Twenty New W Ursae Majoris-type Eclipsing Binaries from the Catalina Sky Survey

Stefan Hümmerich (1,2), **Klaus Bernhard** (1,2), **Gregor Srdoc**

1 - Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V. (BAV)
2 - American Association of Variable Star Observers (AAVSO)

Abstract: A short overview of eclipsing binary stars and their traditional classification scheme is given, which concentrates on W Ursae Majoris (WUMa)-type systems. Details for 20 new WUMa systems are presented, along with a preliminary model of the totally eclipsing system GSC 03090-00153, which was computed using Binary Maker 3.

I. Introduction

Binary stars are of great importance in astrophysics as they allow the derivation of fundamental stellar parameters such as mass, radius and temperature of their components. Eclipsing binaries – binary systems whose orbital plane happens to be aligned with the line-of-sight of an observer from Earth – are especially well suited for these analyses because they provide additional information through their light variations. Thus, they are among the most important of variable stars.

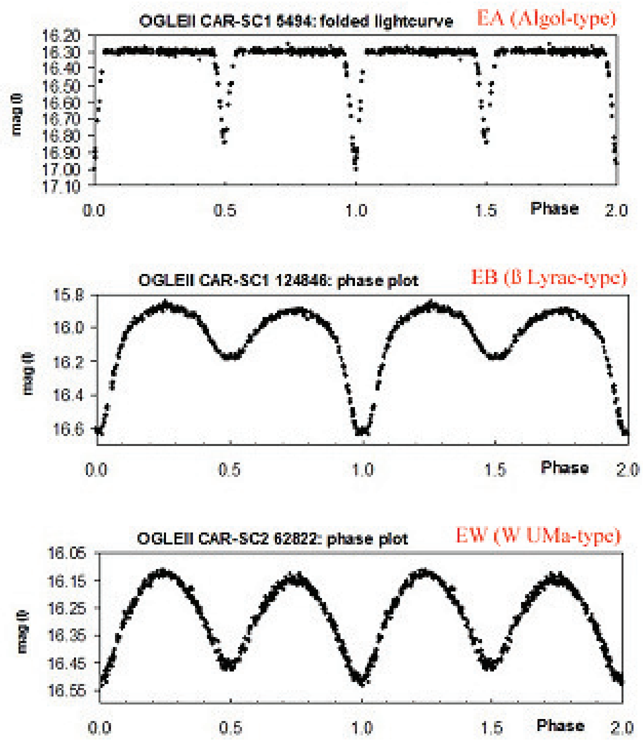

Figure 1. – *Representative light curves of the different types of eclipsing binary stars (EA, EB and EW); graphics are based on OGLE-II data (Szymański, 2005) and were taken from Hümmerich and Bernhard (2012).*

Eclipsing binaries come in a great variety of configurations. Traditionally, they were classified according to their characteristic light variations. While this system has become less important in modern astrophysics and is largely superseded by the concept of Lagrangian surfaces and Roche lobes (cf. e.g. Percy, 2007), it is still widely used today and useful for arriving at a preliminary classification of an eclipsing binary. It also forms the basis of the classification in the present paper.

Generally, the light curve of an eclipsing binary is characterized by periods of constant light that are interrupted by periodic drops in brightness as one star eclipses the other. The GCVS (Samus et al., 2007-2013) differentiates three major groups of eclipsing binaries. **Class EA** – also called Algol-type binaries after their prototype β Persei – encompasses stars that are characterized by light curves with an almost undisturbed maximum light and distinct drops in brightness. Thus, it is possible to exactly determine the beginning and end of the eclipses from an investigation of the light curve. Variables of **Class EB** – also denominated β Lyrae-type binaries after the famous eclipsing system in Lyra – exhibit continuous light variations that make the specification of the beginning and end of eclipses impossible. This is due to the stars being distorted into ellipsoids by tidal effects and rotation. This is also true for stars of **Class EW** – named W Ursae Majoris (WUMa)-type eclipsing variables after their prototype – which will be dealt with in more detail in the following chapter. Representative light curves of the different types of eclipsing binaries are shown in Figure 1; graphics are based on OGLE-II data (Szymański, 2005) and were taken from Hümmerich and Bernhard (2012).

II. WUMa-type Eclipsing Binaries (Class EW)

WUMa-type variables are binary systems made up of similar stars that generally belong to spectral types F to K. They are contact systems, i.e. very

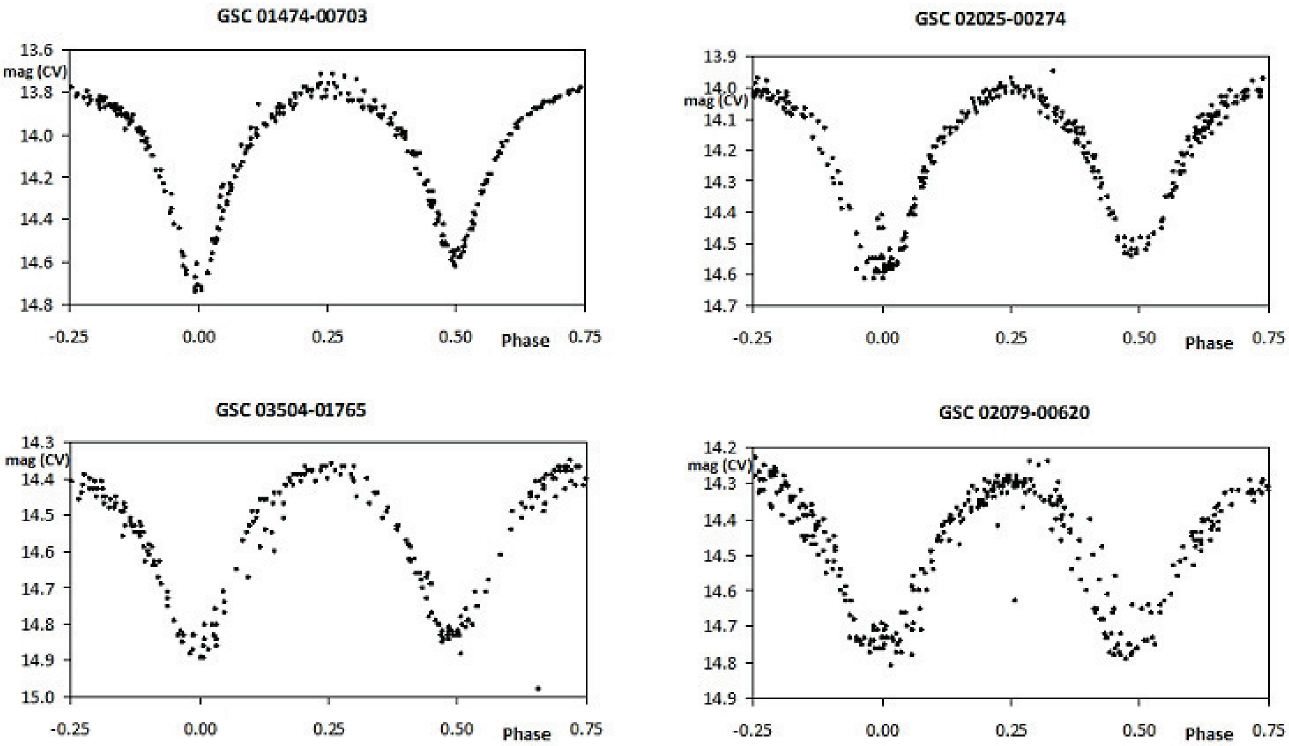

Figure 2. – *Exemplary light curves of four of the W UMa-type variables presented in this paper. There is evidence of light curve variability in GSC 02079-00620 and, possibly, in GSC 02025-00274.*

close systems, in which both stars are actually in contact with each other (or nearly so) and share a common envelope. Because of this, luminosity is transferred from one star to the other (cf. e.g. Jiang et al., 2009), which results in both stars sharing similar surface temperatures although the masses may be different. Because of their close proximity, both stars are ellipsoidal, as is observed in β Lyrae-type systems. WUMa-type systems have short periods, which range from about 0.2 to 1.0 days (cf. e.g. Percy, 2007); the observed amplitudes are usually <1 mag (V). They are easily recognized by their distinctive light curves, which are characterized by continuous light variation and minima of similar depth (cf. Figure 1).

WUMa systems have been subdivided into two classes (cf. Binnendijk, 1970; Sterken and Jaschek, 1996), which are thought to constitute slightly different evolutionary states. **W-type systems** usually have shorter periods (about 0.22 to 0.4 days) and are less massive systems of later spectral types (G to K). **A-type systems**, on the other hand, comprise of more massive stars of earlier spectral types (A to F). They usually have periods in the range of 0.4 to 0.8 days.

Period changes are common amongst WUMa-type stars and are probably connected to mass transfer between the components. Many systems show a complex behaviour, exhibiting sudden period changes of alternating sign rather than a smooth and continuous period evolution (cf. e.g. Sterken and Jaschek, 1996). Additionally, many WUMa variables show evidence of star spots in their light curves and some are strong X-ray emitters, indicating magnetic activity.

For more information on WUMa variables compare e.g. van Hamme (1982), Rucinski (1993) and Li et al. (2007). A good summary about W Ursae Majoris itself can be found in the Variable Star of the Season Archive at the American Association of Variable Star Observers website (AAVSO; http://www.aavso.org/vsots_wuma).

III. Twenty New WUMa-type Systems from the Catalina Sky Survey

During an extended investigation of candidate variable stars from the SuperWASP database (http://www.superwasp.org/; cf. e.g. Bernhard, Srdoc and Hümmerich, 2013), many new WUMa variables have been discovered. In the present paper, we present details for 20 previously unrecorded WUMa stars. Unfortunately, data from the SuperWASP public archive is currently unavailable via the Internet, because of which we had to fall back on data from the Catalina Sky Surveys (Drake et al., 2009; http://nesssi.cacr.caltech.edu/DataRelease/), which is available for most of the candidate variable stars. Periods, magnitude ranges and epochs of the new variable stars were derived using Period04 (Lenz and Breger, 2005). Table 1 provides data of all new W UMa-type binaries presented in this paper, along with remarks on objects of special interest; exemplary light curves are shown in Figure 2.

Quite a few of the presented binaries show indications of secondary variability in their light curves, like e.g. GSC 02079-00620 (cf. Figure 2), which may be due to spot activity on one or both components. Further support for chromospheric activity comes from long-term mean magnitude shifts observed in some systems (e.g. GSC 02612-01769 and GSC 02075-02348). Objects with possible secondary variations are indicated in Table 1 and might be interesting targets for follow-up observations.

Some systems (e.g. GSC 03090-00153 and GSC 03090-00296) exhibit "flat-bottomed" minima indicative of total eclipses. As this puts additional constraints on modelling attempts, we have developed a preliminary model for GSC 03090-00153 using Binary Maker 3 (Bradstreet and Steelman, 2004). This procedure involves the fitting of a theoretical light curve to the observed data in order to derive fundamental parameters of the system. While Catalina Sky Surveys data is limited to one bandpass only, this model – although including a number of assumptions – still provides a lot of information about the system.

Pickles et al. (2010) derive a fitted spectral-type of F2 for GSC 03090-00153, which agrees with the star's J-K index of 0.256 from 2MASS (Skrutskie et al., 2006). We have included this information in our analysis. From our computed model, which produces a solid fit to the observed light curve, we derive a mass ratio of 0.21, temperatures of 7050 K (spectral type ~F2) and 6530 K (spectral type ~F7/8) for the component stars and an inclination angle of 88.9° for the system, which is in agreement with an A-type WUMa variable.

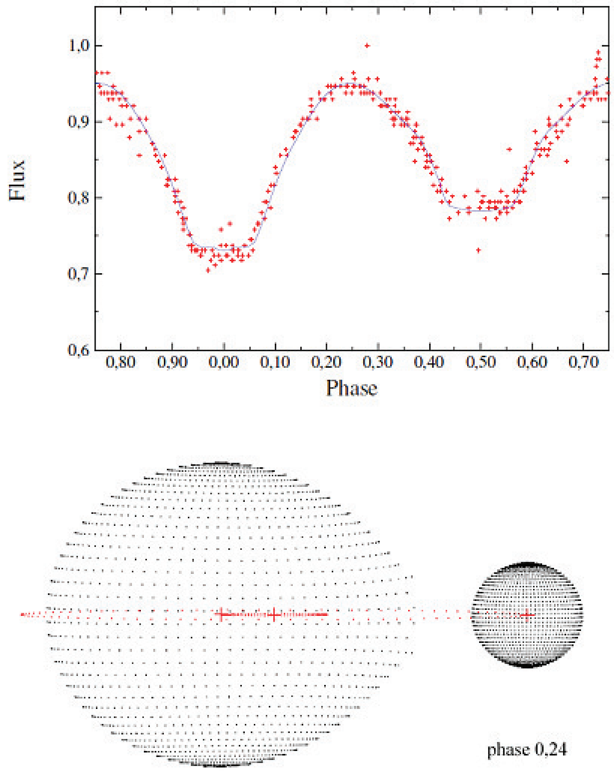

Figure 3. – *Top panel shows the phase plot of GSC 03090-00153, based on data from the Catalina Sky Surveys (red dots) and the corresponding computed light curve (solid blue line). Bottom panel shows the 3D model of GSC 03090-00153 at phase 0.24.*

The latter conjecture is also in accordance with the observed period of 0.426111 days. Figure 3 shows the fit of the computed light curve to the observed data including a 3D model of GSC 03090-00153. A more detailed analysis of GSC 03090-00153 is in preparation.

Table 1. – *Data for all new WUMa-type systems presented in this paper, ordered by right ascension. Positional information was taken from UCAC4 (Zacharias et al., 2012). J-K indices were derived from 2MASS (Skrutskie et al., 2006). The abbreviations in the Remarks column have the following meanings: "lc var" = light curve variable; "tot ecl." = total eclipses; "A-type" = A-type system according to the classification of Binnendijk (1970).*

ID (GSC)	Pos (J2000)	Period (d)	Epoch (HJD)	Mag. Range (CV)	J-K index	Remarks
02544-00521	13 53 12.731 +30 45 13.33	0.3257965	2454141.965	13.75-14.05	0.586	lc var
01474-00703	14 04 17.417 +21 45 52.65	0.3069993	2453885.772	13.80-14.70	0.559	
01482-00837	14 28 55.427 +21 31 11.84	0.2506134	2453537.802	13.70-14.05	0.542	
03045-00012	15 19 15.662 +39 09 53.07	0.6675045	2454232.932	14.10-14.35	0.128	A-type; tot ecl.
02025-00274	15 23 37.662 +22 55 42.80	0.3769321	2454467.035	14.00-14.60	0.363	lc var?
02028-00551	15 25 19.447 +25 42 58.88	0.3972135	2455350.817	13.25-13.70	0.456	
02048-01240	16 35 39.308 +24 51 30.57	0.3245911	2453925.828	14.15-14.40	0.344	lc var

ID (GSC)	Pos (J2000)	Period (d)	Epoch (HJD)	Mag. Range (CV)	J-K index	Remarks
03504-01765	17 14 59.308 +47 39 08.58	0.3311171	2453880.883	14.35-14.85	0.884	
03512-01333	17 15 57.316 +47 54 51.55	0.2740691	2453656.662	14.65-15.05	0.522	
03508-00985	17 16 25.146 +46 12 36.44	0.4405509	2453561.710	14.00-14.45	0.592	
03508-01555	17 17 53.056 +45 38 07.34	0.4067042	2453531.851	14.35-14.80	0.372	Ic var?
02596-00133	17 19 17.308 +32 01 33.73	0.5963582	2454258.889	13.60-13.95	0.203	A-type
03090-00153	17 20 38.745 +40 17 47.28	0.4261110	2454295.784	14.10-14.40	0.265	tot ecl.
02079-00620	17 29 00.871 +24 48 40.87	0.3602838	2454572.873	14.25-14.75	0.362	Ic var; tot ecl.
03090-00296	17 29 43.825 +39 40 36.42	0.3198175	2453644.636	14.50-15.15	0.510	tot ecl.
02075-02348	17 34 07.107 +22 40 37.38	0.4131365	2455004.878	14.10-14.45	0.345	Ic var
02076-01399	17 35 14.169 +23 50 15.75	0.2540383	2453523.876	14.35-14.65	0.608	
02080-03142	17 40 55.824 +25 08 37.77	0.3010301	2454236.898	14.80-15.50	0.584	Ic var
02077-04137	17 47 23.196 +23 04 08.79	0.2768728	2455359.828	14.00-14.30	0.497	
02612-01769	17 59 54.664 +32 38 55.12	0.3287677	2453526.870	13.75-14.00	0.427	Ic var

References

- Bernhard, K.; Srdoc, G.; Hümmerich, S., BAV Rundbrief 3/2013, 62. Jahrgang, 159
- Binnendijk, L., 1970, Vistas in Astronomy, 12, 217
- Bradstreet, D. H.; Steelman, D. P., 2004, Binary Maker 3, Contact Software (http://www.binarymaker.com)
- Drake, A. J. et al., 2009, Astrophysical Journal, 696, 870
- Huemmerich, S.; Bernhard, K., 2012, Peremennye Zvezdy Prilozhenie, 12, 11
- Jiang, D. et al., 2009, MNRAS, 396, 2176
- Lenz, P.; Breger, M., 2005, Comm. in Asteroseismology, 146, 53
- Li, L. et al., 2007, Astrophysical Journal, 662, 596
- Percy, J. R., 2007, "Understanding variable stars", Cambridge University Press
- Pickles, A.; Depagne, E., 2010, PASP, 122, 1437
- Rucinski, S. M., 1993, in "The Realm of Interacting Binary Stars", 111
- Samus, N. N.; Durlevich, O. V.; Kazarovets, E. V.; Kireeva, N. N.; Pastukhova, E. N.; Zharova, A. V. et al., 2007-2013, General Catalogue of Variable Stars, VizieR On-line Data Catalog, B/gcvs
- Skrutskie, M.F.; Cutri, R.M.; Stiening, R. et al., 2006, Astronomical Journal, 131, 1163
- Sterken, C.; Jaschek, C., 1996, "Light Curves of Variable Stars, A Pictorial Atlas", Cambridge University Press
- Szymański, M. K., 2005, Acta Astronomica, 55, 43
- van Hamme, W., 1982, Astronomy and Astrophysics, 105, 389
- Zacharias, N.; Finch, C. T.; Girard, T. M. et al., 2012, UCAC4 Catalogue, VizieR On-line Data Catalog, I/322

Acknowledgements: This publication has made use of the SIMBAD and VizieR databases operated at the Centre de Données Astronomiques (Strasbourg) in France, of the International Variable Star Index (AAVSO), and of the Two Micron All Sky Survey (2MASS).