PERIOD CHANGES OF EARLY-TYPE CONTACT BINARY GK CEPHEI

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1. Introduction

GK Cephei (BV 382, HD 205372, BD+70°1183, Sp. A2V+A2V) is an early-type eclipsing binary usually given in lists of W UMa-type systems. After its discovery by Strohmeier et al. (1961) it has been the subject of several photometric and spectroscopic observations in recent years (e.g. Bartolini et al. 1965, Gleim 1967 and Dworak 1975). Model parameters from the light curve analysis were obtained by Hutchings and Hill (1973). They also concluded that GK Cep is probably a near-contact system.

Since early-type contact binaries are rather fragmentarily studied we decided to include GK Cephei into our observational program. The main goal of this research is to study the period behaviour of the GK Cephei star.

2. Observations

The observational material was obtained with a 0.6/7.5 m reflecting telescope equipped with a double-beam photometer (Szymański and Udalski 1989) at the Mt. Suhora Astronomical Observatory of the Cracow Pedagogical University. The observations were carried out during the period August 1988 - March 1990 in the yellow V filter, using both BD+70°1182 and BD+70°1186 as comparisons stars. Six times of primary and secondary minima were calculated from the observations. They are listed in the Table 1 (Nos. 151-154, 156, 159). The reductions were made using the graphical tracing-paper method.

3. Period study of GK Cephei

In order to study the period behaviour of GK Cephei we have collected all primary and secondary minima available in the literature. They are presented in Table 1. The consecutive columns of Table 1 contain current number, heliocentric time of minimum, error, type of minimum, epoch and O-C according to the elements:

$$JOhel\ Min = 2438694.6956 + 0^{d}.936165706 \cdot E \qquad (1)$$

and references. In the fourth column v, pg, pv, e mean that the time of minimum was derived from the visual, photographic, photovisual and photoelectric observations respectively. The minima Nos. 1-9 in Table 1 are normal minima computed by the authors from the lists of 183 minima published by Strohmeier et al. (1963) and Strohmeier and Bauernfeind (1968). The former minima are in fact times of mid exposure of patrol plates on which the variable appeared faint. In further investigations the visual minima were not taken into account because of their low accuracy.

TABLE 1

No	JDhel 2400000.+	Error	T	Epoch	O-C	Ref	No	JDhel 2400000.+	Error	T	Epoch	O-C	Ref
1	16384.0030*	±0.0120	pg	-23832	0.0085	1	75	42319.5070		v	3872	-0.0222	7
2	18033.5240*	±0.0080	pg	-22070	0.0055	1	76	42319.5270		v	3872	-0.0022	7
3	22854.7670*	±0.0070	pg	-16920	-0.0049	1	77	42402.3660		v	3960.5	-0.0139	6
4	24792.6190*	±0.0070	pg	-14850	-0.0159	1	78	42438.4110		v	3999	-0.0113	7
5	26493.6500*	±0.0050	pg	-13033	0.0020	1	79	42439.3410		v	4000	-0.0174	6
6	27113.3850*	±0.0050	pg	-12371	-0.0047	1	80	42452.4420		v	4014	-0.0227	6
7	28717.9720*	±0.006υ	pg	-10657	-0.0057	1	81	42453.3930		v	4015	-0.0079	6
8	31355.1490*	±0.0070	pg	-7840	-0.0075	1	82	42641.5440		v	4216	-0.0262	7
9	36921.5730*	±0.0180	pg	-1894	-0.0248	1	83	42685.5421	±0.0025	e	4263	-0.0279	9
10	38265.4754		e	-458.5	0.0118	2	84	42802.5810		v	4388	-0.0097	7
11	38355.3472		e	-362.5	0.0117	2	85	42950.4970		v	4546	-0.0079	7
12	38407.3030		e	-307	0.0103	2	86	42957.5060		v	4553.5	-0.0201	7
13	38528.5397		e	-177.5	0.0135	2	87	42958.5010:		v	4554.5	0.0387	7
14	38559.4331		e	-144.5	0.0134	2	88	43017.5220		v	4617.5	0.0813	7
15	38580.4930		e	-122	0.0096	2	89	43068.4460		v	4672	-0.0158	6
16	38606.7068		e	-94	0.0108	3	90	43069.3880		v	4673	-0.0099	6
17	38622.6360		e	-77	0.0252	3	91	43090.4460		v	4695.5	-0.0157	6
18	38627.7712	±0.0003	e	-71.5	0.0114	4	92	43098.4000		v	4704	-0.0191	6
19	38634.7950		e	-64	0.0140	3	93	43099.3380		v	4705	-0.0172	6
20	38642.7590		e	-55.5	0.0206	3	94	43099.3590		v	4705	0.0038	7
21	38644.6350		e	-53.5	0.0243	3	95	43100.2790		v	4706	-0.0124	6
22	38649.7570		e	-48	-0.0026	3	96	43106.3660		v	4712.5	-0.0105	6
23	38652.5850		e	-45	0.0169	3	97	43107.3080		v	4713.5	-0.0107	6
24	38652.5880		e	-45	0.0199	3	98	43159.2460		v	4769	-0.0239	6
25	38687.6860	±0.0003	e	-7.5	0.0116	4	99	43173.2830		v	4784	-0.0293	6
26	38694.7047		e	0	0.0091	3	100	43244.4810		v	4860	0.0201	7
27	38694.7070	±0.0003	e	0	0.0114	4	101	43307.6363		e	4927.5	-0.0158	10
28	38700.7885		e	6.5	0.0078	3	102	43361.4500		v	4985	-0.0316	7
29	38703.6015		e	9.5	0.0123	3	103	43369.3980		v	4993.5	-0.0411	6
30	38706.7487		e	15	0.0106	3	104	43384.4030		v	5009.5	-0.0147	7
31	38709.6866	±0.0003	e	16	0.0123	4	105	43392.3620		v	5018	-0.0131	6
32	38711.5567		e	18	0.0121	3	106	43399.3750		v	5025.5	-0.0214	6
33	38713.4310		e	20	0.0121	2	107	43411.5505		e	5038.5	-0.0160	10
34	38731.6864	±0.0003	e	39.5	0.0123	4	108	43464.4390		v	5095	-0.0209	6
35	38737.3053		e	45.5	0.0142	2	109	43488.3140		v	5120.5	-0.0181	6
36	38748.5433	±0.0003	e	57.5	0.0182	4	110	43517.3270		v	5151.5	-0.0262	6
37	38997.0911*		e	323	0.0140	3	111	43589.3990		v	5228.5	-0.0390	6
38	38997.5592*		e	323.5	0.0140	3	112	43590.3600		v	5229.5	-0.0142	6
39	39405.7367		e	759.5	0.0232	3	113	43597.3860*		v	5237	-0.0094	7
40	40532.3682	±0.0013	e	1963	-0.0007	5	114	43597.4110*		v	5237	0.0156	7
41	40542.2233	±0.0013	e	1973.5	0.0047	5	115	43743.4350		v	5393	-0.0023	7
42	40845.5326	±0.0010	e	2297.5	-0.0037	5	116	43759.3540		v	5410	0.0019	7
43	40852.5482	±0.0008	e	2305	-0.0094	5	117	43772.4480		v	5424	-0.0104	7
44	40867.5261	±0.0005	e	2321	-0.0101	5	118	43875.4570		v	5534	0.0204	7
45	40868.4629	±0.0004	e	2322	-0.0096	5	119	43876.4210		v	5535	0.0482	7
46	40869.3974	±0.0021	e	2323	-0.0111	5	120	44130.5570		v	5806.5	0.0152	7
47	40870.3350	±0.0015	e	2324	-0.0097	5	121	44146.4810		v	5823.5	0.0244	7
48	40876.4245	±0.0005	e	2330.5	-0.0053	5	122	44880.4080		v	6607.5	-0.0025	7
49	41080.5072	±0.0015	e	2548.5	-0.0067	5	123	44937.5160		e	6668.5	-0.0006	8
50	41314.5420		v	2798.5	-0.0133	6	124	45636.3630		v	7415	-0.0013	7
51	41434.4420		v	2926.5	0.0575	6	125	45671.4680		e	7452.5	-0.0025	8
52	41471.3890		v	2966	0.0259	6	126	45679.3930		v	7461	-0.0349	7
53	41507.4260		v	3004.5	0.0205	6	127	45890.5360		e	7686.5	0.0027	6
54	41513.4900		v	3011	-0.0005	6	128	46111.4360		v	7922.5	-0.0324	7
55	41515.4320:		v	3013	0.0691	6	129	46112.3650		v	7923.5	-0.0196	7
56	41522.3670		v	3020.5	0.0029	6	130	46113.2980:		v	7924.5	-0.0427	7
57	41542.4620		v	3042	-0.0497	7	131	46162.4923		e	7977	0.0029	8
58	41570.5860		v	3072	-0.0106	7	132	46236.3630		v	8056	-0.0635	6
59	41574.3690		v	3076	0.0277	6	133	46279.4500		v	8102	-0.0602	6
60	41581.3580:		v	3083.5	-0.0046	6	134	46287.4712		e	8110.5	0.0036	11
61	41589.3140		v	3092	-0.0060	6	135	46311.3413		e	8136	0.0015	11
62	41596.3090		v	3099.5	-0.0322	6	136	46318.3644		e	8143.5	0.0034	11
63	41604.2820		v	3108	-0.0166	6	137	46325.3847		e	8151	0.0024	11
64	41610.3580		v	3114.5	-0.0257	6	138	46332.4057		e	8158.5	0.0022	11
65	41646.3960		v	3153	-0.0301	7	139	46339.4287		e	8166	0.0039	11
66	41647.3510		v	3154	-0.0112	7	140	46434.4488		e	8267.5	0.0032	7
67	41682.4130		v	3191.5	-0.0555	7	141	46434.4504:		e	8267.5	0.0048	7
68	41713.3460:		v	3224.5	-0.0159	7	142	46608.0850*		v	8453	-0.0193	7
69	41814.4730		v	3332.5	0.0052	7	143	46608.5440:*		v	8453.5	-0.0284	7
70	41931.4600		v	3457.5	-0.0285	7	144	46638.9910*		v	8486	-0.0068	7
71	41946.9191*	±0.0014	e	3474	-0.0162	8	145	46639.4600*		v	8486.5	-0.0059	7
72	42086.4060		v	3623	-0.0180	7	146	46646.4917	±0.0005	e	8494	0.0046	12
73	42087.3500		v	3624	-0.0101	7	147	46648.3718		pv	8496	0.0124	13
74	42312.5020		v	3864.5	-0.0060	7	148	46691.4264		e	8542	0.0033	11

TABLE 1 - continued

149	46699.3801		pv	8550.5	-0.0004	13	155	47695.4530		e	9614.5	-0.0078	6
150	46750.4031		e	8605	0.0016	7	156	47703.4120	±0.0015	e	9623	-0.0062	14
151	47393.5450	±0.0005	e	9292	-0.0023	14	157	47804.4440		v	9731	-0.0601	6
152	47402.4360	±0.0010	e	9301.5	-0.0049	14	158	47805.3870		v	9732	-0.0733	6
153	47416.4815	±0.0005	e	9316.5	-0.0019	14	159	47967.4090	±0.0010	e	9905	-0.0079	14
154	47688.4340:	±0.0015	e	9607	-0.0055	14							

Notes: (*)-normal minimum, (:)-uncertain, (1)-Strohmeier et al. (1963), Strohmeier and Bauernfeind (1968), (2)-Bartolini et al. (1965), (3)-Robinson (1967), (4)-Gleim (1967), (5)-Dworak (1975), (6)-BBSAG observers, (7)-BAAVSS observers, (8)-Isles (1985), (9)-Dworak (1976), (10)-Winiarski (1977), (11)-Pohl et al. (1987), (12)-Zola (1985), (13)-Groebel (1987), (14)-this paper.

Figure 1 shows the O-C diagram of GK Cephei computed according to the elements (1). On the diagram there are only presented photographic and photoelectric minima together with their mean errors. Looking at the Fig.1 one can see that GK Cephei exhibits period changes with an amplitude about $0^d.02$. In order to explain the period behaviour we considered two possibilities:

1) the periodical character of the period changes

2) the period of GK Cephei increased and decreased occasionally.

In the first case we fitted the best sinus-curve to the all photoelectric and normal photographic minima. We have obtained the following result:

$$\text{JDhel Min} = 2438694.6914 + 0^d.93661655 \cdot E + 0^d.0149 \cdot \sin(0^\circ.049 \cdot E + 74^\circ) \qquad (2)$$
$$\pm 11 \qquad \pm 14 \qquad \pm 13 \qquad \pm 7 \qquad \pm 6$$

If we assume that the periodical character of the period changes is due to the existence of a third body in the system, the period of orbital motion around the third body is equal 18.8 years. Assuming the circular complanatory orbits both GK Cephei and the whole system ($i = 72^\circ.3$, $M_1 + M_2 = 5.2 M_\odot$, (Bartolini et al. 1965)) we estimated the third's component mass to be equal to 1.34 $M_\odot$.

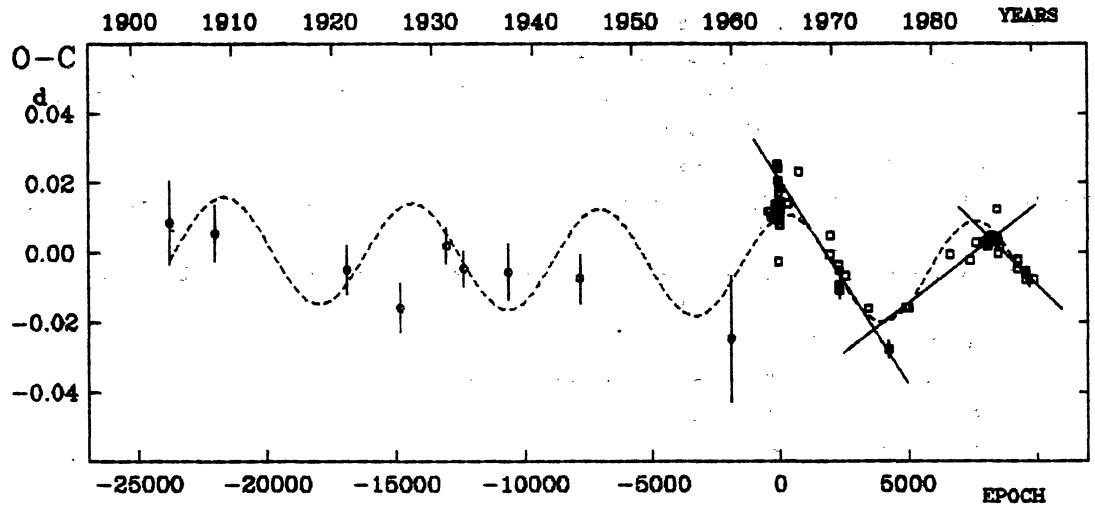

Fig 1. The O-C diagram for GK Cephei

But large discrepancy between fitted sinus-curve and old normal photographic minima as well as the unequal hights of maxima on the O-C diagram suggest that the alternative period changes seems to be more acceptable.

In the second case we considered the photoelectric minima only. From the inspection of the O-C diagram follows that the period of GK Cephei suddenly changes in the years 1965, 1976 and 1986. In order to investigate this period changes the O-C diagram was divided into three parts and the best linear fittings were computed. The results are:

Years:	The linear elements:	ΔP/P:
1965-1976	2438694.7170 + 0.9361538	
	±25 ±11	$+1.89 \cdot 10^{-5}$
1976-1986	2438694.6521 + 0.9361715	
	±33 ±4	$-1.46 \cdot 10^{-5}$
1986-1990	2438694.7652 + 0.9361578	
	±85 ±9	

The intervals of constant period and values of period changes ΔP/P are typical of those known for most W UMa contact binaries (Kreiner 1977).

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