The Light Curves of Classical Symbiotic Stars

Augustin Skopal

Dr. Remeis-Sternwarte, Astronomisches Institut der Universität Erlangen-Nürnberg, Sternwartstr. 7, 96049 Bamberg, Germany

Present address: Astronomical Institute, Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Slovakia

Abstract Results of both photoelectric and visual long-term monitoring of selected classical symbiotic stars (CSS) are presented. We suggest a classification in which the complex behavior in their light curves can be basically divided into two groups: (i) periodic and (ii) non-periodic variations. The possible nature of the observed variations is briefly discussed. Comparison of the visual magnitude estimates to the photoelectric data is provided for individual cases.

1. Introduction

Symbiotic stars represent a group of objects characterized by the simultaneous presence of two extremely different temperature regimes. The cooler is that of an M-giant spectral type, and the hotter is expressed by a hot star continuum ($T_{*} \approx 10^5$ K) and emission lines of high excitation, such as HI, HeII, [FeVII], [OIII], [NeIII], and so on. At present they are commonly accepted as long-period binary systems ($P_{orb} > 200$ days) consisting of a red giant and a hot compact component, embedded in a gaseous nebula.

During *quiescent phases*, the hot star radiation ionizes a portion of the neutral circumbinary material, giving rise to the hydrogen recombination continuum which dominates the optical spectrum. Geometry and displacement of the optically thick part of the HII region in the symbiotic binary then determines the observed shape of the light curve. Generally, we observe a periodic wave-like variation in the optical continuum as a function of the orbital phase.

During *outbursts*, the hot component expands in radius ($\approx$1–50 $R_{\odot}$) and becomes significantly cooler. This results in the disappearance of the HII zone in the system, and thus also the wave-like variation. We observe an increase in the star's brightness, typically by 2–3 magnitudes, on a time-scale of weeks, followed by a gradual decrease into quiescence over a period of a few years. The source of the optical light is restricted mostly to the hot component's (pseudo)photosphere. During outbursts, light curves often display two maxima separated approximately by the orbital period. In addition, in the case of a high inclination of the orbital plane, deep narrow minima are observed in the light curve, caused by eclipses of the hot component by its giant companion. So the profiles of the light curves of symbiotic stars strongly depend on the activity of those stars, and thus reveal a great deal of information about the interaction and energy balance in those systems.

The main aim of this contribution is to present some examples of long-term photometric monitoring of CSS (P_{orb} < 1,000 days, displaying in their spectra all the basic characteristics of symbiotic phenomena) to illustrate the above-mentioned properties of these interacting binaries.

2. Survey of variations in the light curves

The light curves of CSS are very complex. In spite of this, we can recognize two basic types of variations: (i) *periodic* and (ii) *irregular*.

Periodic variations are represented by (a) *narrow minima*, and (b) *wave-like* modulation along the orbit. The former is best documented by the light curves of AR Pav, CI Cyg, AX Per, BF Cyg, and AS 338 during their active phases. As the minima coincide with the inferior conjunction of the cool component, it is believed that they are caused by eclipses of the hot object by the cool giant in the symbiotic system. The light curve of the eclipsing symbiotic binary CI Cyg is depicted in the top panel of Figure 1. Its light curve also illustrates a change from the narrow to the broad minima. This reflects the change in the geometry and localization of the source of the optical continuum when the system returns from the outburst stage to quiescence (section 1).

The wave-like variation is observed in the light curves of many CSS during their quiescent phases (e.g., AG Peg, V1329 Cyg, V443 Her, He2-467, AS 338, AG Dra, Z And, SY Mus). Minimum light occurs when the cool component is in front of the hot star (orbital phase $\varphi = 0$). The light curves display a complicated structure at the positions around the orbital phase $\varphi \sim 0.5$ (the hot star in front): the system is often fainter, and sometimes we observe a secondary minimum (e.g., Z And), which, in the cases of T CrB, BD–21.3873, and EG And, is very pronounced and still present. It is generally thought that the wave-like variation is caused by a reflection effect (a single wave throughout the orbital cycle; e.g., Boyarchuk 1966) or by the tidally-distorted giant star in the system (a double wave; e.g., Bailey 1975). On the other hand, Skopal *et al.* (1993) and Skopal (1996) suggested a model of the circumstellar matter in the symbiotic binary which also could produce the observed wave-like variation along the orbital cycle. This type of variability is shown in the middle panels of Figure 1.

Another type of wave-like variability often develops during outbursts of CSS in which the wave persists throughout one to a few orbital cycles and then disappears. The second maximum is often less pronounced. Minima are placed around the orbital phase $\varphi \sim 0$. It is thought that such evolution is caused by two (or multiple) individual eruptions. However, a dependence of the star's brightness on the orbital phase could be also produced by a collisionally-heated emission region on the giant's hemisphere due to the impact of the ejected material during outburst (see Skopal 1994 for more details). Examples of these light curves are shown in bottom panels of Figure 1.

Irregular and basically unpredictable light variations can be caused by outbursts and by dust formation (on a timescale of years/decades). Short-term irregular variations are represented by flickering (timescale of seconds/minutes), and also by oscillations in the star's brightness (timescale of weeks/months). The light curve of CI Cyg shown in the top panel of Figure 1 is an excellent example (e.g., Skopal *et al.* 1996). These types of variations in the light curves of CSS are summarized in Table 1.

3. Addendum, 2006

An update to this paper has been submitted for publication in the *Journal of the AAVSO*.

4. Acknowledgements

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Table 1. Variations in the optical continuum of Classical Symbiotic Stars.

Type of variability	*Examples*	*Interpretation*
Periodic variations		
Narrow minima	AX Per, AR Pav, CI Cyg, CH Cyg, AS 296, BF Cyg, AS 338	• Eclipses of the hot object by the cool component
Wave-like variations	*Quiescent phase*	
1. $P \sim P_{orb}$	AG Peg, V1329 Cyg, He2-467, AS 338, AG Dra, Z And, SY Mus, V443 Her	• reflection effect, • eclipse-like effect, • optically-thick HII zone between the components
	Active phase	
	AX Per, AR Pav, AG Dra, YY Her	• two individual outbursts, • collisionally-heated region on the giant's hemisphere, • precession of accretion disk (superhumps)
2. $P \sim 0.5 \times P_{orb}$	T CrB, BD–21.3873, EG And, RW Hya, He2-467 in the *V* band, BF Cyg, Z And during quiescent phases, in *V*	• tidal distortion of the cool component, • optically-thick HII zone between the components, • eclipse-like effect
Irregular variations		
Short-term:		
• flickering	CH Cyg, T CrB	accretion disk, "bright spot"
• day/months fluctuations	CH Cyg	mass transfer burst (?)
Long-term:		
• outbursts	Z And, BF Cyg, AG Dra	H-burning
	CH Cyg, T CrB, RS Oph	accretion event
• drop in brightness	PU Vul, CH Cyg	Dust formation (?)

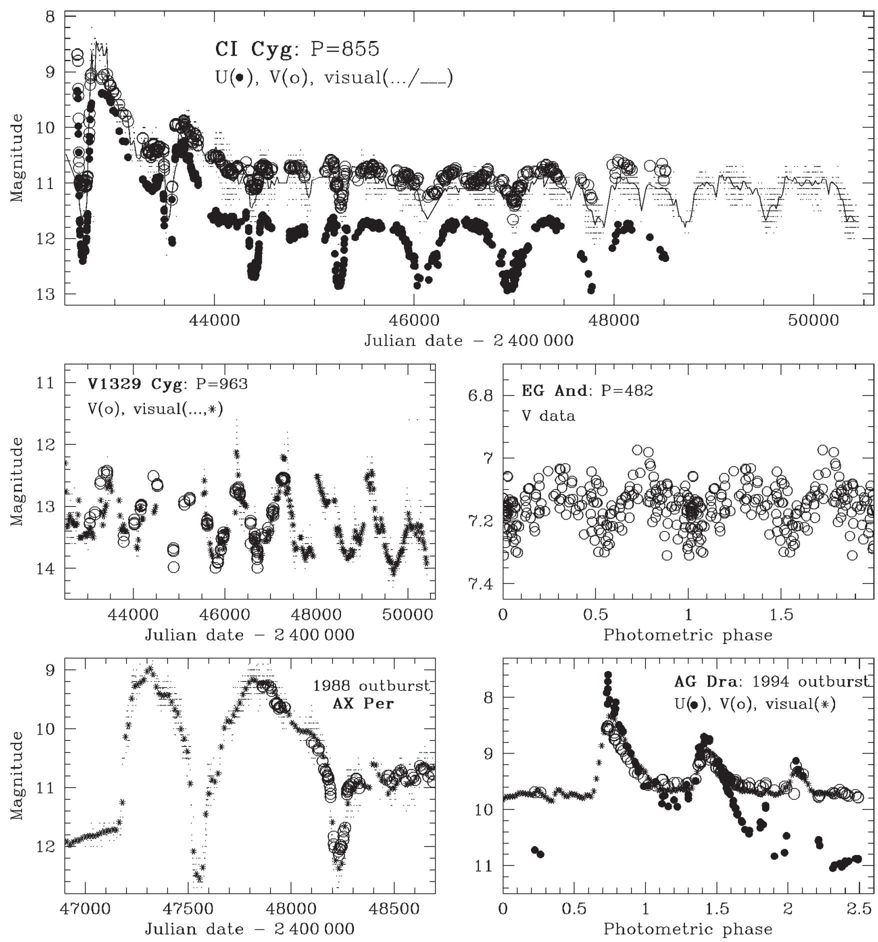

Figure 1. Examples of different types of Classical Symbiotic Star light curves. Visual magnitude estimates were collected by the Association Française des Observateurs d'Étoiles Variables: All data (dots) are 15-day means. (*)