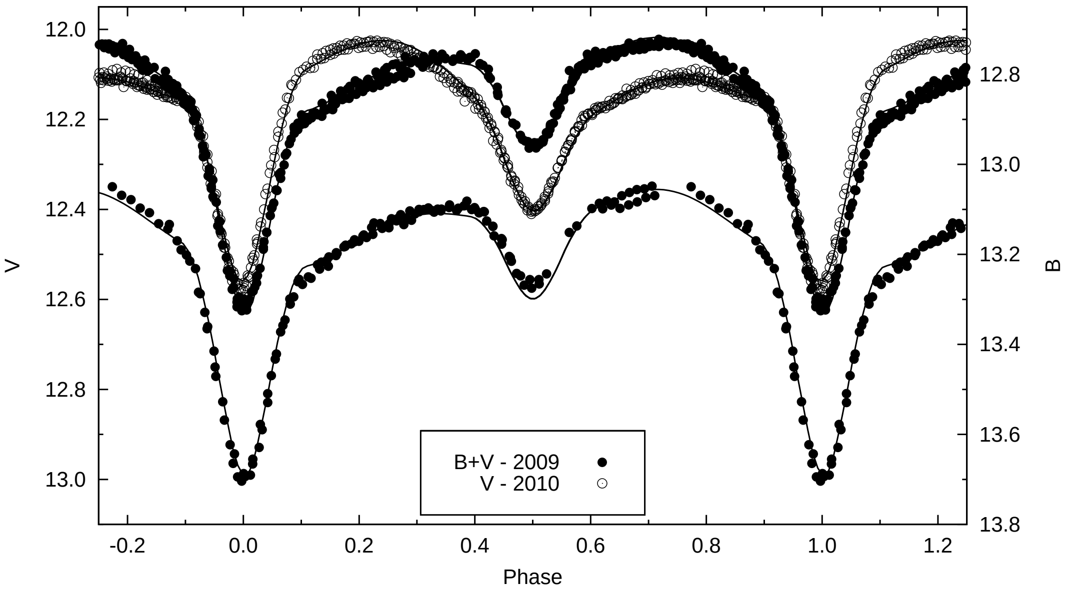

Figure 2. Light curve of BS UMa. B (bottom) and V (top) data from April 2009 are given as filled circles, whereas V data obtained in April 2010 are shown as open circles. The full lines show the model light curves discussed in the text.

Because of this changing aspect of the light curve, several models involving dark spots can explain the light curve equally well. Radial velocity data will be needed, but also more photometry to establish a "quiescent" light curve. Because of the symmetric non-distorted shape of the light curve obtained by SuperWASP (Norton et al., 2007) in 2004 (see Fig. 3), it may be considered to be close to such a quiescent state. Calculations done using Phoebe (Prša & Zwitter, 2005) resulted in the following model parameters (with formal uncertainties): $i = 72.5 \pm 0.2°$, $T_2 = 3550 \pm 10 K$, $\Omega_1 = 4.50 \pm 0.03$, $\Omega_2 = 3.85 \pm 0.02$. Lacking radial velocity data, a mass ratio of 1 was assumed. Building further on this configuration, one spot on each star was introduced to separately model the distorted light curves seen in 2009 and 2010. Because of the uncertainty already present in the quiescent model, on which the models with spots are heavily dependent, only a rough fit was aimed for, and no attempt was made to fit the observations exactly. This would

Table 1: Spot parameters. Coordinates and radii are expressed in degrees.

Year	Star	Colatitude	Longitude	Radius	Temperature factor
2009	Primary	80	285	25	0.80
	Secondary	40	205	60	0.95
2010	Primary	30	160	25	0.65
	Secondary	60	235	20	0.75

probably require a larger number of spots and would likely not lead to a unique solution. Such a detailed model would also fairly soon be made oblivious by the rapid evolution of the spots. The spot parameters from the simple model are listed in Table 1. As can be expected, these spots differ wildly between 2009 and 2010. Unfortunately nothing can be said about the intermediate evolution between the two snapshots.

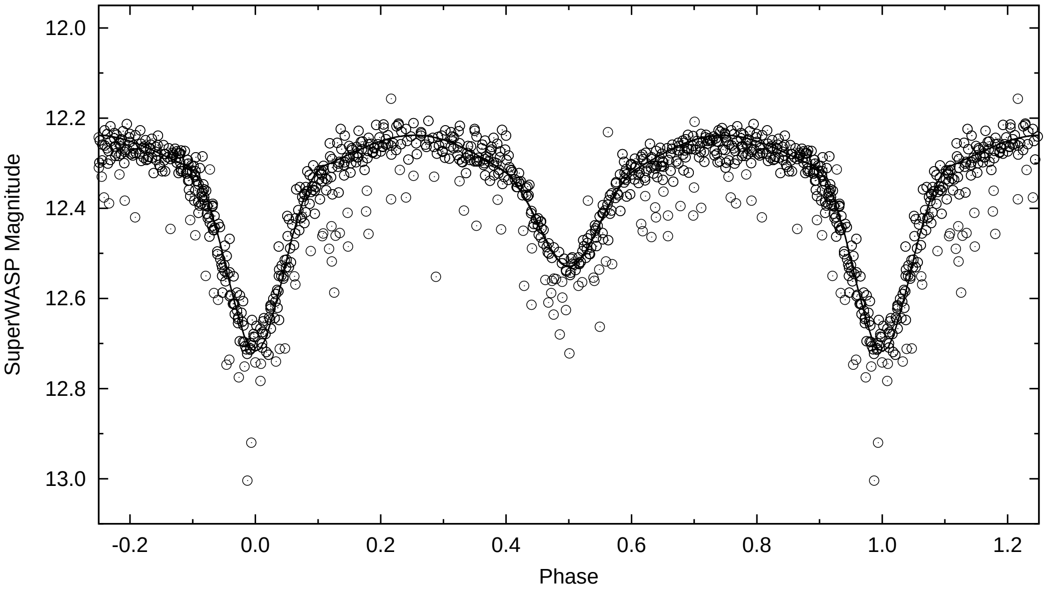

Figure 3. Phase plot of BS UMa from SuperWASP data obtained during May-July 2004.

The secondary in this model is fairly close to filling its Roche lobe (fill-out factor = -0.2). With the fairly limited data set at hand, and depending on the mass ratio, it cannot be entirely excluded that the system is semi-detached, or that this is the case at least part of the time, depending on the activity. Some of the distortions in the light curve could then be explained by gas streams from the secondary impacting on the primary and thereby creating a hot spot, such as in V361 Lyr (Andronov & Richter, 1987) and DK CVn (Terrell et al., 2005).

The times of minimum obtained during 2009 were published by Lampens et al. (2010). Those obtained this year are given in Table 2 (all were obtained from V data only). Together with the times of minimum listed in the *O − C Gateway* since 1999, a new ephemeris for the primary minimum could be calculated as follows:

$$\text{HJD Min} = 24553134.7088(5) + 0^{\text{d}}.34950987(9) \times E \qquad (1)$$

Except for one point, all available times deviate less than 0.004 days from this ephemeris. This is well within the accuracy of the observed times, taking into account the varying shape of the light curve. From the available data, there is therefore no indication of a changing period at present. The $O - C$ values in Table 2 correspond to the ephemeris above.

Table 2: New times of minimum of BS UMa.

HJD - 2400000	Uncertainty	Type	$O-C$
55292.4086	0.0004	II	0.0006
55292.5810	0.0003	I	-0.0017
55293.4569	0.0004	II	0.0004
55303.4158	0.0002	I	-0.0017
55305.3399	0.0005	II	0.0001
55305.5130	0.0002	I	-0.0016

BS UMa is a highly interesting object worthy of further study.

Acknowledgements:

PL thanks the directors of the Royal Observatory of Belgium (ROB) for purchasing and operating an optical telescope at the radio-astronomy site of Humain under the project name *HOACS* (Humain Optical Observatory for Astrophysics of Coeval Stars). The *HOACS* data were acquired with equipment purchased thanks to a research fund financed by the Belgian National Lottery (1999).

This study is based in part on observations made with the William Herschel Telescope, which is operated on the island of La Palma by the Isaac Newton Group in the Spanish Observatorio del Roque de los Muchachos (ORM) of the Instituto de Astrofýsica de Canarias (IAC).

This work has made use of the SIMBAD and VizieR databases operated at CDS, Strasbourg, France and of the *O-C Gateway*, created by A. Paschke and L. Brát. We have used data from the WASP public archive in this research. The WASP consortium comprises of the University of Cambridge, Keele University, University of Leicester, The Open University, The Queen's University Belfast, St. Andrews University and the Isaac Newton Group. Funding for WASP comes from the consortium universities and from the UK's Science and Technology Facilities Council.

PVC is grateful for support from Baader Planetarium.

References:

Andronov, I.L., Richter, G.A., 1987, *Astron. Nachrichten*, **308**, 235

Diethelm, R., 2009, *IBVS*, 5894

Dimitrov, D., Kjurkchieva, D., 2010, *MNRAS*, to be published (arXiv:1005.0260v1 [astro-ph.SR])

Høg, E., Fabricius, C., Makarov, V.V., et al., 2000, *A&A*, **355**, L27

Lampens, P., Kleidis, S., Van Cauteren, P., Hambsch, F.-J., Vanleenhove, M., Dufoer, S., 2010, *IBVS*, 5933

Meinunger, L., Wenzel, W., 1968, *Veröff. Sternwarte Sonneberg*, **7**, 385

Norton, A.J., Wheatley, P.J., West, R.G. et al., 2007, *A&A*, **467**, 785

Prša, A., Zwitter, T., 2005, *ApJ*, **628**, 426

Schlegel, D.J., Finkbeiner, D.P., Davis, M., 1998, *ApJ*, **500**, 525

Southworth, J., Gänsicke, B.T., Marsh, T.R., de Martino, D., Aungwerojwit, A., 2007a, *MNRAS*, **378**, 635

Southworth, J., Marsh, T.R., Gänsicke, B.T., Aungwerojwit, A., Hakala, P., de Martino, D., Lehto, H., 2007b, *MNRAS*, **382**, 1145

Terrell, D., Koff, R.A., Henden, A.A., Hager, T., Kaiser, D.H., Howell, J.A., Gross, J., Cooney, W.R., Munari, U., Siviero, A., 2005, *IBVS*, 5642