PRESENT UNDERSTANDING OF THE LIGHT CURVES OF SYMBIOTIC BINARIES

AUGUSTIN SKOPAL

Astronomical Institute, Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Slovakia; E-mail: astrskop@ta3.sk

(accepted April 2004)

Abstract. We explain a complex behaviour of the light curves (LC) of symbiotic binaries on the basis of their spectral energy distribution (SED) in the optical domain. During quiescent phases we observe a wave-like variation of the optical light as a function of orbital phase. This is produced by the orbitally-related variation of the emission measure (EM) of the symbiotic nebula. During active phases this type of variability disappears, the continuum level increases by 2–3 magnitudes in U and, in the case of a highly inclined orbit, narrow minima – eclipses – in the LC can occur. These phenomena are connected with the creation of a cool pseudo-photosphere around the hot star, whose contribution is significant in the optical, while the nebula practically disappears.

Keywords: stars, binaries, symbiotic

1. Introduction

Symbiotic stars are long-period interacting binary systems consisting of a cool giant and a hot compact star embedded in a gaseous nebula. Many systems show stages of activity, during which the star's brightness increases by ≈2–3 mag.

During so called *quiescent phases* the hot star radiation ionizes a fraction of the neutral giant's wind giving rise to the nebular radiation. As a result the spectrum consists of basically three components of radiation – two of stellar origin (from the hot and the cool star) and a nebular one. In systems with a strong nebula and a late red giant the nebula dominates the UBV passbands (e.g. V1329 Cyg). On the other hand, in systems with earlier type giants (e.g. AG Dra) the nebula becomes more evident only in the U band.

During *active phases* the hot component expands in radius and becomes significantly cooler. As a result the ionized region is suppressed and the source of optical light is restricted mostly to the hot star pseudo-photosphere. The wave-like variation disappears and, in the case of a high orbital inclination, deep narrow minima in the LC, caused by the eclipse of the hot star by its giant companion, are observed.

The aim of this paper is to explain basic characteristics of the LCs of symbiotic binaries on the basis of their composite SED.

Astrophysics and Space Science **296:** 421–425, 2005.

2. Light Curves During Quiescent Phases

According to a simple photoionization model for symbiotic binaries (Seaquist et al., 1984) we reconstructed the SEDs for selected systems during quiescent phases to outline the nature of the orbitally-related changes in their LCs. Here we demonstrate this case for the example of V1329 Cyg. Figure 1 shows that the nebular continuum emission (dashed line) is subject to variation with orbital phase of the binary. A maximum/minimum of the nebular emission at $\varphi = 0.57/0.95$ corresponds to a maximum/minimum in the UBV LCs. Skopal (2001) showed that the observed

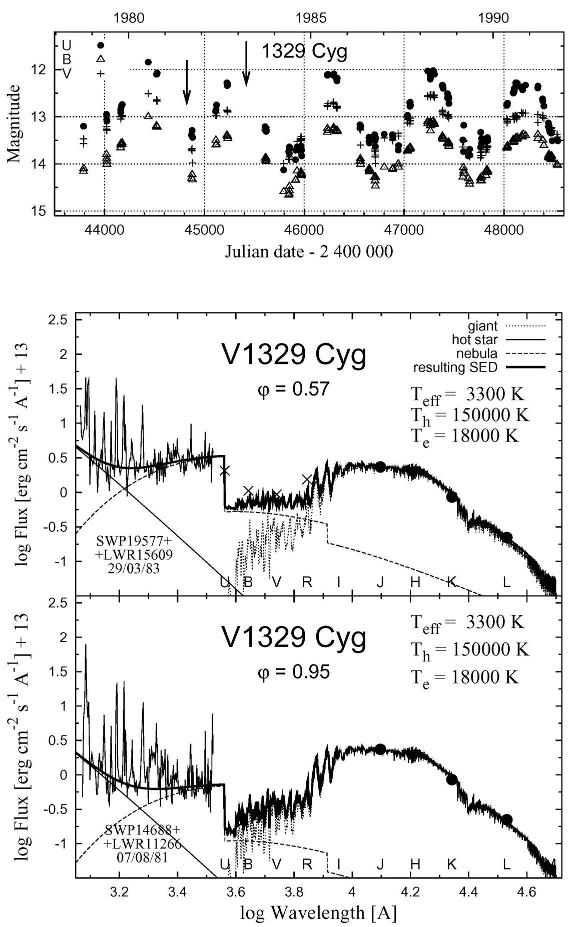

Figure 1. Example of the wave-like orbitally-related variation in the LC of V1329 Cyg during quiescent phase (top). The nature of this type of variability can be understood within an ionization model and its corresponding SED (bottom).

nebular emission is adequately explained by the ionization model and that the variation in EM is fully responsible for the shape of the LCs. Based on these revealings it is possible to reconstruct LCs by converting the observed EM to the scale of magnitudes. The observed nebular flux is connected to EM as

$$F_{\lambda}^{\mathrm{obs}} = \left(\frac{\varepsilon_{\lambda}}{4\pi d^2}\right) \mathrm{EM},$$

where d is the distance to the object and ε_{λ} is the volume emission coefficient. This relation allows us to express the magnitude

$$m_{\lambda} = -2.5 \log(\mathrm{EM}) + \mathrm{C}_{\lambda}, \tag{1}$$

where

$$C_{\lambda} = q_{\lambda} - 2.5 \log\left(\frac{\varepsilon_{\lambda}}{4\pi d^2}\right),$$

and the constant q_{λ} defines magnitude zero. Figure 2 shows the comparison of such reconstructed LC in the B band with that directly obtained by standard photometric measurements for the prototypical symbiotic star Z And.

3. Light Curves During Active Phases

Figure 3 shows the LC of CI Cyg covering its major outburst from 1975 and the SED corresponding to a high level of activity. It is an eclipsing system. During the

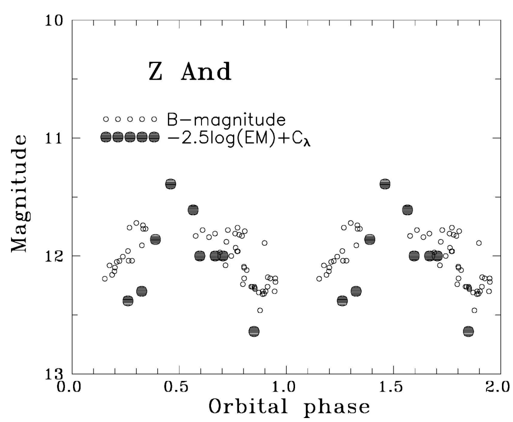

Figure 2. The LCs of Z And in B obtained by standard photometry and from variation in the observed EM (figure taken from Skopal, 2001).

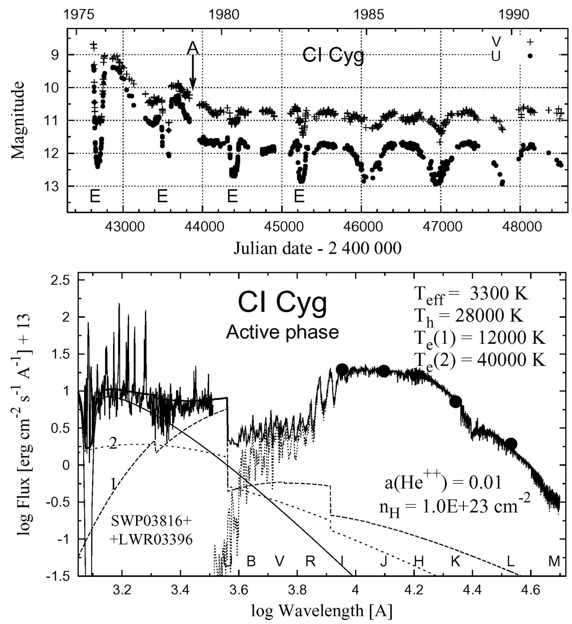

Figure 3. Top: The LC of CI Cyg covering its active phase. Bottom: The SED from the epoch marked by A shows a significant contribution of the stellar component of radiation in the optical. As a result we observe narrow minima – eclipses (E) – in the active LC at the spectroscopic conjunction of the giant. During the following quiescence profiles of minima are broad. Meaning of the lines as in Figure 1.

active phase (until about 1984) the minima – eclipses of the hot object by the giant – are deep and narrow. From about 1985 the LC displays the periodic wave-like variation, which is typical for quiescent phases of symbiotic stars (Section 2 above). Modeling the SED in activity demonstrates the nature of such behaviour. The stellar component of radiation from the hot object, which is subject to eclipse, has a significant contribution in the optical (Figure 3), which forms a narrow minimum at the spectroscopic conjunction of the giant. The nebular component of radiation is located far from the eclipsed object and its amount does not rival that from the hot object, at least in U. After a few orbital cycles, the cool pseudo-photosphere around the hot star dilutes, and its stellar radiation becomes significantly hotter ($\sim 10^5$ K) with a negligible contribution in the optical – typical properties of quiescent phases (cf. Figure 1, Section 2).

Acknowledgements

This work was supported by Science and Technology Assistance Agency, contract no. APVT-20-014402 and by the VEGA grant no. 2/4014/4.

References

Seaquist, E.R., Taylor, A.R. and Button, S.: 1984, *ApJ* **286**, 202.
Skopal, A.: 2001, *A&A* **366**, 157.