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ON THE ORBITAL PERIOD CHANGES OF EG Cep

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EG Cep (BD +76°790, HD 194089, $V_{max} = 9.36$) was discovered by Strohmeier (1958) as an eclipsing binary with the orbital period of 0.5446 days. The shape of the light curve is typical of the β Lyr type with the minima depth 0.87 mag and 0.29 mag in V light.

EG Cep is a poorly observed binary. Its light curves were presented by Geyer (1961), Cochran (Wood, 1971), Van der Wal et al. (1972), Kaluzny & Semeniuk (1984) and Erdem et al. (1993). In the most comprehensive photometric study of EG Cep Kaluzny & Semeniuk (1984) determined the value of interstellar extinction as E(B−V) = 0.035 and the distance d = 120 pc. They used the intrinsic colour index $(B-V)_0 = 0.197$ to derive the spectral type A7 of the primary component, which is in disagreement with the spectral type A3 given in the HD catalogue. Etzel & Olson (1993) measured the half-width of the Mg 448.1 nm line and determined the projected rotational velocity of the primary component as $v_1 \sin i = 146$ km s^{-1}. Other spectroscopic observations of EG Cep are not available.

Photoelectric B and V light curves, analyzed by Kaluzny & Semeniuk (1984) with the Wilson & Devinney method, led to the mass ratio q = (0.45 - 0.50) and a semi-detached configuration with the $M_1 \sim 1.8$ M$_\odot$ unevolved primary and evolved secondary component. Their analysis of the O−C diagram revealed a continuous orbital period increase. The quadratic term of 0.820×10^{-10} days was explained by a mass transfer rate $\dot{M} = 10^{-7}$ M$_\odot$y^{-1} from the secondary to the primary component. Wolf & Diethelm (1992) determined the quadratic term as 0.782×10^{-10} days and noted that omitting the secondary minima, which are mentioned to be asymmetrical, two linear ephemeris are also suitable for explanation of the O−C diagram. Erdem et al. (1993) found the quadratic term to be 0.473×10^{-10} days.

The aim of this study is to present additional times of minimum light of EG Cep, improve its ephemeris formula and examine its orbital period changes.

The first set of our photoelectric observations of EG Cep was performed in 1983-84 using a multi-mode, nebular-stellar photometer attached to the 1.22 m Cassegrain reflector at the Kryonerion Astronomical Station (KAS) of the National Observatory of Athens, Greece. The B & V filters used are in close accordance to the standard UBV system. Estimated uncertainties of a single observation taken at the KAS were 0.008 mag and

Table 1. New times of minimum light of EG Cep.
The epochs were calculated using ephemeris (1)

Epoch	B		V		Obs.
	JD_{hel} 2 400 000+	σ [days]	JD_{hel} 2 400 000+	σ [days]	
34266	45591.44113	0.00003	45591.43957	0.00010	KAS
34268	45592.52767	0.00003	45592.52856	0.00034	KAS
34269.5	45593.34637	0.00014	45593.34689	0.00017	KAS
34914	45944.35676	0.00024	45944.35516	0.00028	KAS
34916	45945.44566	0.00012	45945.44395	0.00006	KAS
34919.5	45947.35141	0.00022	45947.34913	0.00010	KAS
43588	50668.41219	0.00021	50668.41180	0.00017	SL
43599	50674.40330	0.00028	50674.40337	0.00034	SP
43714.5	50737.31060	0.00060	50737.31000	0.00040	SL
43744	50753.37367	0.00039	50753.37436	0.00017	SL
43794	50780.60460	0.00070	50780.60473	0.00030	SP

0.010 mag in B and V passbands, respectively. The stars BD +75°737 (V = 9.5, sp. type A0) and BD +74°857 (V = 10.7, sp. type A2) served as a comparison and check star, respectively. The second set of EG Cep observations was obtained in 1997 at the Skalnaté Pleso (SP) and Stará Lesná (SL) observatories of the Astronomical Institute of the Slovak Academy of Sciences. In both cases 0.6 m Cassegrain telescope equipped with a single-channel pulse-counting photoelectric photometer was used. The accuracy of the SP and SL observations taken in B and V passbands was two times higher in comparison with the KAS data. The stars BD +76°791 (V = 9.2, sp. type K2) and BD +76°789 (V = 9.6, sp. type A0) served as a comparison and check star, respectively. Data reduction, atmospheric extinction correction and the transformation to the standard international system were carried out by usual way.

Our observations led to the determination of 11 new times of minimum light. We have calculated the times of minima separately from B and V observations using Kwee & van Woerden's (1956) method (Table 1).

In order to investigate the real period variations of EG Cep, we have collected all available times of minima from the literature and added our 11 times of minima (BV averages). Complete list of minima times is given in the paper by Chochol et al. (1998). They were used to construct the O−C diagram (Figure 1) applying the following ephemeris:

$$Min\ I = 2426929.4376 + 0.5446216 \times E. \quad (1)$$

To minimize the large scatter appearing in the observational material, mean values were calculated for all kinds of the observational data. Then, the period changes seen in the O−C diagram (Figure 1) are examined using the *classical* parabola as well as the new method proposed by Kalimeris et al. (1994).

a) In the first case, we get the following improvement of the ephemeris:

$$\begin{array}{llllll} \mathrm{Min\ I} = & \mathrm{JD_{hel}}\ 2\,426\,929.4575 & +\ 0.54461943 & \times E & +4.51 & \times 10^{-11} \times E^2. \\ & \pm 12 & \pm 10 & & \pm 19 & \end{array} \quad (2)$$

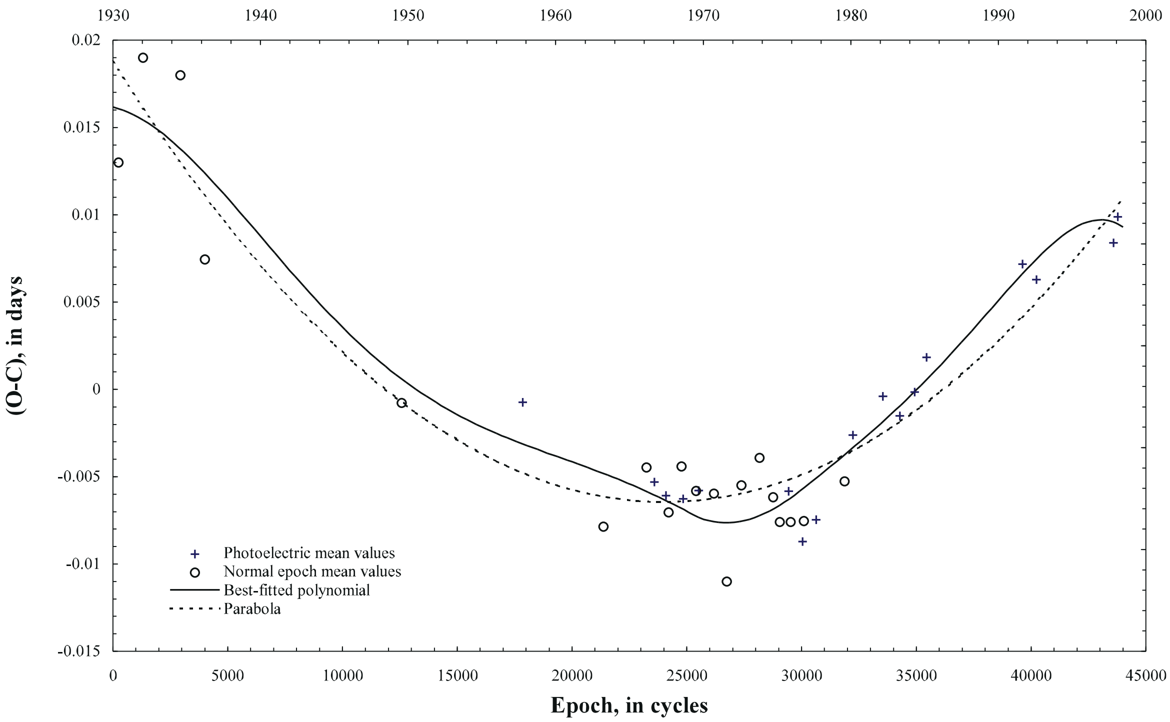

Figure 1. The O−C diagram of EG Cep

The larger value of the quadratic term in the parabolic ephemeris given by Kaluzny & Semeniuk (1984) and Wolf & Diethelm (1992), in comparison with the value published by Erdem et al. (1993) and our ephemeris (1), was caused by the fact that the first two authors omitted Strohmeier's (1958) observations.

b) Using Kalimeris et al. (1994) method, we described the O−C diagram of EG Cep piecewise (Figure 1), using two fourth-order polynomials and connecting their parts (descending and ascending branch) using a spline interpolant (Kalimeris et al., 1995). Then, it is easy to find the way the real orbital period P(E) of the system behaves. In Fig. 2, one can see the variation of the real period P(E) of EG Cep for the last 70 years. It is obvious from Figure 2 that a period jump of the order of $\Delta P = 2.023 \times 10^{-6}$ days occurred at E=27200 cycles corresponding to the year 1972.

The use of the *classical* parabola leads to a continuous increase of the period of EG Cep. On the other hand, one could use two linear fittings for the descending and ascending branches of the O−C diagram of the system and see that a sudden period increase occurred around the year 1972 (Chochol et al., 1998). The answer to what really happens is given using Kalimeris et al.'s (1994) method, as was applied here. Comparing the fittings of the O−C diagram of EG Cep we get from the parabola and from the piecewise description, the great gain is not immediately seen. This comes from the calculation of the real period P(E). Indeed, Kalimeris et al. (1994) method permits us to compute it in a simple and accurate mathematical way. Moreover, the jump in P(E), presented in Figure 2, does not only give the answer (i.e. that really a sudden period change has occurred), but we can also find when this has happened and how large it was. Finally, from a simple linear fitting –after period's jumping– we get the following linear ephemeris:

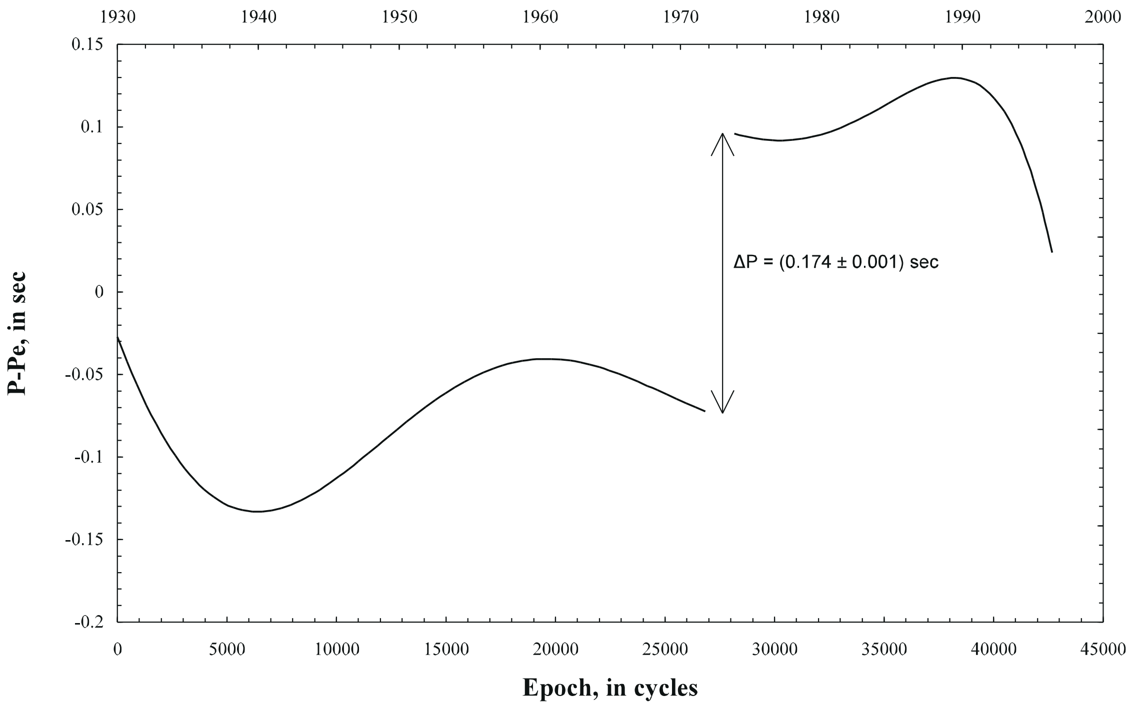

Figure 2. The real period variation of EG Cep

$$\text{Min I} = \text{JD}_{\text{hel}}\ 2\,426\,929.3987 \underset{\pm 20}{} + 0.54462272 \underset{\pm 6}{} \times E. \tag{3}$$

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