A PERIOD STUDY OF THE ECLIPSING BINARY GK CEPHEI

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Abstract

Several new determinations of times of minima based upon photoelectric measurements of the eclipsing binary GK Cephei are reported. These measurements, together with times of minima previously reported in the literature, permit an improvement to the ephemeris equation for GK Cep. Analysis of O-C residuals determined from linear ephemeris equations suggests a periodic oscillation with a period of 18.6 years. Inclusion of a sinusoidal term in the ephemeris equation with this period greatly improves the fit of the ephemeris equation with reported observations of times of minima.

1. Introduction

GK Cep (BV 382, BD+70°1183) is an eclipsing binary star of the W UMa type (Derman and Demircan 1992). Gleim (1967) reports both stars to be of spectral type A2. Light elements for this system were reported by Gleim (1967) and updated by Dworak (1975). Dworak's light elements are those tabulated by Hirshfeld and Sinnott (1985).

This star system was selected for study as part of an undergraduate research experience program at the University of North Texas Astronomy Observatory. A study of GK Cep was of interest due to reports of recent changes in its period by Niarchos, Rovithis-Livaniou, and Rovithis (1991), Derman and Demircan (1992), and Wolf and Diethelm (1992). Furthermore, Wolf and Diethelm (1992) and Derman and Demircan (1992) suggest the possibility of an oscillatory behavior in the light elements for GK Cep.

2. Observations

New observations of GK Cep were made to test for any changes in the light curves as predicted by the ephemeris equations published for GK Cep by Derman and Demircan (1992) and Wolf and Diethelm (1992). The observations to make this test were made on selected nights between 1993 October and 1994 January.

Observations were made with a 0.15 meter refractor, using a solid state PN photoelectric detector (model SSP-3) manufactured by Optec, Inc., to process the light signals. All measurements were made using a Johnson V filter. Magnitude determinations were made using differential photometry with 11 Cep as a comparison star and HD 205509

Table 1. Times of primary minima of GK Cep.

Epoch	*JD*
11343	2449313.604
11357	2449326.683
11374	2449342.638
11389	2449356.668
11390	2449357.598

as the check star. Several curve-fitting routines were used to find the times of the primary minima for the light curves. These times were reduced to heliocentric Julian Days and the minima are reported in Table 1.

3. Period analysis

The light elements determined by Dworak (1975), which are available in Hirshfeld and Sinnott (1985), give this ephemeris equation:

$$\text{Min. I} = 2438694.7063 + 0.936157E. \qquad (1)$$

Niarchos *et al.* (1991) report a discrepancy between observations and the minima predicted from this equation. Derman and Demircan (1992) collected all available times of minima from a study of the literature, together with new measurements of times of minima, and revised the ephemeris equation to be:

$$\text{Min. I} = 2438694.6936 + 0.93616454E. \qquad (2)$$

In addition to the linear ephemeris, Derman and Demircan (1992) report a quasi-periodic oscillation in the period of GK Cep with a period of approximately 18 years. They propose a fourth order polynomial as a best fit for the data and suggest its use in future predictions of times of minima. Their equation is:

$$\text{Min. I} = 2438694.7093 + 0.9361694E - 9.47\text{x}10^{-9}E^2 + 2.02\text{x}10^{-12}E^3 - 1.15 \text{ x } 10^{-16}E^4. \qquad (3)$$

Similarly, Wolf and Diethelm (1992) studied published reports of times of minima for GK Cep determined through photoelectric measurements and proposed the ephemeris equation:

$$\text{Min. I} = 2438694.6846 + 0.9361654E. \qquad (4)$$

Wolf and Diethelm (1992) further report an oscillation of O-C residuals with a period of 20.5 years and an amplitude of 0.0152 day.

In the present study, O-C residuals were calculated using each of the previous ephemiri equations (1), (2), (3), (4). These results are presented in Table 2 and are graphically illustrated in Figure 1. Equations (2) and (4) more accurately predict the newly observed minima; however, these equations systematically predict minima approximately 13 minutes later than were observed. Equation (3) predicts minima which are approximately 2.3 hours earlier than were observed.

The times of minima for GK Cep collected by Derman and Demircan (1992), together with the minima reported by Wolf and Diethelm (1992) and the new minima reported in this study, were used to further analyze the period behavior of GK Cep. The data were averaged and fit to several functional forms to determine if periodic fluctuations exist in the O-C plots. These attempts to fit the data show systematic periodic fluctuations which may give clues to the motion of the system observed. A plot of the average O-C variations of the data points was made using equation (2) above. These variations show a periodic fluctuation which lies outside the expected data spread. The O-C values are minimized if the fluctuating term has a periodicity of 18.6 years. Figure 2 shows an expanded scale for such a fluctuation of O-C residuals for primary minima predicted by equations (1) and (4), and Figure 3 shows an expanded scale for such a fluctuation of O-C residuals for primary minima predicted by equations (2) and (5). In the figures, the plots of O-C residuals are shown as calculated from the

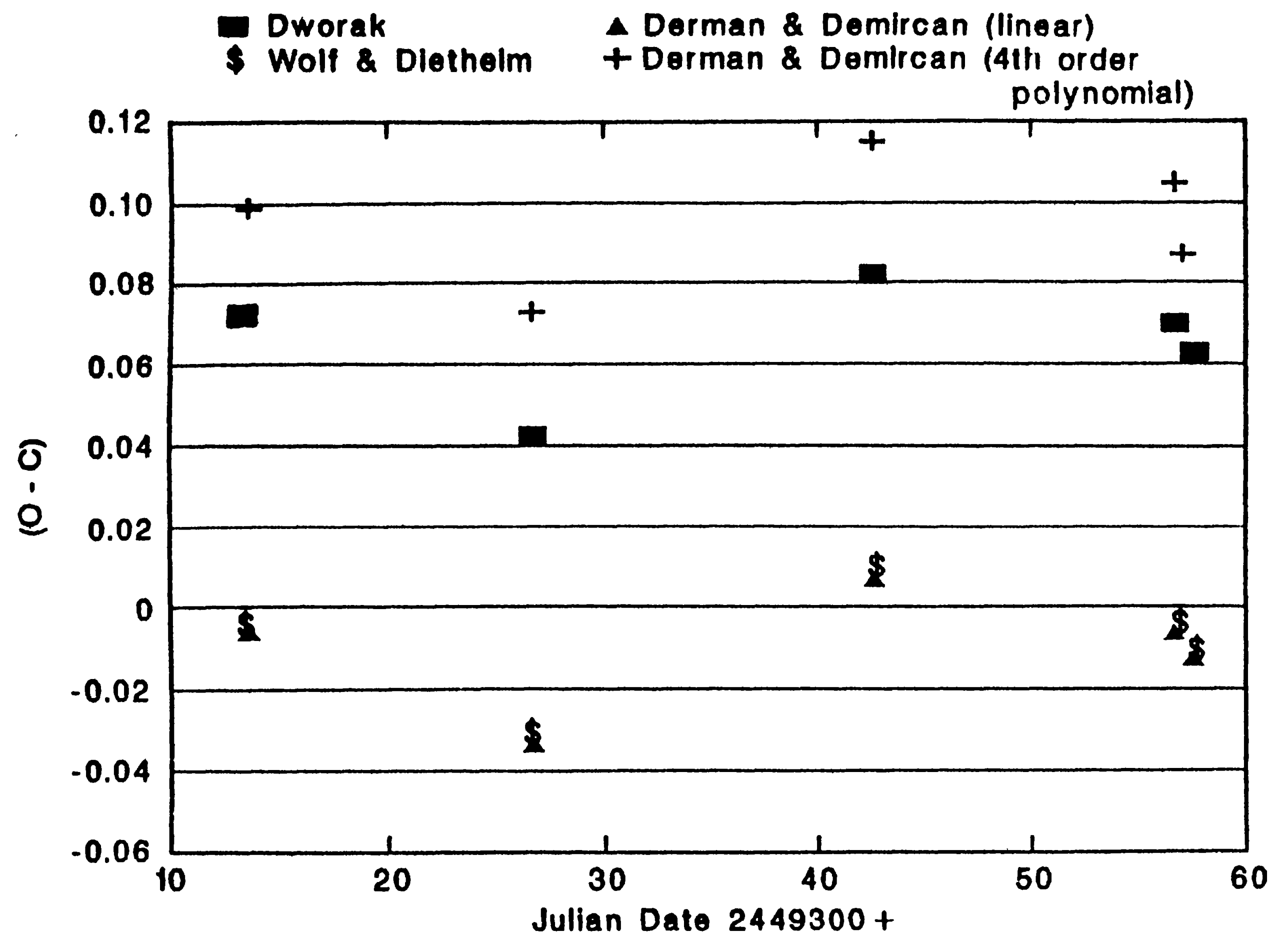

Figure 1. A plot of the difference between observed times of primary minima in this paper and calculated values for several investigations of the star system GK Cephei. The references are given in the narrative. The (O-C) values are determined from each of the ephemiris equations as labelled at the top of the figure.

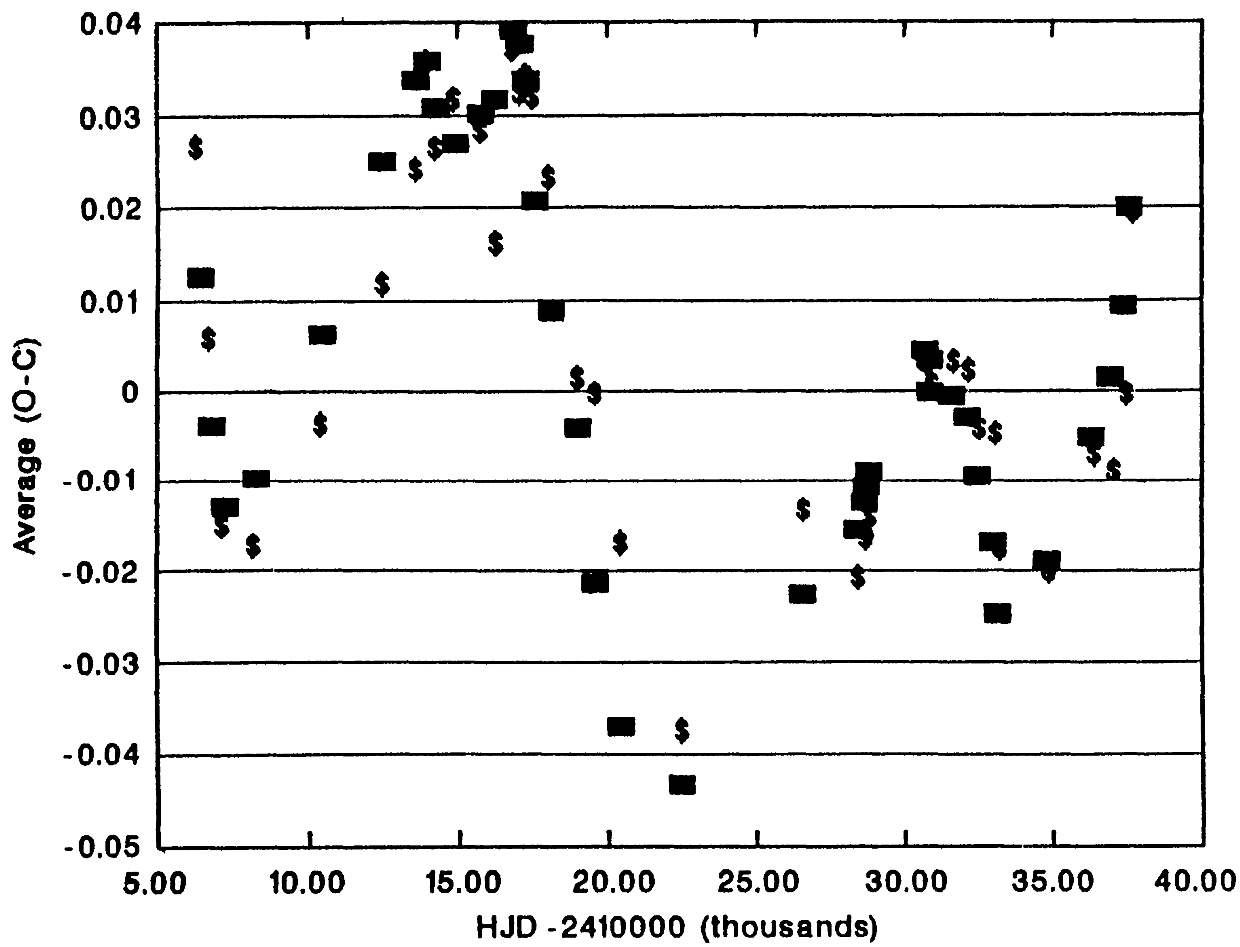

Figure 2. A plot of O-C residual curves for GK Cephei for primary minima. The $ represents a fit of the data to equation (4), and the ■ represents a fit of the data to the equation (1).

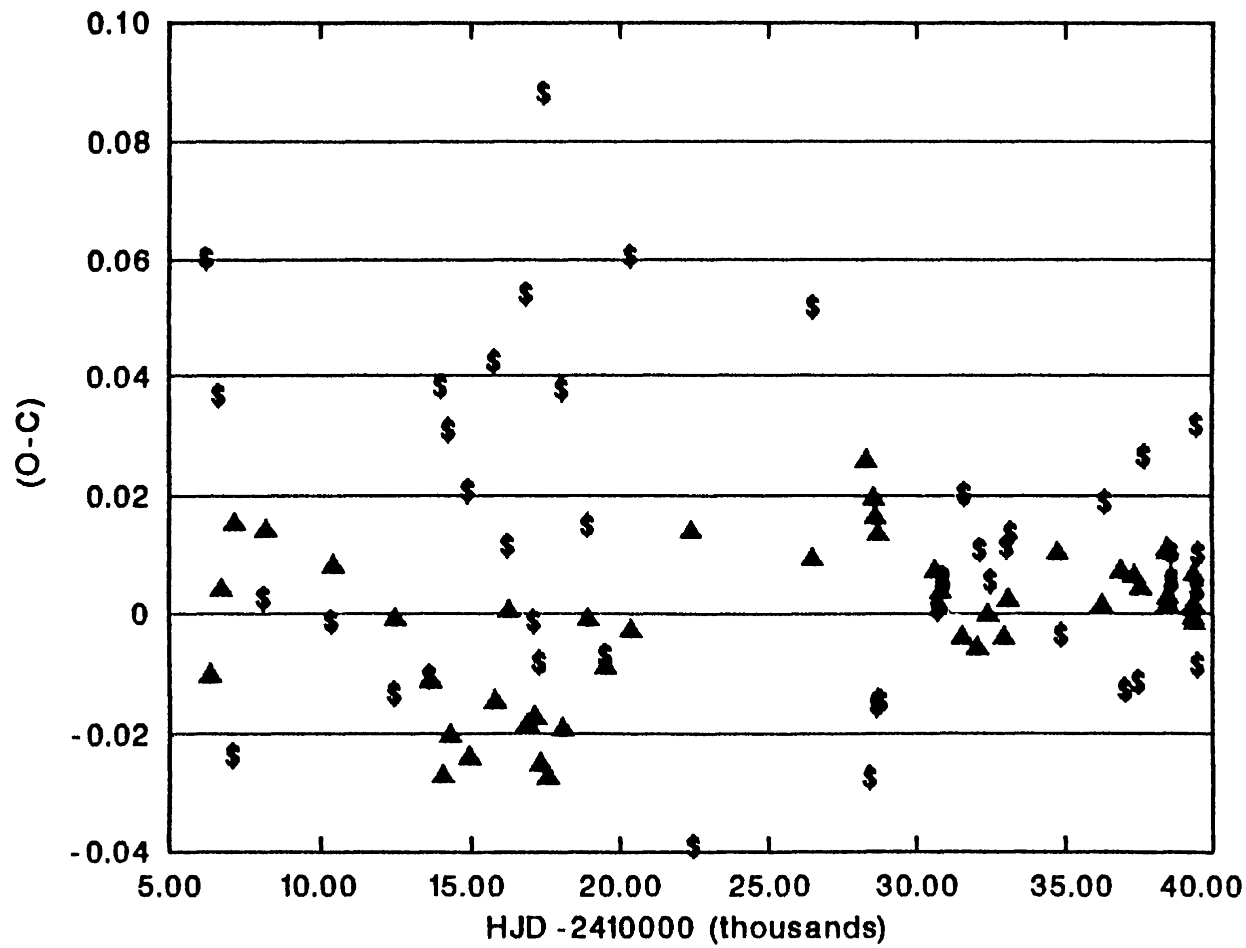

Figure 3. Two plots of (O-C) for two equations. Symbol ($) is for Min. I calculated by equation (2), and the symbol (▲) is for Min. I calculated by equation (5) (derived in this work).

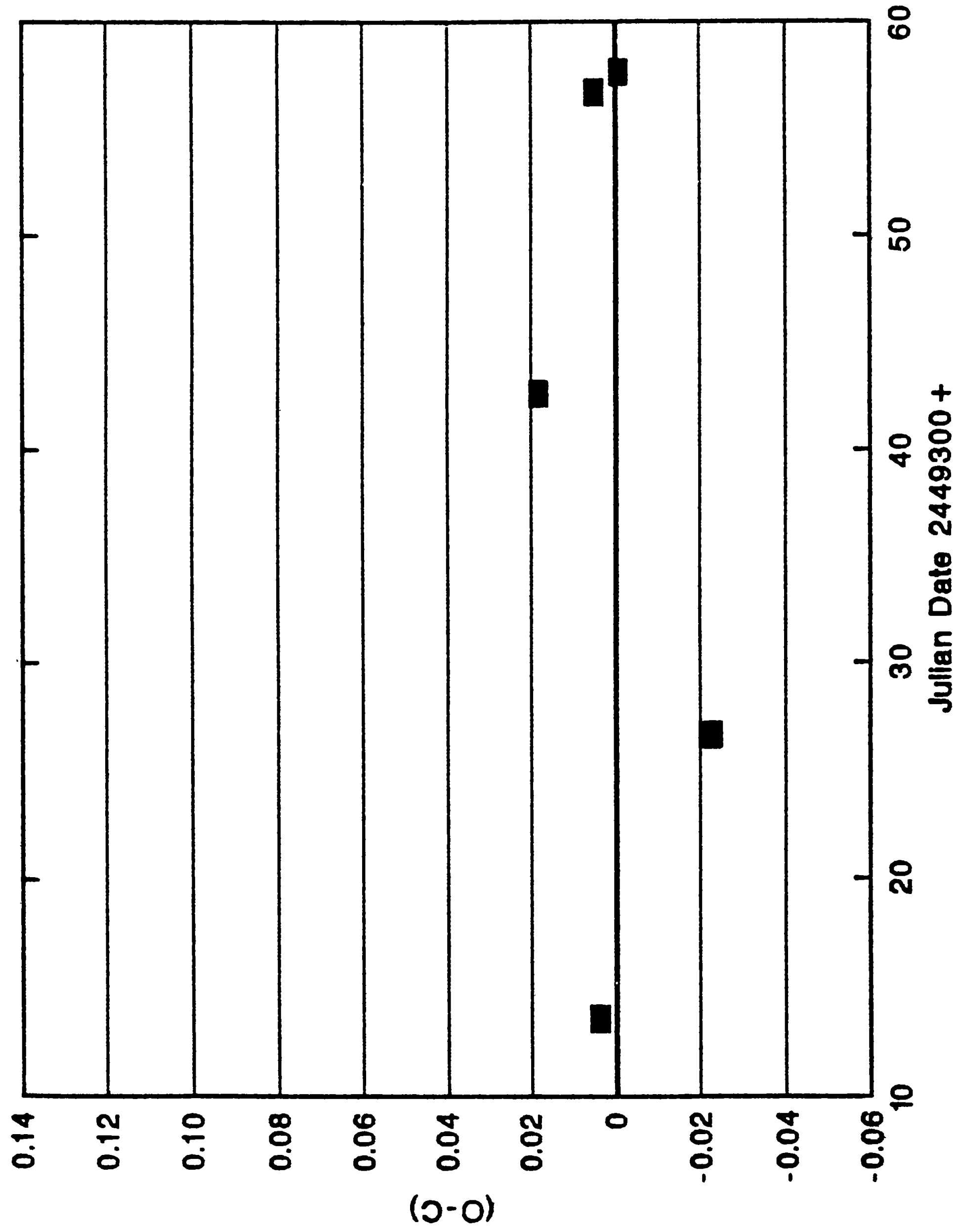

Figure 4. A plot of the variation of O-C for the results of this work as compared to calculations by equation (5).

equation given in the figure captions.

It was hypothesized, based upon past fluctuations in O-C residuals and the variance of new observations from predictions based upon the recently published ephemeris equations of Derman and Demircan (1992) and Wolf and Diethelm (1992), that light time effects of the star system GK Cep may be accounted for by a sinusoidal term in the ephemeris equation. The newly proposed ephemeris equation is:

$$\text{Min. I} = 2438694.6936 + 0.93616454E + 0.015\sin(8.64 \times 10^{-4}E + 0.26), \quad (5)$$

where the argument of the sinusoidal term is in radians. Table 2 shows O-C residuals for this new equation (5), and also gives O-C residuals for investigators cited in the text. Figure 3 graphically illustrates the observed minima for several investigators. Figure 4 shows the O-C values relative to equation (5) for the new values obtained in this work.

4. Summary

New times of primary minima are reported based upon photoelectric measurements made at the University of North Texas Astronomy Observatory. These new measurements, together with the data reported in the literature for the star system GK Cep, appear to show systematic variations when the data are averaged. The curves presented in this paper show the compressed average of all available data. The variation in O-C between predicted times of minima and actual measurements indicates a periodic component superimposed upon the traditional linear ephemeris equation. A period of 18.6 years has been deduced for this periodic variation. The addition of a sinusoidal term to the ephemeris equation and subsequent fitting of this equation to published times of minima permits a more accurate equation for predicting future times of minima for GK Cep. Further refinements to the newly proposed ephemeris equation may be possible as additional timings of minima are made for this star system.

5. Acknowledgements

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Table 2. Values of O-C for GK Cep for several models.

	DWORAK[1] (O-C)[1]	DER & D[2] (O-C)[2]	DER &D[3] (O-C)[3]	W & DIET[4] (O-C)[4]	THIS WORK[5] (O-C)[5]
	0.069	-0.006	0.099	-0.004	0.004
	0.042	-0.033	0.073	-0.031	-0.023
	0.082	0.007	0.115	0.009	0.018
	0.07	-0.006	0.105	-0.004	0.005
	0.063	-0.012	0.098	-0.01	-0.001
Average	0.0652	-0.01	0.098	-0.008	0.0006

1. Equation (1) Dworak (1975); 2. Equation (2) Derman and Demircan (1992); 3. Equation (3) Derman and Demircan (1992); 4. Equation (4) Wolf and Diethelm (1992); 5. Results from this study calculated by equation (5).

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