THREE-COLOUR PHOTOMETRY OF THE ECLIPSING BINARY EI CEPHEI

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Abstract. The photoelectric elements of the system EI Cephei have been determined in *U*, *B*, *V* colours. The absolute dimensions have been determined and some evolutionary aspects have been discussed. A modified period of $8^d.439334$ has been obtained. The system is a detached one.

1. Introduction

Preliminary spectroscopic elements of the system EI Cephei (=BD+75°791=HD 205234=Boss 5536=BV 203) were announced by Harper *et al.* (1935). The eclipsing nature of the system was established by Strohmeier (1960). A photoelectric light curve, obtained without filter, was analysed by Abrami (1966) who gave the light elements:

$$\text{Primary minima} = \text{JD } 2436820.4665 + 8^d.439365.$$

The observations of the system have been improved by us in the following respects:

(i) The photoelectric observations in *U*, *B* and *V* and the colour of the system have been presented for the first time.

(ii) The Roche constants, indicating the system to be a detached one, have been presented.

(iii) The possibility of the presence of a third body has been ruled out.

2. Observations

The star was observed photoelectrically on the 38-cm reflector of the Uttar Pradesh State Observatory on a total of 32 nights, during the period October 1968–December 1970. The light of the star was fed to an unrefrigerated 1P21 photomultiplier and the photocurrent recorded using d.c. techniques. The conventional *U*, *B*, *V* filters of Johnson and Morgan (1953) were used.

The particulars of the variable and the comparison stars are given in Table I.

The ranges of the standard deviations for the comparison star in *U*, *B* and *V* filters are $0^m.003$ to $0^m.026$, $0^m.001$ to $0^m.022$ and $0^m.002$ to $0^m.019$ respectively, with means as given in the last column of Table I. The median values of these standard deviations in *U*, *B* and *V* filters are $0^m.019$, $0^m.012$ and $0^m.016$ respectively.

The data were reduced to the standard system from the observations of 24 stars chosen as standard from the list of Johnson and Morgan (1953).

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TABLE I

Particulars of variable and comparison stars

Star	α_{1950}	δ_{1950}	M_V	Sp	Average standard deviation of the individual observation in U, B and V filters
EI Cephei = BD +75°791 = HD205 234	$21^h28^m42^s.578$	+76°11′02″.28	7^m.3	A	—
Comparison Star = BD+75°787	$21^h23^m05^s.348$	+76°20′15″.56	6^m.7	A	±0^m.017 (U) ±0^m.012 (B) ±0^m.013 (V)

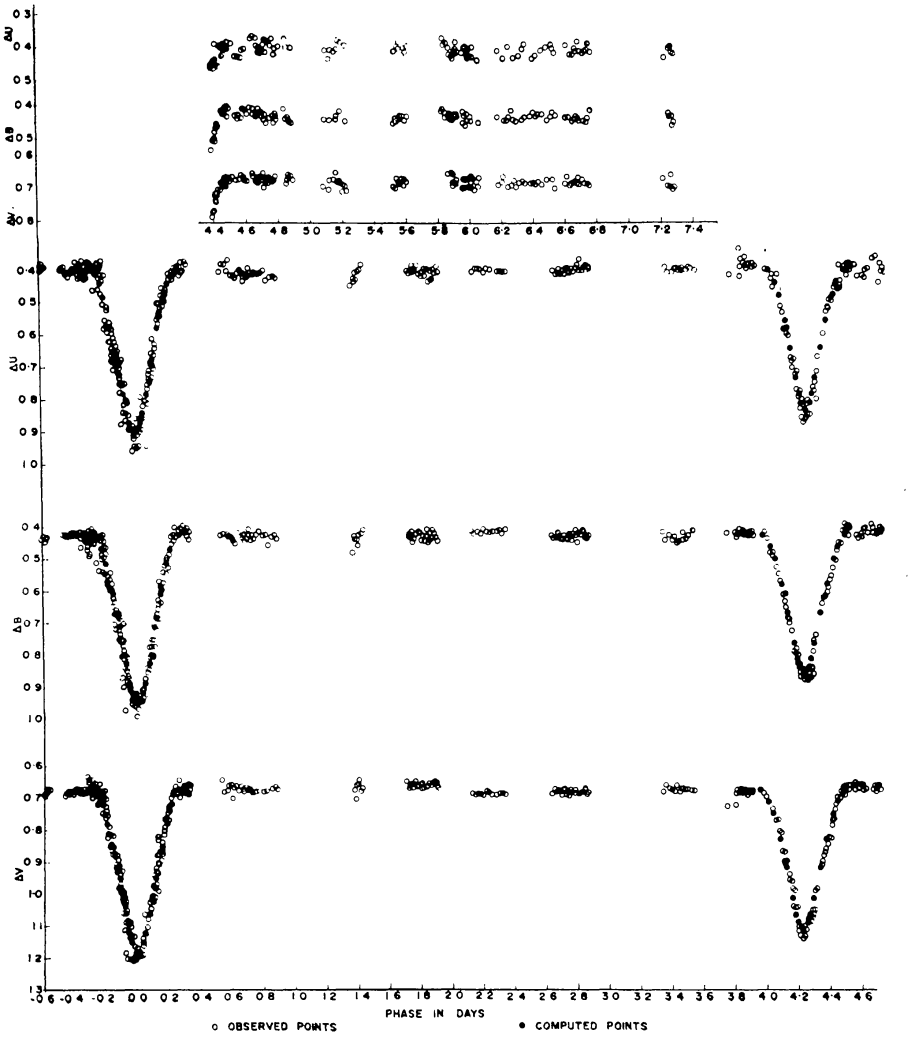

Fig. 1. Light curves of EI Cephei.

3. Epoch and Period

During the course of our observations two primary and two secondary minima were observed. The epochs, determined by the graphical method with an accuracy of $0^d.001$, are listed below:

Primary Minima, JD (Hel)	Secondary Minima, JD (Hel)
(1) 2440 542.214	(1) 2440 926.201
(2) 2440 525.333	(2) 2440 909.328

Based on the epoch of primary minimum, JD 2436 820.4665, given by Abrami (1966) a new period of $8^d.439334$, has been determined. The U, B and V light curves are given in Figure 1.

4. General Discussion of the Light Curves

The U, B and V light curves based upon some 530 observations in each colour are given in Figure 1.

In the computed light curves the primary minimum has depths of $0^m.501$, $0^m.528$ and $0^m.510$ in U, B and V filters respectively, while the secondary minimum has depths of $0^m.435$, $0^m.443$ and $0^m.443$ in these respective filters.

5. Determination of Elements

The χ-values have been determined from the smooth curves drawn through the observed points in U, B and V filters, and are listed in Table III. Since $\chi^{pr} > \chi^{sec}$, hence the primary eclipse is an occultation and the secondary eclipse a transit. After assuming the values of limb darkening $x=0.6$, the nomographic solutions indicate that the

TABLE II

Light elements of EI Cephei

$x=0.6$ (assumed)
$P=8^d.439334$
$k=0.90$
$\alpha_0^{oc}=0.71$
$\alpha_0^{tr}=0.83$

eclipses are partial. Since the χ^{pr} and χ^{sec} values are nearly equal, we have also tried a solution considering primary eclipse to be a transit and secondary eclipse to be an occultation. We find the fit is better in the former case.

The value of $k=0.90$ was arrived at after trials for computation of elements because the theoretical light curves computed on that basis agree well with the observations.

TABLE III

Geometrical elements of EI Cephei

Elements	U	B	V	Mean of the U, B and V filters
$1-\lambda_1$	0.370	0.385	0.375	
$1-\lambda_2$	0.330	0.335	0.335	
L_1	0.529	0.535	0.528	
L_2	0.470	0.466	0.471	
J_2/J_1	0.891	0.870	0.885	0.882
i	86°.4	86°.2	86°.4	86°.3
r_1	0.094	0.097	0.097	0.096
r_2	0.104	0.108	0.108	0.107
θ_e	10°.9	11°.3	11°.3	11°.2
χ^{pr}	0.313	0.321	0.311	
χ^{sec}	0.305	0.311	0.305	

The value of $k=0.90$ was given by assuming $1-\lambda_1=0.370$, 0.385 and 0.375 (in terms of the intensity outside the eclipse as unity) for U, B and V light curves respectively. The corresponding values for the secondary minimum are $1-\lambda_2=0.330$, 0.335 and 0.335 in these respective filters.

The elements have been derived with the help of Merrill's tables (1950) of the χ-function, the procedure described by Russell and Merrill (1952) having been followed. The values of α_0^{oc} and α_0^{tr} determined are 0.70, 0.72 and 0.71; and 0.82, 0.84 and 0.83 for U, B and V filters respectively. The photometric elements are listed in Tables II and III.

6. Existence of a Third Body and Eccentricity

Abrami (1966) obtained a solution assuming the existence of a third body with a contribution of 9% to the total light. However, in the present observations there seems no suggestion for the existence of a third body. The light outside eclipse (constant phase) shows no variations, and we could obtain a satisfactory solution without rectification.

Further, the spectroscopic elements given by Harper (1935) indicate that the system has an eccentricity equal to 0.039, but in the present observations the primary and secondary minima are equally spaced; also the duration of both the eclipses is the same. Hence we do not suspect the system of having any eccentricity.

7. Absolute Dimensions of the System

The absolute dimensions have been determined separately on the basis of the spectroscopic elements given by Harper (1935) and by Popper (1971). The parameters are listed in Table IV, where at first the spectroscopic elements obtained by Harper and Popper are listed and subsequently the absolute dimensions as determined by us on the basis of these elements are given.

TABLE IV

Elements of EI Cephei

Elements	Elements based on the work of	
	Harper	Popper
(a) Spectroscopic elements:		
$a \sin i$	26.7	26.4 ± 0.1
$m_1 \sin^3 i$	1.80	1.68 ± 0.03
$m_2 \sin^3 i$	1.79	1.78 ± 0.03
K_1	79.7	81.2 ± 0.5
K_2	80.3	76.9 ± 0.5
γ_1	−4.7	-1.2 ± 0.4
γ_2	—	-1.0 ± 0.4
(b) Absolute dimensions:		
$A(R_\odot)$	26.8	26.4
$R_1(\odot)$	2.9	2.8
$R_2(\odot)$	2.6	2.5
$m_1(\odot)$	1.8	1.7
$m_2(\odot)$	1.8	1.8
$\varrho_1(\odot)$	0.08	0.08
$\varrho_2(\odot)$	0.11	0.10

8. The Colour and the Evolution of the System

The average colour of the comparison star determined on six nights comes out to be $B-V=+0^m.609$ and $U-B=+0^m.108$. The colour of the system at the maximum phase (outside eclipse) is $B-V=+0^m.357$ ($\pm 0^m.015$) and $U-B=+0^m.083$ ($\pm 0^m.013$). To determine these colours, the values of the differential magnitudes B_v-B_c, etc., at maximum phase were first read out from the curves in Figure 1. Based on these, the differences $(B-V)_v-(B-V)_c$, etc., were formed. On adding the colour of the comparison star to these, the colours $(B-V)_v$ etc. of the binary system were deduced.

When the concerned values based on Harper's spectroscopic elements are plotted on (log m, log R) diagram, the position of primary and secondary components show that they are moderately evolved from the main-sequence (Figure 2). The values of the Roche constants have been obtained (Kopal, 1955) using Harper's spectroscopic elements, the value of C_0 having been read out from the tables, for the case $q=1.00$ (Kopal, 1959). The values of Roche constants ($C_0=4.00$, $C_1=10.6$, $C_2=11.5$) indicate that the system is a detached one.

9. Computed Points

The values of the computed points for the primary and the secondary minimum have been obtained by use of the relation

$$\sin^2 \theta(n) = \sin^2 \theta(1/2)\chi(x, k, \alpha_0, n),$$

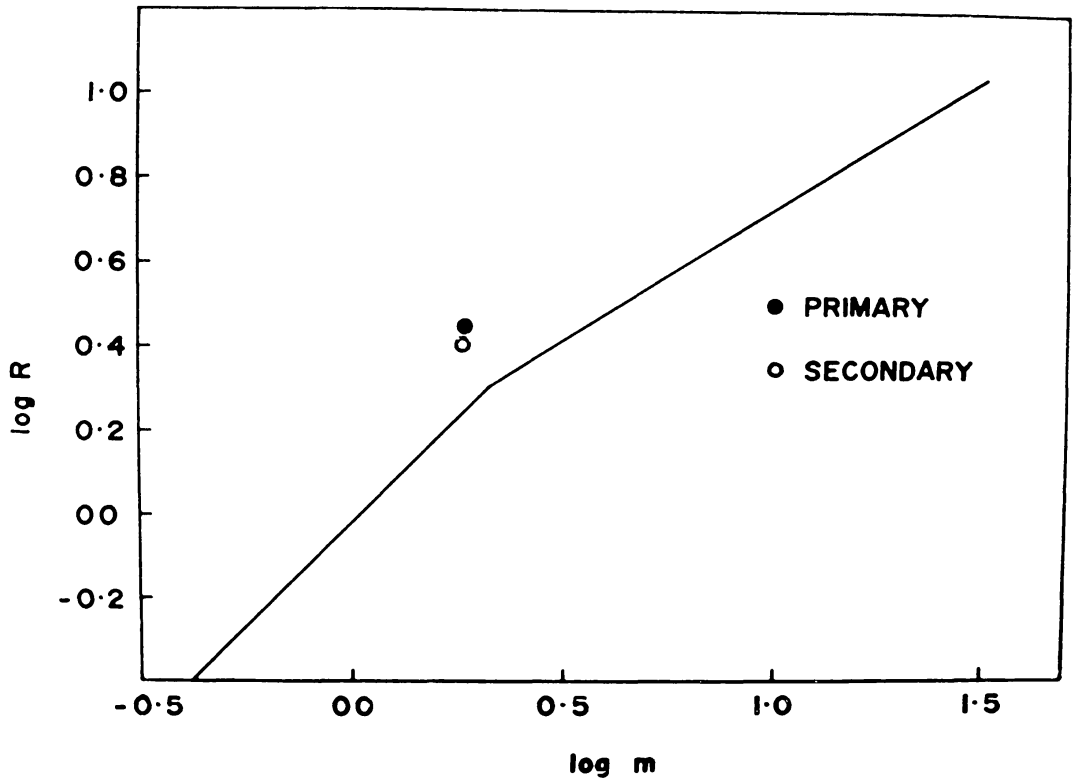

Fig. 2. Position of components of EI Cephei on mass-radius relation for the Main-Sequence stars (Kopal, 1955).

where θ is the phase and x is the limb darkening. The values of χ are determined from the individual light curves for each filter. These computed points for the primary and secondary minima are plotted as filled circles in Figure 1.

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