Remarks on Photometric and Spectroscopic Variations of the B9p Star ET And [*]

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Abstract. The B9p star ET And (HD 219749) shows light and radial velocity variations with periods in scales of months (Ouchrabka, Grygar), days (Hildebrandt, Hempelmann), hours (Hildebrandt, Hempelmann, Panov), and minutes (Panov), the origin of which and their mutual relationship being very puzzling. In order to bring light into this muddle of periods, the authors – together with K.P. Panov of the Bulgarian National Observatory – carried out simultaneous photometric and spectroscopic observations, which allowed to determine the phase relation between radial velocity and light variations. The striking result was, that the relation of the periods in the hour-scale proved to be exactly 2:1. Discussing the results, the possibility of pulsations in the order of minutes to hours is considered but assessed as hardly probable. More probable seems to be an orbital motion in a binary system with excitation of tides, which produce nonradial pulsations with the expected characteristic frequency given by the physical parameters of the star.
(Abstract - added in 2007 to the article, which has been scanned from a reprint of the conference-book.)

Key words: Chemically peculiar stars, radial velocity, short-periodic variations, star: ET And

1. Observational results

The interesting B9p star ET And (HD 219749) shows remarkable light and radial velocity variations. But, comparing the various observational results, no clear decision about their physical origin can be made. Light variations are known in time scales of

1.61883 days ($\triangle m$ = 0.04 mag), HILDEBRANDT and HEMPELMANN (1981); the changes are most probably produced by the rotation of the star;

0.125 days ($\triangle m$ = 0.02 mag), HILDEBRANDT and HEMPELMANN (1988): surprisingly, recent observations in B and V exhibited a period of about 180 minutes and an extremely high amplitude;

0.097 days ($\triangle m$ = mag), PANOV (1978); the light variations occur with the same amplitude in U, B, and V, and are synchronous in phase;

9.3, 7.5, and 5.8 minutes ($\triangle m$ = 0.002 mag), PANOV (1984); unfortunately, these periods are not yet unequivocally determined, though their existence would be an important detail for the stellar model.

Radial velocity variations are established with time scales of

48.304 days, OUHRABKA and GRYGAR (1979), certainly produced by binary motion ($e \approx$ 0.5, $K \approx$ 26 km/s). On the one hand, lines of C IV, N IV, and Si IV indicating velocities as high as 500 km/s, RAKOS (1981), the variations of the $v \sin i$ values, BARYLAK and RAKOS (1983), and the existence of a $Balmer$ progression during the periastron passage, SCHOLZ, GERTH, and PANOV (1985), give a hint of the presence of an expanding envelope and, on the other side, reasons for

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calling in question the earlier derived binary elements e and K;

0.19771 days (amplitude 8 km/s), Gerth, Scholz, and Panov (1984); simultaneous photometric and spectroscopic observations allowed determining the phase relation between the radial velocity and light variations and improving the photometric period from 0.097 days to 0.0989 days, which is exactly half the radial velocity period.

2. Discussion

For the interpretation of the observational facts an important aspect is the evolutionary stage of ET And. By using different spectroscopic methods one obtains an absolute visual magnitude of about $M_v \approx$ -1.5, Scholz (1986); thus, a luminosity class III seems to be very probable. With a bolometric correction of -1.0 mag, mass and radius of ET And can be derived by using a mass-luminosity relationship based on evolutionary models including mass loss (Maeder 1980), log $M/M_\odot$ = -0.122 M_{bol} + 0.32, to $M/M_\odot \approx$ 4.2 and $R/R_\odot \approx$ 5.5.

From the mass function $F(M) \geq$ 0.048 the binary system can be restricted to a combination B9 III + GO V (or earlier). Furthermore, the stellar parameters of ET And rule out the possibility that the short-time variations are produced by the mechanical motion of a third and close companion.

Variations on a time scale of minutes indicated in light are difficult to explain since the acoustic cut-off frequency of an expanding (isotherm) gas is

$$\omega = \frac{\gamma g}{2s}, \tag{1}$$

with s the speed of sound, γ the ratio of specific heats, and g the acceleration due to gravity.

Assuming plausible atomic and stellar values of ET And, one finds that the critical period below which standing atmospheric oscillations are impossible, is $P \approx$ 35 minutes. Even if one takes into account the errors in atomic and stellar parameters as well as one considers that the value g could be affected by contributions of rotation, radiation, turbulence, and possibly a magnetic field, it seems hard to obtain periods of about ten minutes. As highly ionized atoms were found in the atmosphere of ET And, the temperature is partly increasing. Thus, reasons for pulsations on a time scale of minutes could be similar to those of the sun rather than to those of Kurtz's magnetic pulsator for late Ap stars. In each case, the search for magnetic fields (an attempt has been made with the magnetometer in Zelenchukskaya, but still without definite results) and the investigation of the atmospheric structure would be an important task.

At present no final result on the nature of the pulsations, radial or nonradial, can be found. Concerning radial pulsations, one can estimate the fundamental radial period to

$$\log P = \log Q - 0.239 M_{bol} - 3 \log T_{eff} + 12.55. \tag{2}$$

Here, P is the theoretical period of pulsation, and Q is the corresponding pulsation constant. With $\log Q = -1.4$, M_{bol} = -2.5, and T_{eff} = 11000 K it follows that

$P \approx 0.42$ days.

In the radial velocity periodograms this period, though with a small amplitude, is distinctly present. Therefore, the radial velocity variations of 0.2 days happen in the first harmonic, and the light variations in the second one. The reason for such characteristics could be the binary nature of ET And.

According to Fitch (1976) one should remember that short pulsators in binaries (δ Sct stars) with $e \neq 0$ show only radial modes and tidal modulation, whereas in systems with $e = 0$ there exist nonradial modes and no tidal modulation. After that, binary nature and pulsation change together, maybe in the sequence: fundamental radial mode $\longrightarrow$ harmonics $\longrightarrow$ nonradial modes, or: $e \neq 0 \longrightarrow e = 0$. In consequence of the existence of tidal modulations, our observed pulsations could be tidally excited, too. Concerning nonradial pulsations for fast rotators, the observed periods of a nonradially pulsating star can be obtained by Ledoux's formula

$$f_{k,m} = f_{k,0} - m(1 - c_k)\omega - \frac{\omega^2}{2 f_{k,0}}, \tag{3}$$

where $f_{k,0}$ is the pulsational frequency of the nonrotating star, $f_{k,m}$ the observed frequency, and ω is the angular velocity of the star (c_k is a constant smaller than 1).

Corresponding to $m \neq 0$, the pulsational mode is a retrograde or prograde one. Setting for $f_{k,0}$ the characteristic frequency with the relation

$$\frac{1}{2 \int_0^R \frac{1}{s} dr} \approx \sqrt{\frac{G \cdot M}{R^3}}, \tag{4}$$

we get $f_{k,0} \approx$ 165 min. Thus, the variation in brightness of 180 min ($0.^d125$) could be the characteristic frequency of ET And. For an explanation of the $0.^d2$ RV variation and the $0.^d1$ light variation, one has therefore to assume the simultaneous excitation of a retrograde and prograde wave. With $m = +3$ and $m = -3$ it follows that $P \approx 0.^d17$ and $0.^d09$, respectively.

Considering the uncertainties of all stellar parameters, the agreement seems to be sufficient. It is, however, obvious that we cannot draw concrete conclusions concerning temperature and geometry effects or concerning the presence of orbital dependences.

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