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Orbital period study of AK Her

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Abstract. Orbital period changes of the contact binary AK Her are discussed. The $(O-C)$ diagram constructed using all available photoelectric, CCD, photographic and visual minima times including new photoelectric minima times determined from our U, B, V observations taken in 1982 and 2003, can be explained by a long-term orbital period increase modulated by a light-time effect. The period increase is caused either by a mass transfer from the less to more massive component of the binary or by a light-time effect on a very long period orbit. The low-mass third body present in the system is responsible for the 57.2-year light-time effect. A Fourier period analysis of the residuals from the fit revealed the 17.7-year period probably caused by a spot activity cycle.

Key words: contact binaries – third body

1. Introduction

AK Her (HD 155937; BD +16°3130; sp. type F8; $V_{max} = 8.5$) is a W UMa type contact binary system with the orbital period $P = 0.421522$ days, discovered by Metcalf (c.f. Pickering, 1917). It is a brighter component of the visual binary ADS 10408. The visual companion, physical member of the system, with an angular separation $4.7''$ and position angle 322° is 3.5 mag fainter than AK Her at maximum light.

The first photographic light curve of AK Her was obtained by Jordan (1929), the photoelectric one by Stebbins (see Woodward, 1942). A variable light curve and an obvious O'Connell effect was detected during further photometric observations (for details see Tunca *et al.* (1987); Li *et al.* (2001), Awadalla (2003)). The spectroscopic elements of the F8 primary component of AK Her were determined by Sanford (1934). He derived $f(m) = 0.0208$ $M_\odot$. AK Her was found to be an X-ray source (Cruddace & Dupree, 1984), although it seems to be a weak one (McGale *et al.*, 1996).

The orbital period change of AK Her has been studied by many authors. The first $(O-C)$ diagram was published by Seyfert & Mason (1951). Schmidt & Herczeg (1959) were first to propose that a quasi-sinusoidal variation of the orbital period is caused by a light-time effect (LITE) due to the presence of an unseen companion moving on 64-year elliptical orbit around the central binary. The orbital period of this body is too short to be the result of the LITE caused by a visual companion. Further authors proposed the period of this body as follows: Woodward & Wilson (1977) 58 years, Barker & Herczeg (1979) 78.03 years, Glownia (1985) 65.95 years, Tunca *et al.* (1987) 75.72 years, Andronov *et al.* (1989) 66.2 years and Borkovits & Hegedüs (1996) 74.5 years. Search for this component by speckle interferometry (Isobe *et al.*, 1992) and spectroscopy (Hendry & Mochnacki, 1998) yielded a negative result. The latter authors concluded that negative spectroscopic detection of this body for AK Her illustrates the unreliability of the $(O-C)$ curves in determining the presence or absence of tertiary component in W UMa systems. Woodward & Wilson (1977) did not find noticeable third light in the light curve and concluded that the invisible companion must be at least 7 mag fainter than the central binary.

Rovithis-Livaniou *et al.* (1999) used the method described by Kalimeris *et al.* (1994) to investigate the $(O-C)$ diagram of AK Her and found the periods 76.16 and 38.1 years. In their further paper (Rovithis-Livaniou *et al.*, 2001), they used more minima times and found, by the same method, the periods 97.0 and 48.5 years. Due to the fact that the orbital period does not follow the sinusoidal variation in the $(O-C)$ diagram, they did not interpret it by a LITE. They concluded that the first periodicity corresponds to the time interval for which there were available data and the second one is exactly half of it. Li *et al.* (2001) used a method of Kalimeris *et al.* (1994) and found that the period variation of the system contains a component of the long-term decrease and 3 other components of period variations: 42.39 years, 7.64 years and 5.1 years. They proposed that the first one is caused by a LITE, the second one by a magnetic activity cycle and the third one by a mass transfer between the components.

The aim of our paper is to present new times of minima derived from U, B, V observations of AK Her taken in 1982 and 2003 and to study the orbital period variations using all available minima times.

2. Our photoelectric minima times

We have used unpublished U, B, V photometry of AK Her carried out by means of a single-channel refrigerated photon-counting photometer attached to the f/18 Cassegrain focus of the 1.88 m reflector at Kottamia Observatory on July 5-7, 1982 to determine one primary and one secondary time of the minimum using the Kwee & van Woerden (1956) method.

In July and August 2003 we obtained new U, B, V photoelectric photometry of AK Her using the single-channel photoelectric photometer mounted in the Cassegrain focus of the 0.6 m telescope at the Stará Lesná Observatory. For all observations a 10s integration was chosen. BD+16°3123 (F8) and BD+16°3124 (G0) served as the comparison and check star, respectively. All observations were corrected for the differencial extinction. The data reduction was carried out in the usual way. Three new minima positions (2 primary and one secondary) were determined using the Kwee & van Woerden (1956) method. Our minima positions of AK Her, given in Table 2, are averages calculated from minima times in U, B, V passbands.

3. Orbital period variations

To analyze the period changes of AK Her we have collected all available photoelectric, CCD, photographic and visual times of minima from literature. The main source of the older photographic and visual minima times was the compilation provided by Schmidt & Herczeg (1959), Binnendijk (1961) and Purgathofer & Prochazka (1966). We added published minima times from available sources and many unpublished minima times kindly provided by prof. Kreiner (2002). He used them for the construction of the $(O-C)$ diagram of AK Her (Kreiner *et al.*, 2000). The photographic and visual minima times are listed in Table 1. In Table 2 we give original references for photoelectric and CCD minima times. We added also four unpublished minima times determined from Hipparcos observations (Kreiner, 2002). For the photoelectric minima times we give only averages calculated from minima times in different passbands. We accepted the weight $w = 1$ for visual data, $w = 3$ for photographic and photovisual data and $w = 10$ for photoelectric and CCD data.

For the study of period changes we used a standard approach. We have assumed that the times of the minima follow a quadratic ephemeris and are modulated by the LITE. The times of the minima can be computed as follows:

$$\begin{aligned} \text{Min I } &= JD_0 + P \times E + Q \times E^2 + \\ &+ \tfrac{a_{12}.\sin i}{c}\left[\tfrac{1-e^2}{1+e\cos\nu}\sin(\nu+\omega) + e\sin\omega\right], \end{aligned} \tag{1}$$

where $a_{12}\sin i$ is the projected semi-major axis, e is the eccentricity, ω is the longitude of the periastron, ν is the true anomaly of the binary orbit around the center of the mass of the triple system. $JD_0 + P\cdot E + Q\cdot E^2$ is the quadratic ephemeris of the minima in an eclipsing binary and c is the velocity of light.

To obtain an optimal fit and corresponding elements of the LITE orbit including errors, we have used the damped differential correction method for all the data as well as for the selected data. In the second case we excluded all visual, photographic and photovisual minima after JD 2433500 as well as one photographic and two photoelectric secondary minima times, due to the large deviations from the general trend in the $(O-C)$ diagram. They are typed in Tables 1 and 2 in italics. The resulting ephemerides of the binary as well as the elements of the elliptical orbit of the eclipsing pair around the center of mass of the triple system are given in Table 3. Corresponding fits are depicted in Fig. 1.

Table 1. Photographic (pg), phototovisual (pv) and visual (v) primary (I) and secondary (II) minima of AK Her. JD = JD* + 2 400 000

JD*	type		Ref.	JD*	type		Ref.	JD*	type		Ref.
15000.382	I	pg	1	25000.356	II	pg	1	*29800.645*	II	pg	1
15000.586	II	pg	1	25099.400	II	v	5	30169.465	II	pg	1
15600.203	I	pg	1	25113.326	II	v	5	30169.673	I	pg	1
15600.414	II	pg	1	25114.366	I	v	5	30914.500	I	v	1
16500.156	I	pg	1	25114.372	I	v	5	30934.524	II	v	1
16500.366	II	pg	1	25301.527	I	v	5	32352.525	II	v	1
17200.309	I	pg	1	25305.533	II	v	5	32362.430	I	v	1
17200.518	II	pg	1	25306.570	I	v	5	32687.432	I	v	5
17900.027	I	pg	1	25378.449	II	v	5	33493.387	I	v	8
17900.243	II	pg	1	25381.404	II	v	5	33499.499	II	v	8
18800.406	I	pg	1	25409.429	I	v	5	33566.306	I	v	8
18800.620	II	pg	1	25413.227	I	v	2	33731.5405	I	v	2
19800.255	I	pg	1	25416.190	I	v	1	33835.447	II	v	2
19800.459	II	pg	1	25442.738	I	v	1	34211.646	I	v	1
20500.396	I	pg	1	25448.207	I	v	1	34213.747	I	v	1
20500.615	II	pg	1	25718.4236	I	v	5	34216.727	I	v	1
21200.123	I	pg	1	25766.668	II	pg	1	34242.632	II	v	1
21200.336	II	pg	1	25809.450	I	v	5	34253.384	I	v	2
22000.173	I	pg	1	26000.410	I	pg	1	34549.505	II	v	2
22000.381	II	pg	1	26000.628	II	pg	1	34866.273	I	pg	9
22800.220	I	pg	1	26141.1957	I	v	1	34866.486	II	pg	9
22800.434	II	pg	1	26141.4023	II	v	1	34876.819	I	pg	1
22935.948	I	v	1	26700.141	I	pg	1	36545.211	I	pv	9
22973.252	II	v	1	26700.347	II	pg	1	36545.414	II	pv	9
22974.305	I	v	1	27200.044	I	pg	1	36570.502	I	pg	9
22977.254	I	v	1	27200.272	II	pg	1	36570.713	II	pg	9
22978.296	II	v	1	27563.3972	I	v	1	36908.565	I	pv	9
22981.257	II	v	1	27624.5231	I	v	1	36908.765	II	pv	9
23100.340	I	v	3	27860.162	I	v	1	37128.176	I	pv	9
23293.394	I	v	1	27980.294	I	pg	1	37128.386	II	pv	9
23294.442	II	v	1	27980.504	II	pg	3	37168.412	II	v	1
23316.384	II	v	1	28000.105	I	pg	1	37172.418	I	v	1
23342.286	I	v	1	28000.319	II	pg	1	37356.643	I	v	10
23350.302	I	v	1	28329.7288	I	pg	6	37505.427	I	v	10
23573.502	II	pg	1	28329.9428	II	pg	6	37612.513	I	pv	9
23573.703	I	pg	1	28373.571	I	v	7	37612.722	II	pv	9
24000.298	I	pg	1	28398.4421	I	v	7	37824.519	I	v	10
24000.504	II	pg	1	28726.3758	I	v	1	37858.684	I	pg	9
24112.413	I	pg	4	28753.3563	I	v	7	37858.893	II	pg	9
24312.624	I	pg	1	28802.258	I	v	7	37881.413	I	v	1
24361.541	I	v	1	28900.051	I	pg	1	38049.635	I	pv	9
24361.743	II	v	1	28900.250	II	pg	1	38049.843	II	pv	9
24648.381	II	v	5	29164.332	I	v	1	38590.454	I	v	11
24648.595	I	v	5	29400.388	I	pg	1	38595.503	I	v	11
24680.626	I	v	1	29400.615	II	pg	1	38614.479	I	v	11
24949.555	I	v	3	29486.601	II	pg	1	38620.372	I	v	11
24949.561	I	v	5	29486.805	I	pg	1	38897.733	I	pv	9
25000.141	I	pg	1	29800.420	I	pg	1	38897.942	II	pv	9

Table 1. (continued)

JD*	type		Ref.	JD*	type		Ref.	JD*	type		Ref.
39691.469	I	v	12	40581.316	I	pv	9	45911.638	II	v	24
39710.456	I	v	13	40581.506	II	pv	9	45934.421	II	v	25
39718.420	I	v	13	40795.452	I	v	18	45937.386	II	v	25
39956.602	I	v	14	40855.298	I	v	18	46313.381	II	v	26
39996.408	II	v	14	41074.485	I	v	19	46561.448	I	v	27
40005.502	I	v	14	41109.475	I	pv	9	46569.441	I	v	26
40008.454	I	v	14	41109.688	II	pv	9	46573.462	I	v	28
40017.724	I	pv	9	42220.195	I	pv	9	46593.462	I	v	29
40030.582	II	v	15	42220.388	II	pv	9	46613.496	II	v	29
40033.545	II	v	15	43685.398	I	v	20	46616.456	II	v	30
40330.499	I	v	16	43713.420	II	v	20	48495.365	I	v	31
40353.469	II	v	16	43717.426	I	v	21	48540.28	II	v	32
40381.492	I	v	16	43732.396	II	v	20	49534.431	I	v	33
40386.55	I	v	16	43744.412	I	v	21	49569.407	I	v	34
40402.578	I	v	17	43759.375	II	v	20	49894.419	I	v	35
40403.414	I	v	17	44445.382	I	v	22	50670.435	I	v	36
40415.452	II	v	17	44724.441	I	v	23	50949.483	I	v	36

References: 1 - Purgathofer & Prochazka (1966), 2 - Schmidt & Herczeg (1959), 3 - Binnendijk (1961), 4 - Zonn (1938), 5 - Kreiner (2002), 6 - Bailey (1941), 7 - Lause (1938), 8 - Pohl (1951), 9 - Karetnikov (1979), 10 - BAV-M 15, 11 - Oburka (1965), 12 - Kizilirmak & Pohl (1969), 13 - BBSAG 8, 14 - BBSAG 12, 15 - BBSAG 13, 16 - BBSAG 18, 17 - BBSAG 19, 18 - BBSAG 25, 19 - Braune et al. (1972), 20 - Poretti (1984), 21 - Braune et al. (1981), 22 - BBSAG 49, 23 - BBSAG 57, 24 - BBSAG 73, 25 - BAV-M 38, 26 - BAV-M 46, 27 - BBSAG 81, 28 - BAV-M 43, 29 - BAA VSS Circ. 67, 30 - BBSAG 80, 31 - BBSAG 99, 32 - BAV-M 60, 33 - BBSAG 108, 34 - BRNO 31, 35 - BBSAG 113, 36 - BAV-M 113.

As it can be seen from the $(O-C)$ diagrams shown in Fig. 1, the orbital period of AK Her is changing as follows: There is a long-term period increase (caused by the mass transfer between the components or by the LITE on a long-period orbit) and periodic LITE term due to the existence of a low-mass third body on a 57.2-year orbit. The Fourier analysis of the residuals of photoelectric and CCD data revealed the most significant period 17.7 years and other less siginificant periods 3.22, 7.71 and 5.85 years (see Fig. 2). Two of them are close to the periods 7.64 and 5.1 years found by Li *et al.* (2001). The reliable and meaningful interpretation of these periods would require a simultaneous analysis of the light-curve asymmetries and minima shifts caused by the spot activity (see, e.g., Pribulla *et al.*, 2001). On the other hand, the influence of the spot activity on minima times can be clearly seen in the phase diagram (Fig. 3) of the 17.7-year period. The primary and secondary minima behave differently, e.g., the spot(s) visible around the orbital phase 0.75 cause the primary minima to occur sooner and the secondary later.

Woodward & Wilson (1977) estimated the mass of the AK Her central binary to be $M_{1+2} = 2.5\ \mathrm{M}_\odot$. The mass function (see Table 3) provides the minimum mass of the third body 0.22 $\mathrm{M}_\odot$. Supposing that the third body is located on a main sequence of the HR diagram, this mass corresponds to an M5V star

Table 2. Photoelectric (e) and CCD (cc) primary (I) and secondary (II) minima of AK Her. JD = JD* + 2 400 000

JD*	type		Ref.	JD*	type		Ref.	JD*	type		Ref.
26894.449	I	e	1	40058.4030	II	e	20	44821.397	I	e	41
33515.718	I	e	2	40354.5208	I	e	20	44823.2928	II	e	41
33750.513	I	e	3	40368.429	I	e	17	44826.4477	I	e	42
34153.4827	I	e	4	40381.4986	I	e	20	44840.3623	I	e	41
34492.814	I	e	5	40387.8211	I	e	21	45002.6546	I	e	43
34813.59075	I	e	6	40392.455	I	e	22	45120.4646	II	e	44
34859.53645	I	e	6	40394.7765	II	e	21	45156.301	II	e	45
35305.0876	I	e	7	40395.8297	I	e	21	45157.3477	I	e	45
35664.4387	II	e	7	40397.7275	II	e	21	45158.4025	II	e	46
35672.4462	II	e	7	40399.8341	II	e	21	45194.4395	I	e	44
35933.576	I	e	8	40407.4234	II	e	20	45471.3803	I	e	47
35960.5588	I	e	9	40771.4080	I	e	23	45472.4350	II	e	47
36005.453	II	e	8	*40775.419*	II	e	24	45480.8681	II	e	48
36018.5197	II	e	9	40859.296	II	e	24	45502.1493	I	e	49
36025.4708	I	e	9	41077.8537	I	e	25	45515.4303	II	e	47
36317.586	I	e	9	41080.8042	I	e	25	45562.4281	I	e	46
36404.4205	I	e	9	41081.8598	II	e	25	45577.3923	II	e	46
36405.4791	II	e	9	41124.4318	II	e	20	46210.3050	I	e	50
36726.4667	I	e	10	41126.3280	I	e	26	46210.5153	II	e	50
36754.7085	I	e	11	41126.5398	II	e	20	46212.4140	I	e	50
36757.4525	II	e	12	41188.292	I	e	26	46217.4762	I	e	51
36757.6601	I	e	13	41246.253	II	e	26	46224.4309	II	e	52
36788.433	I	e	12	41512.445	I	e	27	46228.4330	I	e	52
37102.6774	II	e	13	41786.435	I	e	27	46230.332	II	e	52
37111.7411	I	e	13	41826.8987	I	e	28	46234.334	I	e	52
37112.5836	I	e	14	41829.8496	I	e	28	46243.3987	II	e	52
37112.7953	II	e	14	41830.6925	I	e	28	46244.4510	I	e	52
37113.6378	II	e	14	41830.9054	II	e	28	46328.3405	I	e	51
37114.6914	I	e	14	41832.3799	I	e	27	46597.4725	II	e	50
37487.5310	II	e	12	41853.456	I	e	27	46598.3146	II	e	50
38171.4512	I	e	15	42186.4592	I	e	29	46612.4410	I	e	52
38176.5076	I	e	10	42240.4139	I	e	29	46613.496	II	e	53
38227.511	I	e	16	42532.5291	I	e	30	46634.3582	I	e	52
38531.432	I	e	17	42596.8128	II	e	31	46642.3659	I	e	52
39263.406	II	e	18	42665.3091	I	e	32	46643.4213	II	e	52
39269.7319	II	e	19	42914.4284	I	e	33	46977.4748	I	e	50
39274.7908	II	e	19	42938.457	I	e	34	46978.5262	II	e	50
39278.7936	I	e	19	43266.3968	I	e	35	46979.3711	II	e	50
39279.8488	II	e	19	43656.5194	II	e	36	46991.3855	I	e	54
39280.9017	I	e	19	43681.8098	II	e	25	47011.4056	II	e	50
39281.7442	I	e	19	44372.4713	I	e	37	47273.6000	II	e	55
39283.8513	I	e	19	44475.3248	I	e	38	47294.4624	I	e	56
39285.7517	II	e	19	44479.3280	II	e	38	47690.4851	II	e	57
39287.8578	II	e	19	44491.3392	I	e	39	47702.4944	I	e	57
39616.432	I	e	18	44494.2919	I	e	39	48100.4112	I	e	58
39683.453	I	e	18	44502.2990	I	e	39	48327.1929	I	cc	59
39980.419	II	e	17	*44506.2976*	II	e	39	48359.228	I	cc	59
39981.473	I	e	17	44751.4257	I	e	40	48390.4213	I	e	60

Table 2. (continued)

JD*	type		Ref.	JD*	type		Ref.	JD*	type		Ref.
48422.2454	II	cc n	59	50275.4763	I	e	67	52044.3948	II	cc	74
48440.796	II	cc n	59	50310.4578	I	e	67	52066.5225	I	cc	74
48444.378	I	e	60	50508.574	I	cc	67	52073.479	II	cc	74
48460.3916	I	e	60	50512.5802	II	cc	67	52076.4277	II	cc	74
49486.3778	I	e	61	50635.6645	II	cc	68	52087.3897	II	cc	74
49490.3894	II	e	61	50865.6038	I	e	69	52112.4686	I	e	75
49491.4403	I	e	61	50866.6601	II	cc	69	52126.3805	I	e	75
49492.2806	I	e	61	50884.5722	I	cc	69	52136.2880	II	e	76
49494.3923	I	e	61	50889.2102	I	cc	70	52143.2440	I	e	76
49495.4460	II	e	61	50890.2662	II	cc	70	52360.5365	II	cc	77
49496.2906	II	e	61	50903.5413	I	cc	69	52437.4639	I	cc	77
49511.4625	II	e	62	50971.4060	I	cc	69	52747.4943	II	cc	78
49818.5420	I	e	63	51301.4589	I	cc	71	52758.4549	II	cc	78
49867.4379	I	e	63	51617.6013	I	cc	71	52766.4631	II	cc	78
49886.4065	I	e	63	51680.4087	I	cc	71	52848.4484	I	e	45
49930.4590	II	e	64	51713.4988	I	e	72	52855.4015	II	e	45
50248.4941	I	cc	64	51728.46203	I	e	73	52859.4092	I	e	45
50259.4535	I	e	66	51996.5479	I	e	72				

References: 1 - Woodward (1942), 2 - Seyfert & Mason (1951), 3 - Piotrowski (1952), 4 - Labs & Stock (1953), 5 - Fitch (1964), 6 - Kwee (1958), 7 - Hinderer (1960), 8 - Szczepanowska (1962), 9 - Schmidt & Herczeg (1959), 10 - Purgathofer & Widorn (1965), 11 - Bookmyer (1961), 12 - Herczeg (1962), 13 - Binnendijk (1961), 14 - Szafraniec (1962), 15 - Bertiau (1963), 16 - Pohl & Kizilirmak (1964), 17 - Kurutac & Ibanoglu (1969), 18 - Kizilirmak & Pohl (1969), 19 - Bookmyer (1972), 20 - Battistini *et al.* (1974), 21 - Bookmyer (1974), 22 - Pohl & Kizilirmak (1970), 23 - Van der Wal *et al.* (1972), 24 - Kizilirmak & Pohl (1971), 25 - Barker & Herczeg (1979), 26 - Pohl & Kizilirmak (1972), 27 - Pohl & Kizilirmak (1974), 28 - Woodward & Wilson (1977), 29 - Pohl & Kizilirmak (1975), 30 - Pohl & Kizilirmak (1976), 31 - Scarfe & Barlow (1978), 32 - Brancewicz & Kreiner (1976), 33 - Pohl & Kizilirmak (1977), 34 - Braune *et al.* (1979), 35 - Ebersberger *et al.* (1978), 36 - Pohl & Gulmen (1981), 37 - Diethelm (1980), 38 - Elias (1980a), 39 - Elias (1980b), 40 - Elias (1981), 41 - Diethelm (1981), 42 - Elias (1982), 43 - Pohl *et al.* (1983), 44 - Braune *et al.* (1983), 45 - this paper, 46 - Huebscher & Mundry (1984), 47 - Glownia (1985), 48 - Scarfe *et al.* (1984), 49 - Kim (1984), 50 - Rovithis-Livaniou *et al.* (1999), 51 - Isles (1986), 52 - Pohl *et al.* (1987), 53 - Isles (1988), 54 - Huebscher & Lichtenknecker (1988), 55 - Diethelm (1988), 56 - Keskin & Pohl (1989), 57 - Isles (1992), 58 - Hanzl (1991), 59 - Kreiner (2002), 60 - Blaettler (1991), 61 -Varicatt & Ashok (2001), 62 - Blaettler (1994), 63 - Hegedüs *et al.* (1996), 64 - Agerer & Huebscher (1996), 65 - Agerer & Huebscher (1997), 66 - Selam *et al.* (1999), 67 - Biro *et al.* (1998), 68 - BBSAG 115, 69 - Borkovits & Biro (1998), 70 - Park *et al.* (1999), 71 - Biro & Borkovits (2000), 72 - Agerer & Hubscher (2002), 73 - Albayrak *et al.* (2000), 74 - Borkovits *et al.* (2001), 75 - Albayrak *et al.* (2002), 76 - Jassur *et al.* (2002), 77 - Borkovits *et al.* (2002), 78 - Borkovits *et al.* (2003).

according to the new Allen's tables (Cox, 2000). The absolute magnitudes of the AK Her main sequence F8 primary component and M5 tertiary component are 4.0 and 12.3, respectively. The negative result in spectroscopic detection of the tertiary component can be caused by this difference.

As it can be seen in Fig. 1, there is a large scatter of the data in the $(O-C)$ diagram from the general trend given by our solution. The scatter of visual and

Table 3. The light-time effect solution and corresponding quadratic ephemeris of the binary system for all data and selected data (see the text)

Element		All data	Selected data
P_3	[days]	21010(340)	20900(290)
e_3		0.22(6)	0.15(5)
ω_3	[rad]	1.1(3)	0.8(4)
T_0	[JD]	2 439 600(1 000)	2 438 600(1 400)
$a_{12} \sin i$	[AU]	1.67(7)	1.66(6)
$f(m_3)$	[$M_\odot$]	0.00142(17)	0.00141(16)
JD_0	[JD]	2 452 848.4597(7)	2 452 848.4597(7)
P_{binary}	[days]	0.42152357(5)	0.42152358(4)
Q	[days]	1.23(5) 10^{-11}	1.24(5) 10^{-11}
$\sum$(O-C)^2	[days^2]	0.02911	0.0160

photographic minima times is mainly a consequence of the method of observation. The scatter of photoelectric data is caused by the uncertainity of the determination of minima positions due to the activity of the system. As it was shown by Woodward & Wilson (1977) and Tunca *et al.* (1987), the secondary minimum exhibits different duration of totality, an occasional shift from the phase 0.5 as well as mid-eclipse brightening, which is detected also in other contact systems during totality (e.g., Pribulla *et al.*, 1999).

Petrova & Orlov (1999) included AK Her into the list of systems which exhibit an apsidal motion and estimated an apsidal period 56.7 years, close to our value of the period of the third body. As seen in Fig. 1, and as it was already pointed out by Rovithis-Livaniou *et al.* (2001), the primary and secondary minima follow the same trend. Therefore, the 57.2-year periodicity cannot be explained by the apsidal motion.

4. Conclusion

Our analysis of the $(O-C)$ diagram of AK Her shows that the orbital period variation can be explained by the combination of 3 effects:

1) a long-term period increase given by a quadratic term (see the ephemeris in Table 2). It is caused either by a real orbital period change due to the mass transfer from the less massive to a more massive component of the central binary or by an apparent change due to a LITE on a long period orbit. If this is the case, the visual component ADS 10408 B or fifth body in the system can be responsible for this orbital period change.

2) the 57.2-year LITE orbit due to the existence of the low-mass third body ($m_3 = 0.22\ M_\odot$) moving around the central binary. This period is close to the

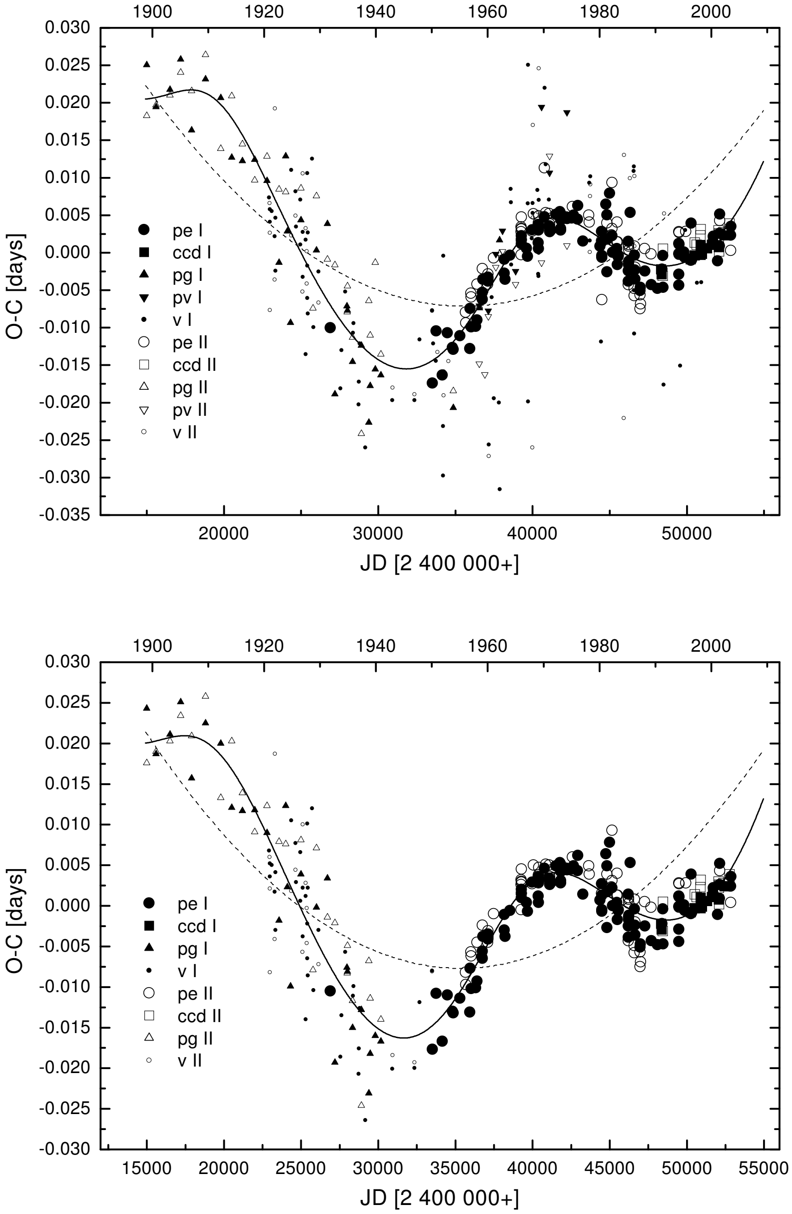

Figure 1. The $(O - C)$ diagram, corresponding to the ephemeris $JD_{\rm minI} = 2\,452\,848.4460 + 0.42152255{\times}E$, for weighted minima times, quadratic ephemeris (dashed line) and the light-time effect best fits for an elliptical orbit (solid line) for all available data (top) and selected data, described in the text (bottom).

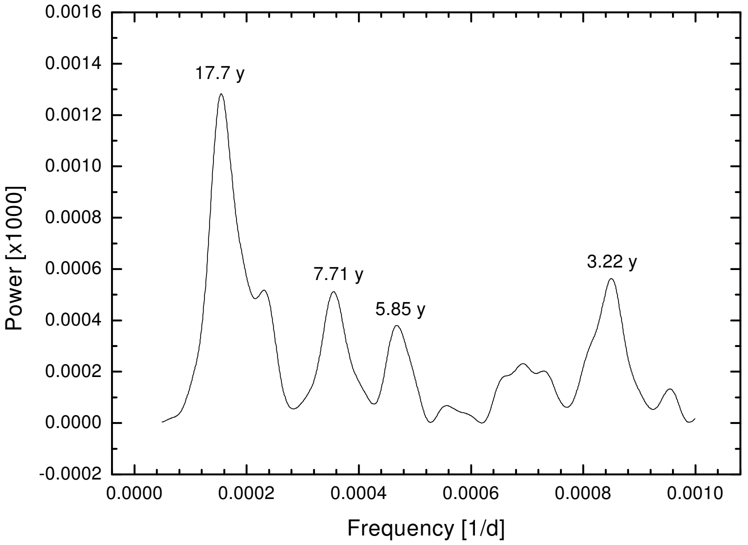

Figure 2. Power spectrum for the residuals of photoelectric and CCD data of the fit in the $(O-C)$ diagram.

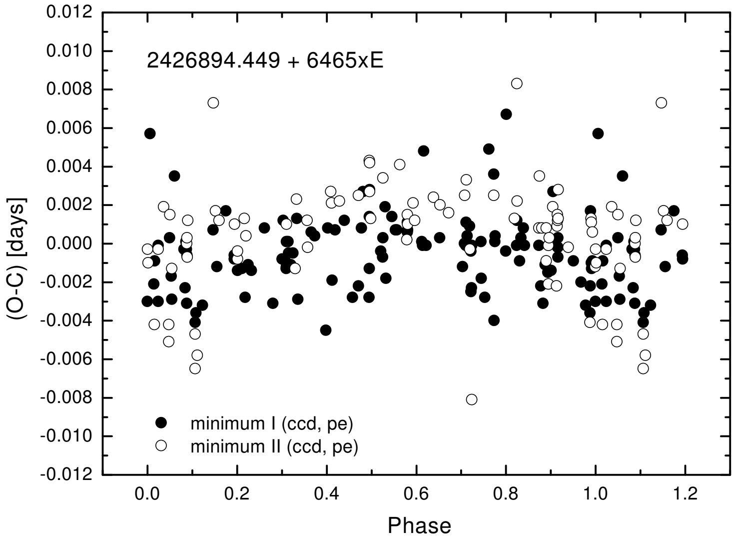

Figure 3. Phase diagram for the 17.7-year period of the spot activity cycle.

value of 58 years, presented by Woodward & Wilson (1977). The low luminosity of the third body prevents its spectroscopic detection.

3) the 17.7-year orbital period variation probably caused by the spot cycle on the surface of the contact binary.

We have found a simple solution of the orbital period variations of AK Her using the classical approach. The different results found by Rovithis-Livaniou *et al.* (1999, 2001) and Li *et al.* (2001), using the Kalimeris *et al.* (1994) method, are inconsistent. However, the authors used different sets of data for the period analysis. Particularly striking is the fact that Li *et al.* (2001) found the long-term period decrease contrary to our results.

It is no doubt that the low-mass body orbiting the central binary causes the periodic variation of the orbital period. Future observations of minima times of AK Her will decide if the system is quadruple or quintuple.

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