The 2003 Eclipse of EE Cephei

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Abstract An eclipse of the long period system EE Cephei occurred in 2003. CCD observations of this eclipse show an asymmetrical light curve that supports the disk model for the occulting object suggested by Graczyk *et al.* (2003).

1. Background

The variability of EE Cephei was first identified by Romano (1956). His initial analysis indicated that this star was an R CrB type variable. However, this was later changed to an eclipsing binary type by Romano and Perissinotto (1966). The eclipsing nature was confirmed by Meinunger (1973).

Campaigns to observe the previous two eclipses have been led by Halbach (1992 and 1999). The light elements from the *General Catalogue of Variable Stars* (GCVS; Kholopov *et al.* 1985) were used to predict these eclipses. These are given in equation 1:

$$\mathrm{JDmin} = 2434346.0 + 2049.53\ \mathrm{E} \tag{1}$$

2. Observations

Observations by Dvorak were made with a Meade LX200-10" f10 and a CB245 CCD camera. The rest of the observations were made with a ST9E CCD on an LX200-10" f6.3 located at the Milwaukee Astronomical Society Observatory. A Johnson *V* filter was used for all observations.

Field photometry of the following stars, provided by Brian Skiff (private communication), was used for the comparison and check stars.

	GSC Nr.	Mag. *V*	*B*−*V*
Comparison Star	3973 1177	10.386	0.396
Check Star	3973 2150	11.248	0.109
Check Star	3973 1103	11.232	0.410

All observations are listed in Table 1. The resulting light curve is shown in Figure 1.

3. Analysis

Graczyk *et al.* (2003) proposed a disk model for the occulting component that consists of an optically thick disk surrounded by a semi-transparent layer. In an ordinary eclipsing binary four contacts are seen: 1st (beginning of partial), 2nd (beginning of total), 3rd (end of total), and 4th (end of partial). In EE Cephei the thick disk is responsible for these four contacts, but as described by Graczyk *et al.*, the semi-transparent layer causes two additional contact events. The 1– contact occurs before 1st, when the semi-transparent layer begins its transit of the primary, and the 4+ contact signals the end of this transit following the 4th contact.

Using the method described by Mikołajewski and Graczyk (1999), the time of mid-eclipse was determined to be HJD 2452795.0 ± 1.0. Halbach (1992) provided an analysis of all known eclipse timings and proposed the elements shown in Equation 2:

$$\begin{aligned} \mathrm{JDmin} = {} & 2434346.17 + 2049.41\mathrm{d} \\ & \pm 0.77 \qquad \pm 0.17 \end{aligned} \tag{2}$$

Applying these elements to the 2003 eclipse (E = 9) yields a predicted time of minimum of 2452790.9, differing from observation by 4.1 days. However, given the strong asymmetry of the light curve, estimation of the time of minimum is difficult. Additionally, the observed epochs used by Halbach were times of minimum light, rather than of mid-eclipse as defined by Mikolajewski and Graczyk, and used in this paper. The time of minimum light for the 2003 eclipse data is 2452792.1 ± 0.5, differing from Halbach's elements by just 1.2 days.

The times of minimum are listed in Table 2. The Cycle and O−C are calculated using equation 1. These O−C values are plotted in Figure 2. Times of minimum obtained with PEP or CCD observations are circled. The variation in the O−C values are probably due to changes in the shape of the light curve rather than the orbital period of the system.

The light curve during the previous eight observed events has varied greatly (see Graczyk 2003). Depth, width, and even the shape of the light curve have exhibited large variations. The maximum magnitude outside of eclipse is 10.8 *V*; the minimum magnitude has varied from 11.6 to 12.5 *V*. The 11.43 *V* magnitude minimum of this eclipse makes it the shallowest observed, along with the E = 3 eclipse in 1969.

Although the 1−st contact was missed, extrapolating the light curve yields a total duration (contacts 1− through 4+) for this eclipse of 50 ± 5 days. This is much longer than the typical 30 days seen in most previous eclipses. The 1st contact is not sharply defined in the 2003 data; however the 2nd, 3rd, 4th, and 4+ contacts all look similar to the characteristic light curve given in Figure 3 of the Graczyk *et al.* (2003) paper. The time between the 4th and 4+ contacts was about six days, much shorter than the typical ten to twelve days of previous eclipses. Graczyk *et al.* (2003) suggested that there was an inverse linear relationship between eclipse depth and duration. The 2003 eclipse data, with a total duration of approximately 50 days (0.024 ± 0.002 fraction of the period) and depth of 0.60 *V*, fits the relationship reasonably well.

4. The next eclipse

The next eclipse of EE Cephei will occur during December 2008 and January 2009. The system will be well placed in the evening sky but this can be a cloudy time of the year in much of the Northern Hemisphere so a coordinated effort from several locations will be required to fully cover the eclipse of this interesting system.

5. Acknowledgements

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References

Gerner, H. 2003, private communication.
Graczyk, D., Mikołajweski, M., Tomov, T., Kilev, D., and Iliev, I. 2003, *Astron. Astrophys.*, **403**, 1089 .
Halbach, E. A. 1992, *J. Amer. Assoc. Var. Star Obs.*, **21**, 129.
Halbach, E. A. 1999, *J. Amer. Assoc. Var. Star Obs.*, **27**, 35.
Kholopov, P. N., *et al.* 1985, *General Catalogue of Variable Stars*, Fourth Edition, Moscow.
Meinunger, L. 1973, *Mitt. Veränderliche Sterne*, **6**, 89.
Mikołajewski, M., and Graczyk, D. 1999, *Mon. Not. Roy. Astron. Soc*, **303**, 521.
Poklar, R. 2003, private communication.
Romano, G. 1956, *Doc. Obs. Circ.*, No 9.
Romano, G., and Perissinotto, M. 1966, *Mem. Soc. Astr. Ital.*, **37**, 255.
Skiff, B. 2003, private communication.
Simmons, N. 2003, private communication.

Table 1. CCD observations of EE Cephei contributed to this paper. These observations are plotted in Figure 1.

JD (Heliocentric)	Magnitude (V)	Observer	JD (Heliocentric)	Magnitude (V)	Observer
2452769.6850	10.87	G. Samolyk	2452800.8120	11.19	S. Dvorak
2452773.6717	10.90	R. Poklar	2452801.8135	11.10	S. Dvorak
2452775.7158	10.92	R. Poklar	2452802.6977	11.03	G. Samolyk
2452780.6665	10.98	H. Gerner	2452802.7004	11.03	G. Samolyk
2452781.6803	10.98	G. Samolyk	2452802.7029	11.05	G. Samolyk
2452783.7047	11.05	H. Gerner	2452802.8800	11.02	S. Dvorak
2452785.7370	11.07	G. Samolyk	2452803.8672	10.94	S. Dvorak
2452786.6073	11.10	G. Samolyk	2452804.7272	10.87	G. Samolyk
2452787.7065	11.09	G. Samolyk	2452804.7288	10.88	G. Samolyk
2452787.7079	11.11	G. Samolyk	2452804.7300	10.88	G. Samolyk
2452789.8841	11.20	G. Samolyk	2452804.7311	10.89	G. Samolyk
2452789.8864	11.21	G. Samolyk	2452804.8853	10.86	S. Dvorak
2452791.7295	11.28	H. Gerner	2452805.7953	10.85	S. Dvorak
2452791.7319	11.29	H. Gerner	2452806.6306	10.86	G. Samolyk
2452791.8267	11.31	N Simmons	2452806.6320	10.87	G. Samolyk
2452792.6492	11.39	G. Samolyk	2452806.6330	10.85	G. Samolyk
2452792.6507	11.43	G. Samolyk	2452806.6341	10.86	G. Samolyk
2452792.6532	11.42	G. Samolyk	2452807.6301	10.83	G. Samolyk
2452793.8812	11.42	S. Dvorak	2452807.6316	10.83	G. Samolyk
2452796.7151	11.35	G. Samolyk	2452807.6327	10.85	G. Samolyk
2452797.8785	11.33	S. Dvorak	2452810.8051	10.82	G. Samolyk
2452800.6093	11.21	R. Poklar	2452810.8146	10.82	G. Samolyk
2452800.6162	11.17	R. Poklar	2452810.8157	10.80	G. Samolyk
2452800.6186	11.17	R. Poklar	2452812.6859	10.83	G. Samolyk
2452800.6253	11.19	R. Poklar			

Table 2. Times of minimum available to the authors. The cycle and O–C are calculated using equation 1. The O–C values are plotted in figure 2.

JD(min) Hel. 2400000+	*Cycle*	*O–C*	*Method*	*Observers*
32297	–1	0.5	pg	Weber
34346	0	0.0	pg	Romano
36399	1	3.5	pg	Romano, Perissinotto
38440	2	–5.1	pg	Romano, Perissinotto
40493	3	–1.6	pg	Baldinelli, Ghedini, Tubertini
42543.3	4	–0.8	vis	Bauer, Braue, Klebert
42543.7	4	–0.4	PEP	Locher
42544	4	–0.1	pg	Baldinelli, Ghedini, Tubertini
42544	4	–0.1	vis	Duruy, Thouet, Vedrenne, Verdenet
42544.1	4	0.0	PEP	Rossiger, Pfau, Uhlig
42544.2	4	0.1	vis	Peter
42544.2	4	0.1	pg	Sharof, Perova
42545.48	4	1.4	PEP, pg	Bahyl
44594.1	5	0.4	PEP, pg	Baldinelli, Ferri, Ghedini
46643	6	–0.2	vis	AAVSO Data
48691.0	7	–1.7	vis	E. Halbach
48691.0	7	–1.7	CCD	Borovicka
48692.5	7	–0.2	vis	M. Baldwin
48693.0	7	0.3	vis	G. Samolyk
50743.8	8	1.6	vis	G. Samolyk
50743.9	8	1.7	CCD	S. Cook
50744.0	8	1.8	vis	R. Berg
52795.0	9	3.2	CCD	This Paper

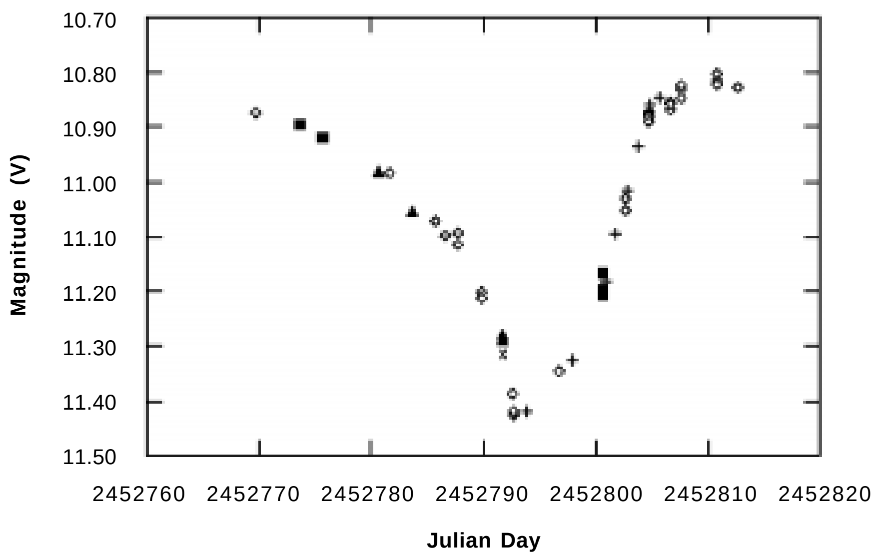

Figure 1. Observations of EE Cep from Table 1. Symbols: diamond, G. Samolyk; square, R. Poklar; triangle, H. Gerner; “x”, N. Simmons; “+”, S. Dvorak.

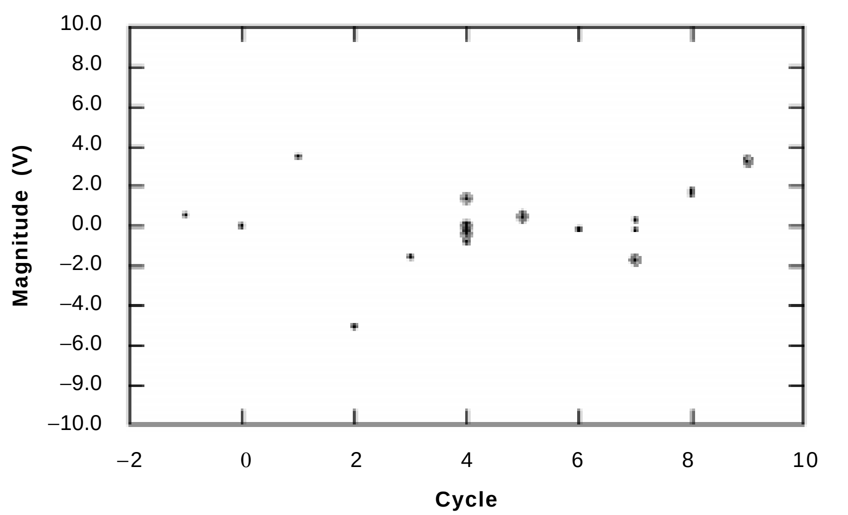

Figure 2. Times of minimum of EE Cep listed in table 2. The O–C values were calculated using equation 1. Times of minimum obtained with PEP or CCD observations are circled.