Asymmetric Planetary Nebulae 5
(Ebrary, Cambridge, USA),
A.A Zijlstra, I. McDonald, eds.

Probing the symbiotic nebulae by the multicolour photometry

Zuzana Carikova

Astronomical Institute, Slovak Academy of Sciences, SK-05960 Tatranska Lomnica, Slovakia

A. Skopal

Symbiotic stars are long-period interacting binary systems, which comprise a late-type cool giant and a hot compact star, most probably a white dwarf (WD), which accretes from the giant's wind. Accretion process makes the WD very hot and luminous. Its radiation thus ionizes a fraction of the circumstellar medium, giving rise to a strong nebular emission spectrum. In this contribution we introduce a method of disentangling the composite spectrum of symbiotic binaries on the basis of simple multicolour photometry. After correcting observed UBV flux-points for the interstellar extinction and the influence of strong emission lines, we modelled the total flux in the continuum, considering contributions from the nebula and the giant. In this way we determined the electron temperature and emission measure of the nebula as well as the V magnitude of the giant. We applied the method to classical symbiotic stars AX Per, AG Dra, AG Peg and Z And, the symbiotic novae RR Tel and V1016 Cyg and the classical nova V1974 Cyg during its nebular phase. We found that during quiescent phases the electron temperature was around of 20000 K and emission measure of $\sim 10^{59}$ cm^{-3}, while during active phases both parameters increased to ~30000–40000 K and $\sim 10^{60}$ cm^{-3}, respectively. For the symbiotic novae we obtained higher values of emission measure, in order of $\sim 10^{61}$ cm^{-3}. Our results are in a good agreement with those obtained independently by a precious modelling the UV-IR SED. In general, this method of disentangling the UBV magnitudes can be applied to any spectrum composed from a nebular and stellar component of radiation.

Probing the Symbiotic Nebulae by the Multicolour Photometry

Zuzana Cariková, Augustin Skopal

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

Abstract

Symbiotic stars are long-period interacting binary systems, which comprise a late-type cool giant and a hot compact star, most probably a white dwarf (WD), which accretes from the giant's wind. Accretion process makes the WD to be very hot and luminous. Its radiation thus ionizes a fraction of the circumstellar medium, giving rise to a strong nebular emission spectrum. In this contribution we introduce a method of disentangling the composite spectrum of symbiotic binaries on the basis of simple multicolour photometry. We applied the method to classical symbiotic stars AX Per, AG Dra and Z And. Our results are in a good agreement with those obtained independently by a precious modelling the UV-IR SED (spectral energy distribution). In general, this method of disentangling the UBV magnitudes can be applied to any spectrum composed from a nebular and stellar component of radiation.

I. Symbiotic stars

Symbiotic stars are long-period (P_{orb} ~ 1–3 years or more) interacting binary systems, which comprise a late-type giant and a hot compact star, most frequently a white dwarf. During quiescent phases, the WD accretes a fraction of the wind from the giant. The accretion process leads to heating up the WD's surface to a very high temperature and increases its luminosity. Such the hot and luminous WD is capable of ionizing neutral wind particles of both the stars giving rise to a strong nebular radiation. Examples of ionization structure in symbiotic binaries are shown in Fig. 1. The HI/HII boundaries were calculated for different mass-loss rates from the giant and a constant flux of ionizing photons from the hot star according to a steady state approximation of Seaquist et al. (1984). During quiescent phases, the symbiotic nebula represents mostly the ionized part of the stellar wind from the giant. During active phases, the mass loss rate from the hot component increases, and can temporary exceed that from the giant. As a result, properties of the symbiotic nebula change significantly during the active phases. Accordingly, the observed flux, F_λ , is given by superposition of three basic components of radiation – that from the nebula, F_λ^{nebula} , the cool giant, F_λ^{giant} , and the hot stellar source, F_λ^{hot} , i.e.

$$F_\lambda = F_\lambda^{nebula} + F_\lambda^{giant} + F_\lambda^{hot}. \qquad (1)$$

Contributions of individual components of the radiation depend on the wavelength as well as on the level of the activity (Fig. 2). During active phases of symbiotic binaries with a high orbital inclination, we observe narrow minima in their light curves. They can be interpreted as eclipses of the hot object by the cool giant. This implies that during the activity the hot stellar source contributes a dominant amount of its radiation within the optical. It is believed that an optically thick disk is formed around the hot star at the orbital plane during active phases (see Skopal, 2005). Its relatively cool rim mimics a warm pseudophotosphere, while the circumstellar material above/below the disk can easily be ionized by its hot central part. Therefore the observed depths of the minima are partially filled in by the nebular radiation. During quiescent phases the optical region is dominated by the extensive nebula, which thus prevents from observing eclipses.

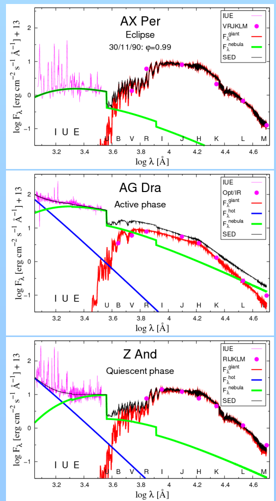

Figure 2 The model SED and its components of radiation represent a graphic form of Eq. (1).

II. Disentangling UBV magnitudes

The aim of this poster is to introduce a method of disentangling photometric UBV magnitudes of symbiotic stars into their individual components. This means to determine physical parameters of their radiation. In our approach we assume that the contribution from the hot stellar source can be neglected within the optical. This assumption can be applied for systems during quiescent phases, while during active phases, it is valid for non-eclipsing binaries. For eclipsing systems it can be used only during eclipses.

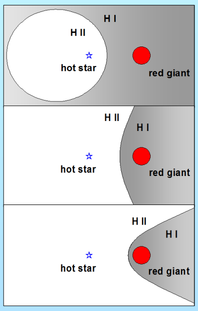

Figure 1 Examples of HI/HII ionization boundary in symbiotic binaries calculated for stationary case and pure hydrogen. The ionization front is close to the cool star when its mass-loss rate via the wind is small relatively to the flux of ionizing photons from the hot star (bottom) and moves towards the hot stellar source with increasing mass-loss rate (middle) until we get an oval shaped ionized nebula around the hot star (up).

Method: First, we corrected the observed UBV magnitudes for the interstellar extinction and the influence of emission lines (see Skopal, 2007). Then we derived a series of equations, which describe contributions from the hydrogen nebula and the giant within the photometric UBV passbands. In this way, and knowing the spectral type of the cool giant allowed us to derive the electron temperature, T_e, and emission measure, *EM*, of the symbiotic nebula, and the brightness of the cool giant (e.g. in the V passband). The electron temperature of the nebula can be determined from the equation

$$\frac{\varepsilon_B(T_e)}{\varepsilon_V(T_e)}\left[10^{-0.4(V^{cont}+UB-q_B)} - 10^{-0.4(U^{cont}-BV-q_B)}\right] + \\ + \frac{\varepsilon_U(T_e)}{\varepsilon_V(T_e)}\left[10^{-0.4(B^{cont}-BV-q_U)} - 10^{-0.4(V^{cont}-q_U)}\right] + \qquad (2) \\ + \left[10^{-0.4(U^{cont}-q_V)} - 10^{-0.4(B^{cont}+UB-q_V)}\right] = 0,$$

where $\varepsilon_U, \varepsilon_B, \varepsilon_V$ are volume emission coefficients, which depend on the electron temperature of the nebula, U^{cont}, B^{cont}, V^{cont} are magnitudes of the continuum, *UB* and *BV* are U-B and B-V indices of the cool giant, and the constants q_U, q_B, q_V defines the magnitude zero for different filters. The derivation of this equation can be found in Cariková & Skopal (2010). The emission measure of the nebula (for distance *d* of symbiotic system) and brightness of cool giant are given by e.g.

$$EM = 4\pi d^2 \frac{F_V^{nebula}}{\varepsilon_V}, \qquad (3)$$

$$V^{giant} = -2.5\log\left(10^{-0.4\left(V^{cont}+q_V\right)} - F_V^{nebula}\right) - q_V, \qquad (4)$$

where

$$F_V^{nebula} = \frac{10^{-0.4\left(BV+V^{cont}+q_B\right)} - 10^{-0.4\left(B^{cont}+q_B\right)}}{10^{-0.4\left(BV+q_B-q_V\right)} - \dfrac{\varepsilon_B(T_e)}{\varepsilon_V(T_e)}}. \qquad (5)$$

III. Application to selected symbiotics

We applied the method to the 1994 eclipse, observed during the 1989–1995 active phase of AX Per, active as well as quiescent phase of AG Dra, and a quiescent phase of Z And. Results are shown in Fig. 3. More examples can be found in Cariková & Skopal (2010). During quiescent phases we found the electron temperature of the symbiotic nebula T_e ~ 20 000 K, while during active phases our method indicated higher values of T_e ~ 30 000 – 40 000 K. During quiescence the emission measure was in the order of ~ 10^{59} cm^{-3}, while during activity we identified its increase to ~ 10^{60} cm^{-3}.

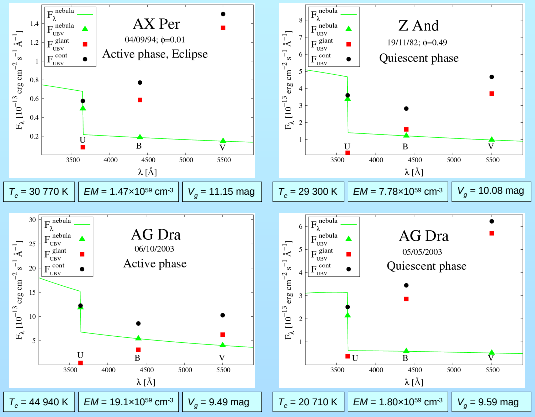

Figure 3 The UBV SED for selected symbiotic stars. The UBV fluxes in the continuum, and their disentangled components from the nebula, and the giant, are denoted by symbols in the legend. The nebular continuum is drawn with a solid line.

IV. Conclusion

In this contribution we presented a method of disentangling the composite spectrum of the optical continuum on the basis of simple multicolour (UBV) photometric measurements. Our method allows us to determine the physical parameters of the main contributing components of the radiation within the optical region – the nebula and the giant. Our model parameters are well comparable with those determined independently by another method, e.g. by a precise modelling the UV-IR SED as introduced by Skopal (2005). This approach thus provides a good estimate of the physical parameters of contributing sources of radiation within the optical on the basis of a simple UBV photometry. Finally, we note that our method of disentangling the UBV magnitudes can be applied to any spectrum composed from a nebular and stellar component of radiation.

Acknowledgement

This research was supported by a grant of the Slovak Academy of Sciences, VEGA No. 2/0038/10.

References

Cariková, Z., Skopal, A., 2010, New Astronomy 15, 637
Seaquist, E. R, Taylor, A. R., Button, S., 1984, ApJ 284, 202
Skopal, A., 2005, A&A 440, 995
Skopal, A., 2007, New Astronomy 12, 597