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What is the structure of the symbiotic nebula in AX Persei?

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Abstract. We present high-resolution optical spectroscopy and UBV photometry of the eclipsing symbiotic binary AX Per during its transition period from the active phase to quiescence.

Spectroscopic observations made at the middle of 1992.8 and 1994.7 eclipses revealed that a significant part of the flux emitted in the H I, He II, but also in the nebular [O III] lines originates at a vicinity of the hot star, within the radius of $\sim 100\,\mathrm{R}_\odot$ from its center. Our observation contrasts strongly with the current opinion, according to which nebular lines originate only at further distances from the hot components in symbiotic binaries.

The presented observations have thus important implication for the real ionization structure of the nebula in AX Per. We suggest that the H I and He II emission originate in major part in a high-density region confined to the orbital plane around the accretor, and a part of the nebular [O III] emission arises in a low-density gas placed symmetrically above and below the orbital plane at the hot star. This view satisfies well theoretical calculations of the 3D flow structure of wind accretion in binary systems.

1. Introduction

AX Persei is an eclipsing symbiotic binary with the orbital period of 680 days (Skopal 1991). The cool component of the binary is a normal giant of the spectral type M4.5 (Mürset & Schmid 1999) and of the effective temperature $T_{\rm eff} = 3\,400\pm150$ K (Skopal 2000). Mikolajewska & Kenyon (1992) determined the mass ratio, $q = M_{\rm g}/M_{\rm h} = 2.4$, by solving the spectroscopic orbit of AX Per for both components. Mürset et al. (1991) derived the temperature of the hot component, $T_{\rm h}(\mathrm{in\ \ quiescence}) \sim 10^5$K and its luminosity, $L_{\rm h} \approx 710(d/2.6\,\mathrm{kpc})^2\,\mathrm{L}_\odot$.

For the orbital inclination $i = 90^\circ$ the giant's radius $R_{\rm g} = 102 \pm 3\,\mathrm{R}_\odot$ (Skopal 1994) and the distance $d = 1\,730 \pm 230$ pc (Skopal 2000). These quantities agree well with those obtained from empirically determined dependencies of effective temperature upon spectral type (cf. Belle et al. 1999, Skopal 2000). AX Per is a well detached binary (Ivison et al. 1993, Skopal 1994, Mürset & Schmid 1999).

The aim of this contribution is to present the standard UBV photometry and the optical high-resolution spectroscopy to point the problem of the geometric structure of the ionized region in AX Per.

2. Observations

2.1. Optical photometry

Photoelectric photometry of AX Per was performed at the Skalnaté Pleso and Stará Lesná Observatories. Our UBV measurements cover a transition period of AX Per from its recent (1989) active phase to the present quiescence, until 2000.7 (Fig. 1). Prior to JD 2 450 000 (1995.8), the minima – eclipses – were narrow with broader ingress/egress wings. The former feature implies the presence of a shell around the hot star, which developed during the outburst, while the latter obviously reflects simultaneous presence of a nebula extended around the hot component.

A drastic change in the light curve (LC) profile occurred after a brightening of about 0.6 mag observed at JD 2 450 000 (October 1995). The narrow minima developed abruptly in very broad waves. The change of the LC reflects a change in geometry and location of the main source of the optical continuum. Generally, this variation is connected with changes in the energy distribution of the hot star spectrum (Skopal 1998). The cool shell around the hot star was subject to expansion and dilution between the time of the last eclipse (JD 2 449 592) and the beginning of the wave variation (see Skopal et al. 2000 in more detail).

2.2. Optical spectroscopy

Our high-dispersion spectroscopy was secured at the Asiago and Okayama Astrophysical Observatories. Observations were taken during the post-outburst phase. Two spectra were allocated at the middle of eclipses: on 1992 October 13 (orbital phase $\varphi = 0.00$) and on 1994 August 20 ($\varphi = 0.99$). Other two spectra were made out of eclipses: on 1993 November 3 ($\varphi = 0.57$) and on 1994 December 12 ($\varphi = 0.15$). The spectrum from the post-outburst phase resembled that of a typical symbiotic spectrum of a quiescent phase. The line spectrum was characterized by strong emissions of H I, He I, He II, [O III], [Ca V], [Fe VI], [Fe VII] and N III. The lines of [O III], He I and He II exhibited single narrow profiles. Numerous Fe I absorptions and TiO bands were also present.

3. Results

The main observational results of this contribution are shown in Figs. 1 and 2. Spectra taken at the middle of 1992.8 and 1994.7 eclipses showed that about 60, 40 and 80% of the flux emitted in the He II, nebular [O III] and Hα lines, respectively, is subject to eclipse, and thus has an origin at the vicinity of the hot star. As the orbital inclination $i \sim 90^{\circ}$ (Sect. 1) and the spectra were taken just at the *middle* of both minima, the eclipsed portion of these lines creates around the hot star, within the radius corresponding to the giant's stellar disk, i.e. $102 \pm 3\,R_{\odot}$.

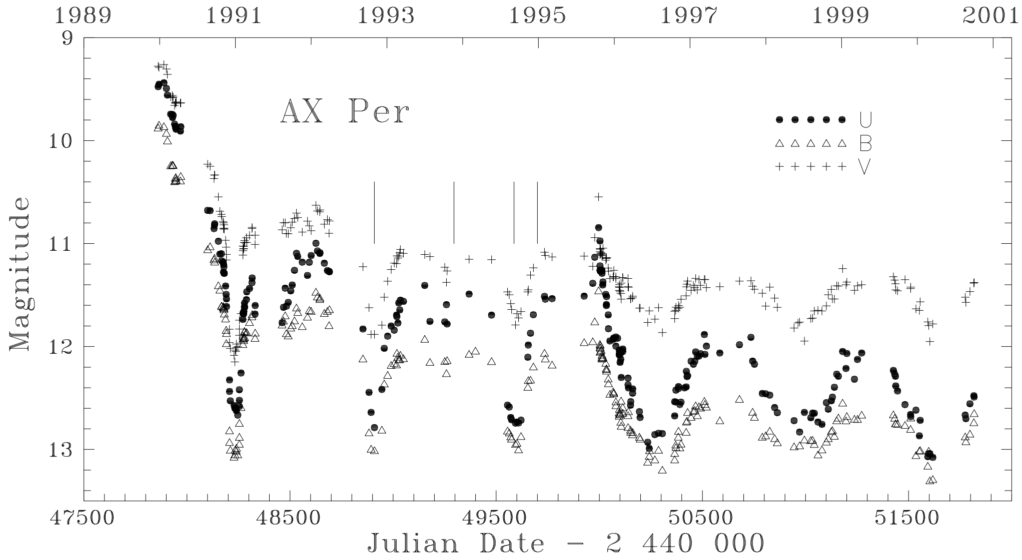

Figure 1. The UBV LCs of AX Per covering its transition period from the recent activity to the present quiescent phase. Our spectroscopic observations are marked by vertical bars. Note that two spectra were taken just at the middle of eclipses.

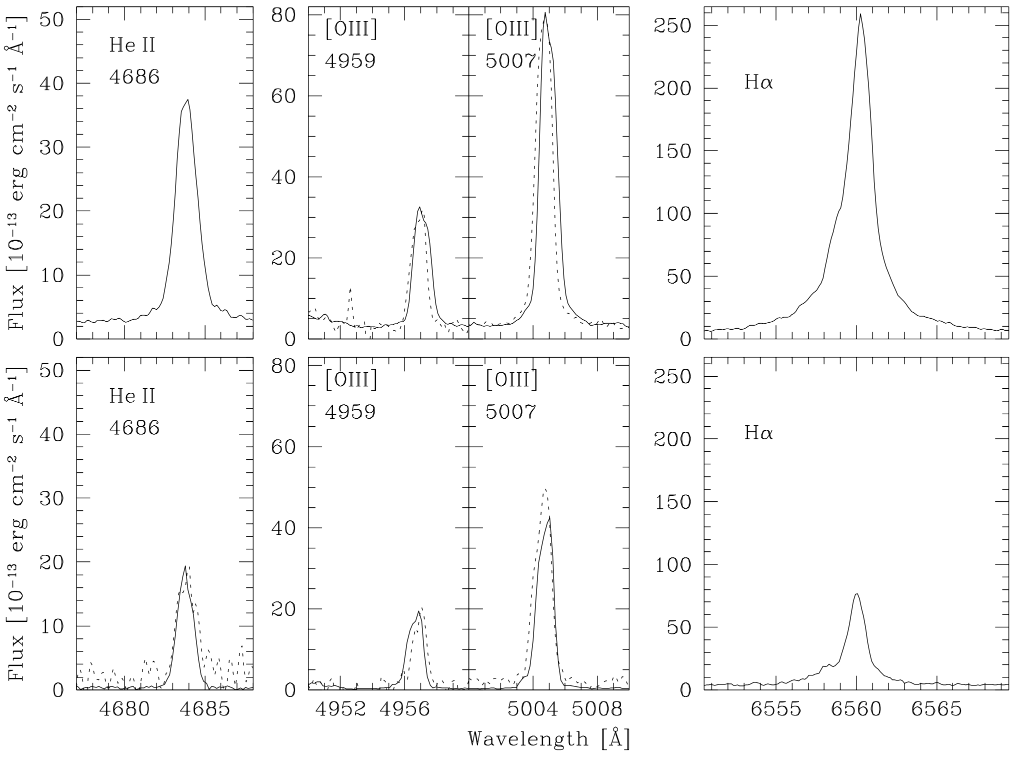

Figure 2. The line profiles of Hα, He II and [O III] in the AX Per spectrum. Top panels: Observations made *out* of eclipses on 1993 November (the solid line) and on 1994 December (dashed line). Bottom panels: Observations made *at the middle* of eclipses on 1994 August (solid line) and on 1992 October (dashed line). A significant decrease of emission in nebular lines implies their origin at the vicinity (to $r = R_{\rm g} = 102\,{\rm R}_{\odot}$) of the hot star.

The H II and [O III] emission regions are very different in the particle concentration – n_e(H II)$\sim 3\times10^9\,\mathrm{cm}^{-3}$ around the hot component and n_e([O III])$\sim 10^7\,\mathrm{cm}^{-3}$ (Skopal et al. 2000). However, a significant fraction of their emission measures comes from a small zone around the hot star (they are subject to eclipse). Our observation contrasts strongly with the current opinion, according to which nebular lines originate only at further distances from the hot components in symbiotic binaries. Thus the problem states: "How it is possible that the regions, different significantly to each other in the density, can co-exist in a close vicinity of the hot star". Generally, our observations imply a complex structure of wind accretion around the hot component. A better insight into this problem is outlined by a three-dimensional numerical simulations of the wind-driven accretion (Theuns & Jorissen 1993), which suggests a high-density region confined to the orbital plane – the H I and He II emission could originate in major part here. In the model, a low-density gas is placed symmetrically above and below the orbital plane around the accretor (at $\sim\pm0.3\,A$) – a part of the nebular [O III] emission then could arise here.

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