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# Spectral Observations of Z Andromedae during Its 2000 Active Phase

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**Abstract.** High resolution CCD data were taken in the H$\gamma$ and He II 4686 lines of the symbiotic binary Z And during its quiescent and active phases at the end of 2000. Typical features in the spectrum during the active phase were the greater number of the emission lines and their increased width compared with the quiescent state. The He I triplet lines had blueshifted absorption components, which are supposed to appear in the expanding photosphere (pseudophotosphere) of the hot secondary of the system during the active phase. The absence of the absorption components of the singlet lines is probably due to the close similarity between this pseudophotosphere and the photospheres of some O stars whose UV flux at wavelengths less than 504 Å is partly blocked by their metal lines.

## 1. Introduction

Symbiotic stars are a group of eruptive variables whose optical spectrum is characterized by absorption features typical of late-type giants and numerous emission lines of moderate to high excitation. Z And is considered as a prototype of the symbiotic class. This system consists of a normal cool giant of spectral type M3.5 and a hot compact object with temperature higher than $10^5$ K (Fernández-Castro et al. 1988). It has undergone a great number of active phases, the last of these being in 2000–1. Optical high resolution spectroscopy is of great importance to examine the dynamics of the circumbinary symbiotic nebulae; moreover, in some cases it provides a possible indication of the behavior of their hot components. The spectral images acquired by us during the 2000 outburst of Z And revealed deep absorption components of the helium triplet lines, which are supposed to indicate an expanding photosphere (pseudophotosphere).

## 2. Observations

The regions of the H$\gamma$ and He II 4686 lines were observed on four nights with the Photometrics CCD camera mounted on the coudé spectrograph of the 2 m RCC telescope of the National Astronomical Observatory Rozhen. The spectral resolution was 0.2 Å/pix on all occasions. The spectra were obtained on 1999 January 7 at the quiescent state of the system and on 2000 November 17, and

2000 December 5 and 6 (the maximum of the light) during its outburst. The IRAF package was used for data reduction.

## 3. Analysis of the Spectrum

The most intense emission lines in the regions observed by us during the 2000 outburst were those of the elements H I, He I, He II, N III, C III, the forbidden O III line $\lambda$ 4363 Å, and numerous Fe II lines. A characteristic common to almost all of them was their great width (FWHM), which was increased compared to that of the quiescent state of the system (see Figure 1).

The absorption spectrum of Z And during the active phase consisted of metal lines and molecular bands belonging to its cool giant and strong absorption components of the He I triplet lines with wavelengths $\lambda\lambda$ 4471 Å and 4713 Å (Figure 1). The He I 4471 line reached a residual intensity of 0.46 in November and 0.60 in December. Since the contribution of the cool giant's continuum at the same time was about 0.07–0.08 of the total continuum of the system at the wavelengths of these lines (Tomov, Taranova, & Tomova, in preparation), their appearance can be related to the hot companion. The absorption components were shifted to the short wavelength side and could be considered as belonging to P Cyg-type line profile. The P Cyg profile indicates radial flow of the gas from the star (stellar wind). If there was a stellar wind of the companion at that time, the absorption components of the He I singlet lines as well as the hydrogen lines would be expected too, but they were not observed.

Let us consider the absorption lines as not related to the emissions and suppose they are purely photospheric lines. Their radial velocities are about $-60$ km s$^{-1}$ and are related to orbital phases, close to the spectral conjunction where the radial velocity of the hot companion is close to 0 km s$^{-1}$ (Mikołajewska & Kenyon 1996). (We emphasize that the absorption negative velocity of about $-60$ km s$^{-1}$ is based of all of our three spectra, but in November it was a little less than this value and in December a little more.) In this case, only the supposition can be made that the companion's photosphere has been expanded, and that we have observed an ejected shell of material (pseudophotosphere).

It is necessary also to explain the lack of helium absorption singlet lines in the spectrum. Helium is ionized from its ground level by radiation at wavelengths less than 504 Å. According to the plane–parallel photosphere model of Herrero, Puls, & Villamariz (2000) some part of the flux energy in the UV region 228–912 Å of the spectrum of the high luminosity O stars, having $T_{\rm eff} = 40\,000$ K, $\log g = 3.4$, and a helium abundance $a({\rm He}) = 0.09$, is blocked by their metal absorption lines. Because of this line blocking the ionization from the ground level of He I is considerably reduced and its population increases greatly. The connection of the singlet system of transitions to the ground level (which also belongs to this system) is different from that of the triplet system. The increased population of the ground level causes reduced absorption of the flux in the singlet lines of these stars compared with their triplet lines. This model is in agreement with the observed spectra of stars with $T_{\rm eff} \gtrsim 40\,000$ K, $\log g \sim 3.5$–3.8, and $a({\rm He}) = 0.07$–0.25, whose helium singlet lines are very weak or absent.

We will assume that physical conditions in the supposed pseudophotosphere are close to those in O-type photospheres if its temperature and the gravity

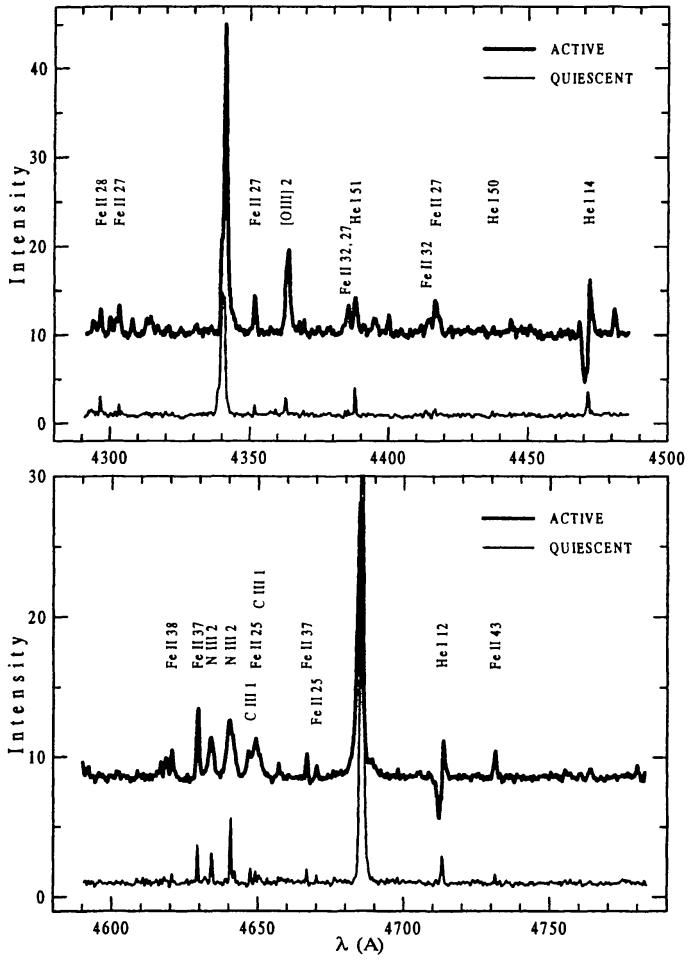


Figure 1. The Hγ and He II 4686 spectral regions of Z And. The spectra were normalized with respect to the local continuum, which was fixed taking into account the TiO molecular bands. The quiescent continuum corresponds to unity. The ratio of the continuum levels is equal to the ratio of the energy fluxes at the average wavelength.

acting to it from the star are also close to those of O stars. The observational fact of the He II 4686 line in the spectrum during the active phase as well (Figure 1), even though its flux has decreased, means that the temperature of the hot companion remains comparatively high (its quiescent temperature was found to be about 110 000 K by Fernández-Castro et al. 1988 and Mürset et al. 1991) and is probably not lower than that of O stars. The other parameter is the stellar gravity. If the compact companion has a mass of 0.5 $M_{\odot}$ (Mikołajewska & Kenyon 1996) and its pseudophotosphere is at a distance of 1 $R_{\odot}$, the gravity will be $\log g = 4.1$. However, the (pseudo)photospheric density is function of both the stellar gravity and the gas pressure. The gas pressure can expand the pseudophotosphere in both the outward and inward radial directions, and this possibility can contribute to the equalization of its density with the densities of the O photospheres. That is why we assume that its physical conditions can

be close to those of O-type photospheres, and probably for that reason only the absorption components of the helium triplet lines are present in the spectrum of Z And. It is worth noting that similar absorption components (in He I 4026 and He I 4471) have been observed in PU Vul (Tomov et al. 1991). From the above considerations they probably have the same origin.

The O stars also have emission lines of highly ionized elements, such as He II, N III, and C III, emitted in their wind region. If the absorption helium lines indicate a pseudophotosphere of the hot companion of Z And, we may also suppose that the remarkable variations in the profiles of the same lines in the spectrum of this star during the active phase (Figure 1) are partly caused by the presence of wind-emission components also connected with this pseudophotosphere. The H$\gamma$ line of O stars is an absorption line. In the spectrum of Z And it is purely in emission but its width was decreased during the active phase. One possibility for the decrease in the width could be filling the pseudophotospheric absorption by photons from the circumbinary nebula.

## References

Fernández-Castro, T., Cassatella, A., Giménez, A., & Viotti, R. 1988, ApJ, 324, 1016

Herrero, A., Puls, J., & Villamariz, M. R. 2000, A&A, 354, 193

Mikołajewska, J., & Kenyon, S. J. 1996, AJ, 112, 1659

Mürset, U., Nussbaumer, H., Schmid, H. M., & Vogel, M. 1991, A&A, 248, 458

Tomov, T., Zamanov, R., Iliev, L., Mikołajewski, M., & Georgiev, L. 1991, MNRAS, 252, 31P

# Part 3

# Evolutionary Paths to and from Symbiotic Stars and Related Objects