MODEL OF THE SYMBIOTIC STAR EG ANDROMEDAE

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ABSTRACT. Based on the new spectroscopic and photometric data, a model of the symbiotic star EG And has been worked up. New orbital elements were derived. An external envelope closed to the EG And system and rotating with it has been suggested to explaine strong phase dependend variations of the spectrophotometric parameters and radial velocities of the emission H_γ line as well as the two minima in the U light curve.

1. INTRODUCTION

Symbiotic star EG And is a low excited binary consisting of an M2 III semiregular variable primary and a hot secondary surrounded by a common envelope. Optical spectrum is characterized by the M giant spectrum, emission hydrogen lines and nebular [Ne III] and [O III] lines. Very strong variations both in intensity and radial velocity of the Balmer lines were observed (e.g. Martini, 1968; Mammano and Martini, 1969). Smith (1980) proposed a period of 470 days for the changes of strength an radial velocity of H_α emission line. Stencel (1984) found the UV continuum variability that might be related to the 470 days periodicity. He interpreted these changes by an eclipse-like effect. Oliversen et al. (1985) studied the high-dispersion IUE and optical spectra. They interpreted the remarkable emission line strength and profile variations as indication of the partial eclipse of the hot component with surrounding nebula by the M giant. Chochol et al. (1987) confirmed an eclipsing nature of the system and derived new ephemeris $JD_{min} = 2446\,336.7 + 474 \times E$ from UBV observations and variations of the H_γ line profile. New UBV photometry and radial velocity analysis (Skopal et al., 1988) confirmed the minimum in the U light curve and gave the new orbital period of 481.7 days. Recently, Munari et al. (1988) using new echelle spectrograms derived independently practically the same value, 481.2 days.

2. OBSERVATIONS

Spectroscopic observations taken on the years 1966 - 1987 consist of 44 spectrograms covering the optical spectrum region. 35 spectra have been carried out at the Asiago Astrophysical Observatory. They were obtained at Cassegrain focus of 1.22 m telescope with a prism spectrograph equipped with a Carnegie-RCA S-20 image intensifier operated at a reciprocal dispersion of 6 nm/mm at H_γ. 6 spectra were obtained with a Canadian Copernicus spectrograph, mounted in the F/15 focus of the 90 cm Schmidt-Cassegrain telescope of the Toruň Observatory. 3 spectra were obtained in the coudé focus of the 2-m telescope of the Astronomical Institute at the Ondřejov Observatory.

UBV photometry was obtained by single channel photoelectric photometer installed in the Cassegrain focus of 0.6 m telescope at the Skalnaté Pleso Observatory. The star HD 3914 was used as a comparison star.

3. RESULTS AND DISCUSSION

The radial velocities of the absorption neutral metals are shown in Fig. 1.

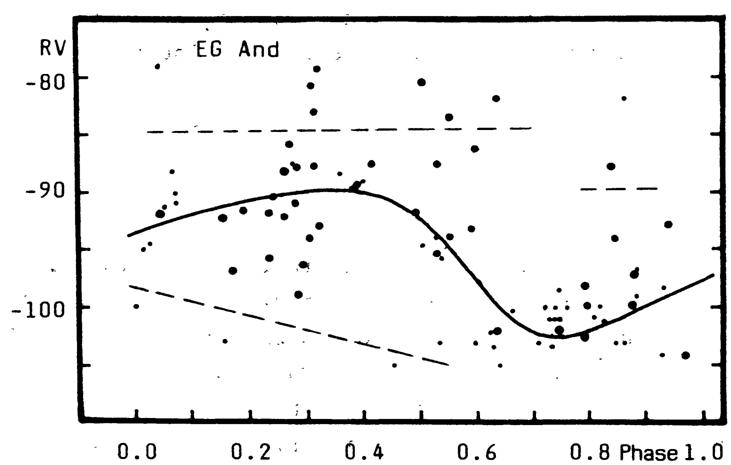

Fig. 1. Radial velocities of the absorption components of neutral metals: • - our observations, ∙ - data taken from literature. The data (12 values) out of the broken lines were omitted in our analysis.

The values around the phases 0.3 and 0.5 (12 values) do not reflect the orbital motion, so they were omitted in our analysis. The other data were analysed by the Simplex method of the least square minimization. New elements of the spectroscopic orbit have been determined (Table 1). The small value of the mass function does not enable us to suppose the orbit's plane inclination to be 90 degrees: A possible orbit's inclinations for mass of the secondary component 0.5 $M_{\odot}$ (white dwarf?), mass ratio between 2 and 5 and mass function 0.011 give values between 36 and 68 degrees, although the U light curve exhibits two deep minima (Fig. 2). Moreover, the time positions of these minima are in good agreement with the time positions of the star's conjuction determined by our orbital elements (the differences are about 13 and 16 days for primary and secondary minimum respectively). This fact proof reality of the orbital geometry as well as the primary and secondary eclipse-like effect.

Table 1

ORBITAL ELEMENTS OF EG ANDROMEDAE

Period	P = 482.2 ± 0.6 days
Eccentricity	e = 0.29 ± 0.07
Periastron angle	$\omega = 118^{o} \pm 15^{o}$
Periastron passage	T_0 = JD 2442 290 ± 17
Semiamplitude	K = 6.35 ± 0.43 km/s
Gamma velocity	V_0 = -95.2 ± 0.3 km/s
$a_1 \sin i$	= 57.8 $R_{\odot}$
Mass function	f(m) = 0.011 $M_{\odot}$

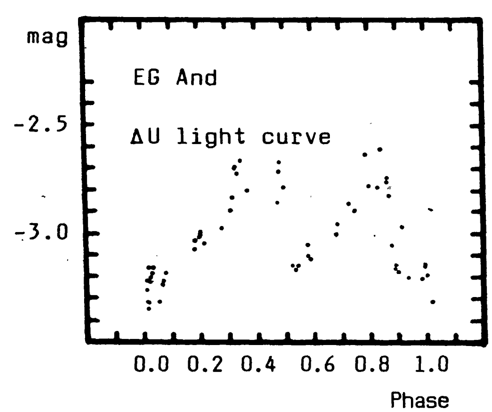

Fig. 2. Phase diagram of ΔU magnitude. The minimum observed between the phases 0.5 and 0.6 corresponds to the time of secondary conjunction of the binary.

Relative intensities of the emission component of H_γ line and the equivalent width of its absorption component and radial velocities of the emission hydrogen lines (H_α, H_γ, H_δ) are shown in Figs. 3 and 4. The strong phase dependence of these parameters is very important.

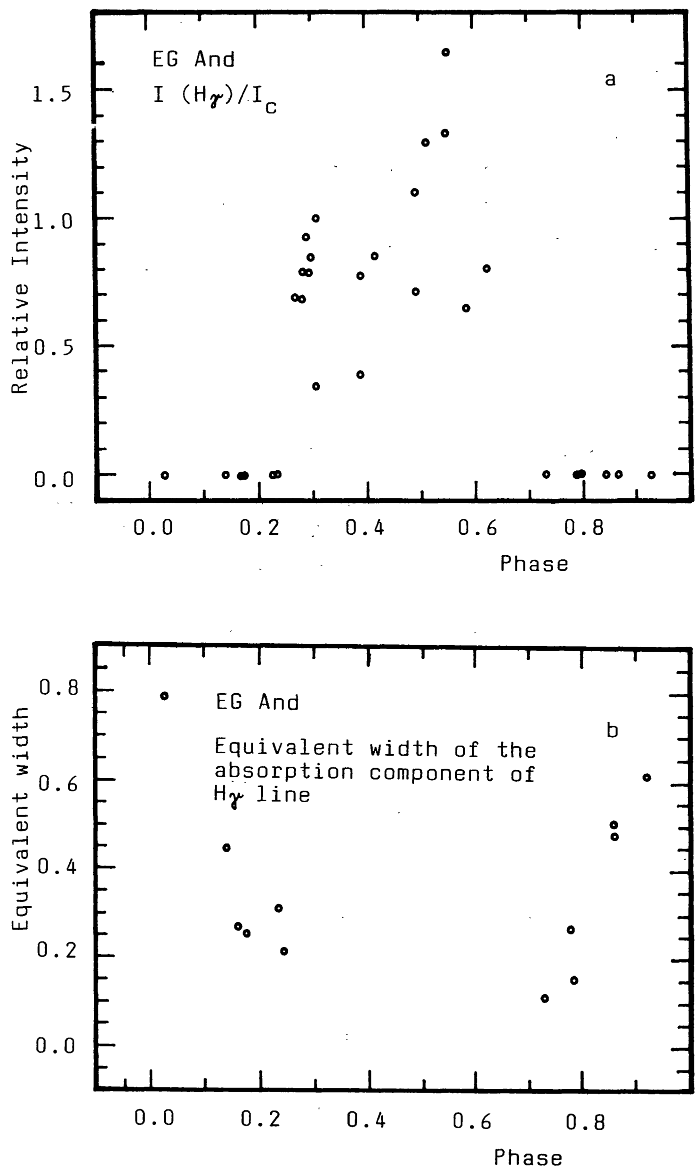

Fig. 3. Spectrophotometric parameters of H_γ line.
a) Relative intensisty. I_c is the local continuum intensity.
b) Equivalent width of the absorption component of H_γ line.

The behaviour of the spectrophotometric data, radial velocities of the emission hydrogen lines as well as the shape of the U light curve suggest the existence of an external envelope closed to the EG And system and rotating with it. The radiation of the binary components is transferred by this envelope. The long-term light variations are given mainly by the shape of the envelope and orbit's geometry. The observed trend of the U light curve reflects a symmetry of that envelope (Roche geometry corresponding to the equipotential surrounding the whole mass of the system?). The opacity of the envelope's material in the line of sight depends on the orbital phase of the binary. Let us assume that only hot component can more significantly contribute to the ionization of the hydrogen atoms. Then, the larger value of the optical depth between the phases 0.7 to 0.3 (the cool component's side) implicate creation of the absorption components of H_γ line. In binary positions between the phases 0.3 and 0.7 (the hot star's side) only the emission components were observed. The smaller values of the optical depth of the envelope's material at the binary phases between 0.3 to 0.7 can be caused by the smaller geometrical thickness in the direction of the line of sight, lower density of the envelope's material caused probably by a stellar wind of the hot star and the higher density flux of the ionization radiation at the vicinity of the hot source.

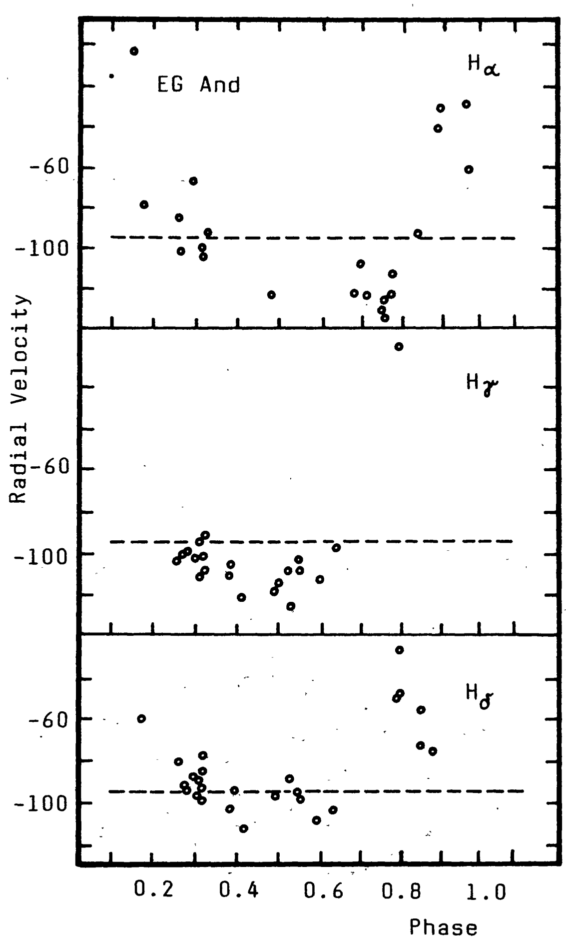

Fig. 4. Radial velocities of the emission hydrogen lines. H_α line: according to data published by Smith (1980), H_δ, H_γ - our observations.

Radial velocities of the emission hydrogen lines are influenced by that envelope too. The resultant shift of the hydrogen emission lines will be determined by the combination of the orbital motion of the hot component and the dynamics of the envelope's material. But neither dynamics and the geometry of that envelope nor the semiamplitude of the radial velocity curve of the hot component are known individually. Perhaps, a simple revolving matter around the system might be assumed as the first approximation to fit the resulting radial velocity curve of the emission hydrogen lines.

On the other hand, the relative intensities of the nebular [O III] 436.3 nm line and its radial velocities indicate the existence of an extended and stable nebular envelope around the whole EG And system.

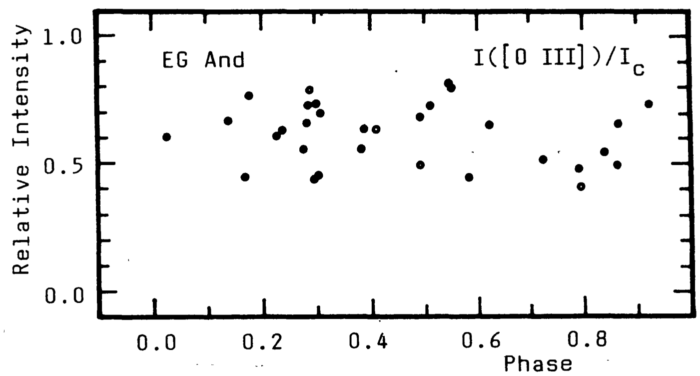

Fig. 5. Relative intensity of [O III] 436.3 nm line.

This interpretation is schematically shown at the Fig. 6 as the new working model of this symbiotic star.

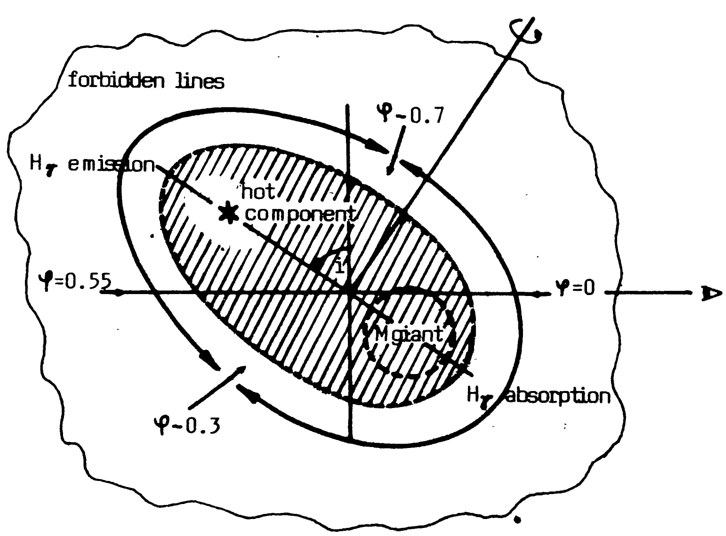

Fig. 6. Schematic picture of our new working model of the symbiotic star EG And.

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