A Note on the Orbital Period of TW Andromedae

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Abstract: *History of period behaviour and corrected light elements of the eclipsing binary TW And are presented in this note.*

The variability of TW And (= AN 21.1909 = BD +32°4756 = SAO 53603 = PPM 64956 = GSC 2263.0975 = HIP 262, R.A.(J2000) 00 h 03 m 18.2 s, Decl.(J2000) +32° 50' 45.1", Max. = 8.80 mag V, Min. = 10.86 mag V, Sp. F0V+K0) was discovered by Kopff at Königstuhl Observatory in the year 1909. The early observations of this Algol-type eclipsing binary were reviewed by Dugan (1933). The first and up to now the only extensive photoelectric photometry of TW And was done by Walter (Ammann and Walter, 1973) at the Catania and Tübingen observatories in 1963-1970. These measurements were used by Ammann and Walter (1973), Mezzetti et al. (1980) and more recently by Vivekananda Rao and Sarma (1997) for the determination of geometric and physical parameters of the binary. Main spectroscopic work on TW And yielding radial velocity curves and reliable mass ratio of the binary components was completed by Hiltner et al. (1949) and Popper (1989).

The times of minimum light from the 1910s to 1930s suggested a continuous decrease in orbital period of TW And. While for the first part of this time interval the light elements

$$Min.I = JD(hel)\ 2420051.620 + 4.122745 \times E$$

(Dugan, 1933) had been valid, for the 1930s Wood and Forbes (1963) calculated the following cubic elements

$$Min.I = JD(hel)\ 2428882.52903 + 4.1227228 \times E - 0.20 \times 10^{-8} \times E^2 + 0.22 \times 10^{-11} \times E^3$$

with the period shorter by about 2 seconds. Horrocks (1941) concluded that the period decrease is uncertain and that the period of TW And could had been constant within the limits of observational errors since the moment of discovery. According to the authors of GCVS4 (1985) the mean linear elements for the interval before 1947 (JD 2420050 - 2432000) are the following:

$$Min.I = JD(hel)\ 2428845.422 + 4.122739 \times E.$$

New and different ephemeris was derived by Ammann and Walter (1973) from their B and V-filter photoelectric data obtained in 1965-1970:

$$Min.I = JD(hel)\ 2439020.4104 + 4.122774 \times E.$$

It did not confirm the trend toward the period shortening, on the contrary, there had to be a remarkable period increase in TW And. According to Ammann and Walter the period change occured at the beginning of the 1950s and before that time the star have probably had a constant period of 4.122745 days. The last mentioned ephemeris was taken into the main table of GCVS4 (1985) and its period value (P = 4.122774 days) is still being used for the prediction of times of minimum.

When Hiltner et al. (1949) calculated orbital phases of their radial velocity measurements of TW And they found quite satisfactory the light elements given by Dugan (1933). However, Popper (1989) for the same purpose computed the elements of his own using visual minima timings of AAVSO and BBSAG:

$$Min.I = JD(hel)\ 2443790.449 + 4.12276035 \times E.$$

He stated that these elements were valid for the time interval spanning his spectroscopic observations, i.e. JD 2443120 - 2446342 (the years 1974 - 1985).

Quite recently Qian (2003) found in the O-C diagram of TW And continuous period increase described by quadratic light elements

$$Min.I = JD(hel)\ 2439020.4084 + 4.12276287 \times E + 1.83 \times 10^{-9} \times E^2$$

as well as cyclic changes of O-C values with a period of 56.4 years and semi-amplitude of 0.0106 day. Kreiner (2004) from his 11 photoelectric times of minima obtained within the interval 1996-2003 computed the following light elements:

$$Min.I = JD(hel)\ 2452501.8619 + 4.122783 \times E.$$

Because there is an apparent discrepancy between the period values given by Ammann and Walter (1973), Popper (1989), Qian (2003) and Kreiner (2004) suggesting another possible period changes in TW And, the author of this note made a new period analysis of this variable star.

Altogether 172 times of minimum light of TW And were retrieved from original literature, electronic databases, and from the list kindly provided by J. M. Kreiner.

The old individual photographic data published by Shapley (1922) and the visual ones published by Szafraniec (1959) enabled to determine additional 7 times of minima of this eclipsing binary. They are listed together with all other minimum timings in Table 1 at the end of this paper.

The Hipparcos Catalogue Epoch Photometry Data enabled to determine one primary (JDhel 2448284.256) and one secondary minimum timing (JDhel 2448302.799) of TW And. The primary minimum is poorly covered by measurements so its accuracy is not better than ±0.01 day. The secondary minimum is covered satisfactorily but it is inaccurate for another reason (see below).

The author of this note observed TW And visually in 1994. He used a 0.2-m refractor at the Petřín Hill Observatory in Prague (Czech Republic). Visual estimates were done by the method of Nijland-Blazhko using the B.R.N.O. finding chart and the comparison stars thereupon. Total 67 estimates were obtained (for details see http://www.geocities.com/sunhillobserv/pmvisobs/twand.htm).
From 55 estimates obtained on the nights of 3/4 September, 6/7 October, and 10/11 October one normal minimum timing was derived: JDhel 2449632.410.

First view of an O-C diagram of TW And based on the light elements given by Ammann and Walter (1973) seems to confirm a period decrease some time after the year 1970. However, there is another, more probable explanation of the course of O-C residuals in the diagram: the given period value is in error and no period change occurred at that time.

To determine the correct light elements the author of this note retained the initial epoch of Ammann and Walter (1973) as the best fixed point in the whole history of observation of TW And and took into account only their three individual photoelectric times of mimima, the initial epoch from the elements in Popper (1989), and the normal minimum determined from his own visual observations. The correct value of the period was found graphically. (This is because many of the visual minimum timings of TW And seem to be of dubious quality or even completely false and the use of exact statistical procedures cannot provide meaningful results). The resulting elements are as follows:

$$Min.I = JD(hel)\ 2439020.4104 + 4.122766 \times E.$$

These elements were used for calculation of epochs and O-C residuals in Table 1 and for plotting an O-C diagram in Figure 1. In this O-C diagram the Hipparcos secondary minimum is much more deviated than the primary. To find the reason for this large deviation the Hipparcos data were superposed on the measurements of Ammann and Walter (1973) using the new elements from the present paper (see Figure 2). As can be seen, the descending branches of both the curves coincide well but the ascending branch of the Hipparcos curve is distorted. There are no signs of a phase shift of the secondary minimum giving evidence for an eccentric orbit.

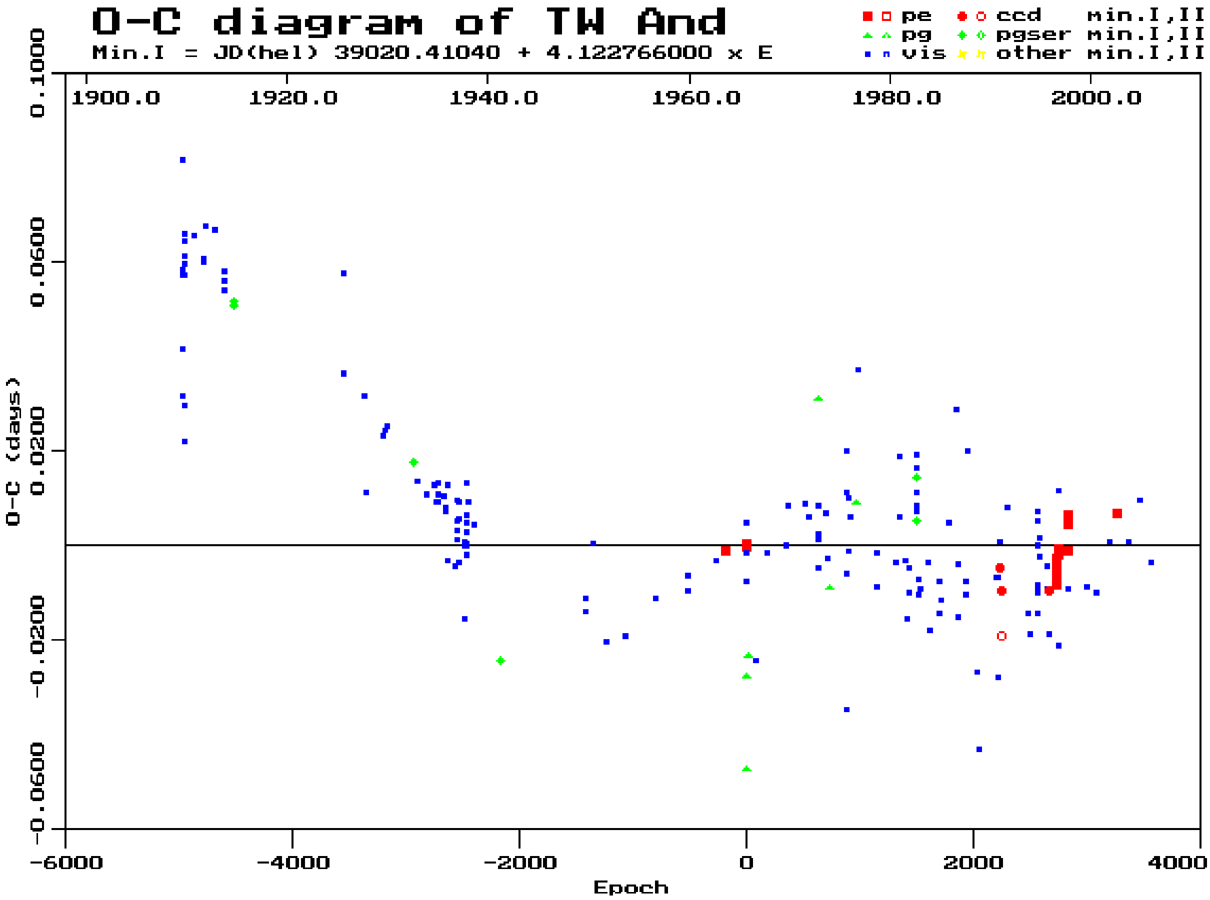
In the same manner, i.e. graphically, were dermined also light elements for the time interval before the abrupt period increase discovered by Ammann and Walter (1973) and mentioned in GCVS4 (1985):

$$Min.I = JD(hel)\ 2428845.428 + 4.122742 \times E.$$

Now we can conclude: As to the first part of observations of TW And (JD 2418542 - 2429118), the linear light elements derived by the author of this note are similar to those presented in GCVS4 but they had been valid only till 1939 and not till JD 2432000, i.e. 1946. Approximately in 1939 the period of this binary abruptly increased by 2.1 seconds. Since that time the period has been constant and times of minima can be described by the new light elements given in this paper. The elements published by Ammann and Walter (1973) and Popper (1989) have never been valid. The elements given by Kreiner (2004) suggest another period increase after 1995 but the data presented here cannot confirm this period change.

Acknowledgement. This work made use of the B.R.N.O., Cracow, and VSNET/VSOLJ on-line databases for retrieving times of minimum of TW And. Thanks go also to Prof. Jerzy M. Kreiner for his list of minimum timings of TW And.

Figure 1: O-C diagram of TW And.



Remark: Prof. Kreiner's list of minima made available to me does not contain his new photoelectric times of minima obtained in 1996 and later but most of them are displayed in his Atlas of O-C diagrams (Kreiner et al., 2001). To get a notion about their position in my O-C diagram of TW And I measured their positions in the Atlas and placed them (without knowing their real numeric values) in Figure 1 together with all other minimum timings.

Figure 2: Phase curve of the secondary minimum of TW And.

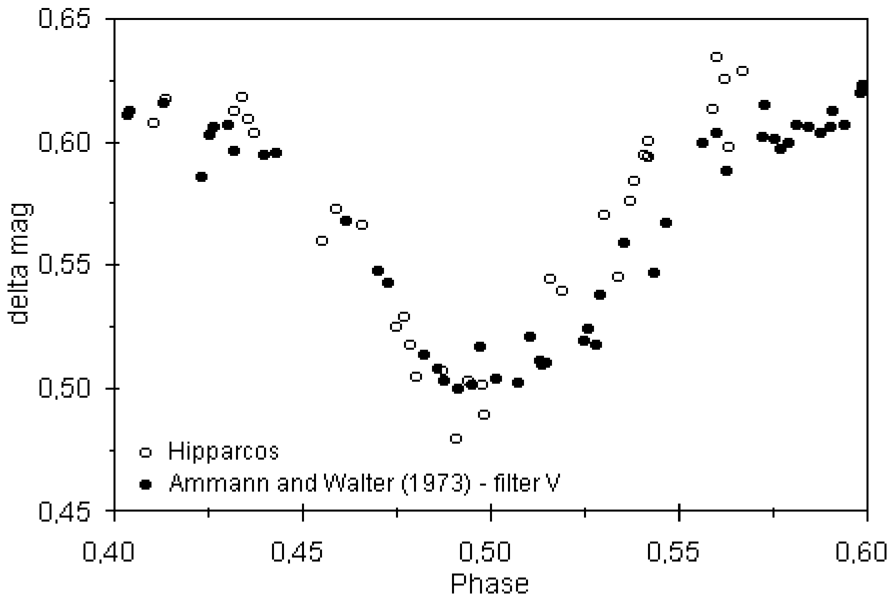


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Table 1. Times of minima for TW And.

No.	Min.JD(hel)	Epoch	(O-C)	Meth	Observer	Source
1	18542.69	-4967	0.058	V	A.Kopff	AN 183:109
2	18559.18	-4963	0.057	V	A.Kopff	AN 183:109
3	18567.4	-4961	0.032	V	J.van der Bilt	AN 183:123
4	18567.41	-4961	0.042	V	A.Kopff	AN 183:109
5	18567.45	-4961	0.082	V	G.van Biesbroeck,..	AN 182:389
6	18600.38	-4953	0.030	V	A.Kopff	AN 183:109
7	18604.495	-4952	0.022	V	G.van Biesbroeck,..	AN 182:389
8	18604.539	-4952	0.066	V	J.van der Bilt	AN 183:123
9	18629.267	-4946	0.057	V	G.van Biesbroeck,..	ApJ 42:315
10	18629.271	-4946	0.061	V	J.van der Bilt	AN 183:123
11	18629.271	-4946	0.061	V	J.van der Bilt	Princ.Cont. 14:11
12	18629.274	-4946	0.064	V	G.van Biesbroeck,..	Ann.Belg. 13:318
13	18633.392	-4945	0.059	V	J.van der Bilt	AN 183:123
14	18967.342	-4864	0.065	V	J.van der Bilt	Princ.Cont. 14:11
15	19272.422	-4790	0.061	V	J.van der Bilt	Princ.Cont. 14:11
16	19301.2808	-4783	0.0602	V	?	MNRAS 101:243
17	19342.516	-4773	0.068	V	J.van der Bilt	Princ.Cont. 14:11
18	19680.5819	-4691	0.0668	V	R.Lehnert	AN 194:165
19	20051.618	-4601	0.054	V	J.van der Bilt	ApJ 56:439
20	20051.620	-4601	0.056	V	J.van der Bilt	Princ.Cont. 14:11
21	20051.622	-4601	0.058	V	J.van der Bilt	AN 196:396
22	20397.927	-4517	0.051	S	M.B.Shapley	this paper
23	20397.928	-4517	0.052	S	M.B.Shapley	this paper
24	24413.487	-3543	0.037	V	J.Gadomski	AcA Ser.C 1:11
25	24413.508	-3543	0.058	V	J.Gadomski	SAC 6(1928):67
26	25118.475	-3372	0.032	V	K.Kordylewski	SAC 7(1929):67
27	25184.419	-3356	0.011	V	J.Mergentaler	this paper
28	25852.319	-3194	0.023	V	K.Kordylewski	this paper
29	25889.425	-3185	0.024	V	J.Pagaczewski	this paper
30	25996.618	-3159	0.025	V	R.S.Dugan	Princ.Cont. 14:11
31	26932.478	-2932	0.018	S	G.R.Miczaika	AN 258:409
32	27093.262	-2893	0.014	V	V.Dombrovsky	Astron.Cirk. 1:6
33	27394.221	-2820	0.011	V	J.Mergentaler	this paper
34	27398.344	-2819	0.011	V	S.Piotrowski	this paper
35	27670.4486	-2753	0.0130	V	S.Piotrowski	AcA Ser.C 2:123
36	27769.391	-2729	0.009	V	F.Lause	AN 260:289
37	27806.496	-2720	0.009	V	F.Lause	AN 260:289
38	27806.4977	-2720	0.0108	V	F.Lause	AN 260:289
39	27827.114	-2715	0.013	V	F.Lause	AN 260:289
40	28037.372	-2664	0.010	V	F.Lause	AN 260:289
41	28066.229	-2657	0.008	V	F.Lause	AN 260:289
42	28107.456	-2647	0.007	V	F.Lause	AN 260:289
43	28107.4562	-2647	0.0074	V	F.Lause	AN 260:289
44	28132.198	-2641	0.013	V	F.Lause	AN 260:289
45	28136.305	-2640	-0.003	V	F.Lause	AN 260:289
46	28466.125	-2560	-0.004	V	F.Lause	AN 277:40
47	28478.499	-2557	0.001	V	F.Lause	AN 277:40
48	28503.244	-2551	0.010	V	F.Lause	AN 277:40
49	28532.0968	-2544	0.0031	V	F.Lause	AN 277:40
50	28532.099	-2544	0.005	V	F.Lause	AN 277:40
51	28544.471	-2541	0.009	V	F.Lause	AN 277:40
52	28569.195	-2535	-0.004	V	F.Lause	AN 277:40
53	28573.327	-2534	0.006	V	F.Lause	AN 277:40
54	28779.444	-2484	-0.016	V	F.Lause	AN 277:40
55	28804.197	-2478	0.001	V	F.Lause	AN 277:40
56	28808.319	-2477	0.000	V	F.Lause	AN 277:40
57	28837.183	-2470	0.005	V	F.Lause	AN 277:40
58	28845.422	-2468	-0.002	V	-	GCVS4 (remark)
59	28845.424	-2468	0.000	V	F.Lause	AN 277:40
60	28845.4269	-2468	0.0030	V	F.Lause	AN 277:40
61	28870.167	-2462	0.006	V	F.Lause	AN 277:40
62	28874.288	-2461	0.005	V	F.Lause	AN 277:40
63	28882.52903	-2459	0.00022	V	-	AJ 68:257
64	28882.542	-2459	0.013	V	F.Lause	AN 277:40
65	28936.134	-2446	0.009	V	F.Lause	AN 277:40
66	29117.531	-2402	0.005	V	F.Lause	AN 277:40
67	30086.352	-2167	-0.024	S	S.Gaposchkin	HA 113:69
68	33174.317	-1418	-0.011	V	A.Szczepanowska	AcA Ser.C 5:74
69	33211.419	-1409	-0.014	V	A.Szczepanowska	AcA Ser.C 5:74
70	33483.536	-1343	0.000	V	E.Pocher	AN 281:113
71	33949.388	-1230	-0.020	V	A.Szczepanowska	AcA Ser.C 5:74
72	34654.382	-1059	-0.019	V	A.Szczepanowska	AcA 6:144
73	35693.327	-807	-0.011	V	V.P.Tsesevich	Astron.Cirk.174:17

74	36868.317	-522	-0.010	V	R.Rudolph	AN 286:209
75	36868.320	-522	-0.007	V	W.Braune	AN 286:209
76	37948.488	-260	-0.003	V	V.Znojil	BRNO 6
77	38286.5568	-178	-0.0012	E	K.Walter	AA 24:131
78	39020.4101	0	-0.0003	E	K.Walter	AA 24:131
79	39020.4104	0	0.0000	E	K.Walter	AA 24:131
80	39020.4107	0	0.0003	E	K.Walter	AA 24:131
81	39024.486	1	-0.047	P	K.Häussler	Hartha BZ 75
82	39024.538	1	0.005	V	W.Braune	AN 290:105
83	39053.365	8	-0.028	P	K.Häussler	Hartha BZ 75
84	39053.385	8	-0.008	V	M.Winiarski	IBVS 1255
85	39053.391	8	-0.002	V	W.Braune	AN 290:105
86	39057.492	9	-0.023	P	K.Häussler	Hartha BZ 75
87	39391.435	90	-0.024	V	M.Seidl	AN 292:185
88	39791.366	187	-0.002	V	M.Winiarski	IBVS 1255
89	40475.747	353	0.000	V	M.E.Baldwin	IBVS 795
90	40512.860	362	0.008	V	M.E.Baldwin	IBVS 795
91	41172.503	522	0.009	V	H.Peter	Orion 127
92	41267.324	545	0.006	V	W.Braune	AN 294:123
93	41601.293	626	0.031	P	K.Häussler	Hartha BZ 75
94	41605.380	627	-0.005	V	M.E.Baldwin	JAAVSO 5:29
95	41605.386	627	0.001	V	H.Peter	BBSAG 6
96	41605.387	627	0.002	V	K.Wälke	AN 294:225
97	41605.393	627	0.008	V	K.Locher	BBSAG 6
98	41877.494	693	0.007	V	K.Locher	BBSAG 10
99	42005.290	724	-0.003	V	K.Locher	BBSAG 12
100	42009.407	725	-0.009	P	K.Häussler	Hartha BZ 75
101	42640.219	878	0.020	V	M.E.Baldwin	JAAVSO 7:28
102	42660.778	883	-0.035	V	M.E.Baldwin	JAAVSO 7:28
103	42681.438	888	0.011	V	K.Locher	BBSAG 24
104	42689.666	890	-0.006	V	M.E.Baldwin	JAAVSO 7:28
105	42710.296	895	0.010	V	K.Locher	BBSAG 24
106	42722.653	898	-0.001	V	M.E.Baldwin	JAAVSO 7:28
107	42780.379	912	0.006	V	K.Locher	BBSAG 26
108	43015.380	969	0.009	P	K.Häussler	Hartha BZ 75
109	43048.390	977	0.037	V	J.Veselý	BRNO 21
110	43790.442	1157	-0.009	V	H.Peter	BBSAG 39
111	43790.449	1157	-0.002	V	-	ApJS 71:595
112	44462.458	1320	-0.004	V	D.Brozman	BRNO 23
113	44561.414	1344	0.006	V	K.Locher	BBSAG 51
114	44590.286	1351	0.019	V	N.Stoikidis	BBSAG 52
115	44767.543	1394	-0.003	V	K.Locher	BBASG 55
116	44845.863	1413	-0.016	V	E.Halbach	AAVSO 6
117	44895.347	1425	-0.005	V	K.Locher	BBSAG 57
118	44928.324	1433	-0.010	V	N.Stoikidis	BBSAG 58
119	45200.442	1499	0.005	V	P.Svoboda	BRNO 26
120	45200.442	1499	0.005	V	P.Fišer	BRNO 26
121	45200.442	1499	0.005	S	K.Carbol	BRNO 26
122	45200.444	1499	0.007	V	M.Varady	BRNO 26
123	45200.444	1499	0.007	V	R.Pliska	BRNO 26
124	45200.444	1499	0.007	V	J.Března	BRNO 26
125	45200.445	1499	0.008	V	M.Zejda	BRNO 26
126	45200.445	1499	0.008	V	P.Troubil	BRNO 26
127	45200.448	1499	0.011	V	P.Neugebauer	BRNO 26
128	45200.451	1499	0.014	V	V.Bulant	BRNO 26
129	45200.453	1499	0.016	V	R.Polloczek	BRNO 26
130	45200.456	1499	0.019	V	N.Kesslerová	BRNO 26
131	45233.433	1507	0.014	S	H.Vielmetter	BAVM 36
132	45233.435	1507	0.016	V	T.Gráf	BRNO 26
133	45295.250	1522	-0.010	V	I.Zelinka	BRNO
134	45295.253	1522	-0.007	V	K.Locher	BBSAG 64
135	45365.338	1539	-0.009	V	T.Brelstaff	BAA-VSS 60:15
136	45604.464	1597	-0.004	V	K.Locher	BBSAG 68
137	45670.414	1613	-0.018	V	K.Locher	BBSAG 70
138	46016.730	1697	-0.014	V	S.Cook	AAVSO 6
139	46049.719	1705	-0.007	V	P.Atwood	AAVSO 6
140	46078.574	1712	-0.012	V	D.Williams	AAVSO 6
141	46404.289	1791	0.005	V	M.Kohl	BBSAG 79
142	46614.574	1842	0.029	V	K.Locher	BBSAG 80
143	46742.336	1873	-0.015	V	H.Peter	BBSAG 82
144	46742.347	1873	-0.004	V	K.Locher	BBSAG 82
145	46981.461	1931	-0.011	V	K.Locher	BBSAG 84
146	47014.446	1939	-0.008	V	W.Braune	BAVM 50
147	47076.315	1954	0.020	V	K.Locher	BBSAG 86
148	47385.476	2029	-0.027	V	K.Locher	BBSAG 89
149	47480.283	2052	-0.043	V	K.Locher	BBSAG 90
150	48123.471	2208	-0.007	V	H.Peter	BBSAG 96

151	48189.414	2224	-0.028	V	K.Locher	BBSAG 96
152	48189.435	2224	-0.007	V	H.Peter	BBSAG 96
153	48230.665	2234	-0.005	C	HIPPARCOS	J.Kreiner (p.c.)
154	48255.407	2240	0.001	V	K.Locher	BBSAG 97
155	48284.256	2247	-0.010	C	HIPPARCOS	this paper
156	48302.799	2251.5	-0.019	C	HIPPARCOS	this paper
157	48490.412	2297	0.008	V	H.Peter	BBSAG 98
158	49224.242	2475	-0.014	V	S.Cook	AAVSO 6
159	49302.570	2494	-0.019	V	M.E.Baldwin	AAVSO 6
160	49574.683	2560	-0.008	V	M.E.Baldwin	AAVSO 6
161	49599.418	2566	-0.010	V	A.Kratochvíl	BRNO 31
162	49599.419	2566	-0.009	V	L.Honzík	BRNO 31
163	49599.433	2566	0.005	V	M.Větrovcová	BRNO 31
164	49599.435	2566	0.007	V	M.Rottenborn	BRNO 31
165	49607.659	2568	-0.014	V	M.E.Baldwin	AAVSO 6
166	49632.410	2574	0.000	V	P.Molík	this paper
167	49661.267	2581	-0.002	V	A.Kratochvíl	BRNO 31
168	49661.271	2581	0.002	V	M.Větrovcová	BRNO 31
169	49933.363	2647	-0.009	V	M.Větrovcová	BRNO 32
170	49978.718	2658	-0.004	V	M.E.Baldwin	AAVSO 6
171	50007.563	2665	-0.019	V	M.E.Baldwin	AAVSO 6
172	50007.572	2665	-0.010	C	S.Cook	AAVSO 6
173	50349.750	2748	-0.021	V	M.E.Baldwin	AAVSO 6
174	50370.397	2753	0.012	V	K.Locher	BBSAG 113
175	50720.811	2838	-0.009	V	R.Hill	AAVSO 6
176	51401.068	3003	-0.009	V?	?	VSNET/VSOLJ
177	51747.379	3087	-0.010	V	R.Meyer	BAVM 143
178	52217.385	3201	0.001	V	R.Meyer	BAVM 154
179	52501.8619	3270	0.0067	E	-	krakow.pl/ephem/
180	52910.010	3369	0.001	V	K.Hirosawa	VSOLJ V.S.Bull.42
181	53293.436	3462	0.010	V	R.Meyer	BAVM 174
182	53746.927	3572	-0.004	V	K.Hirosawa	VSNET-ECL Jan2006

Notes to the table:

Times of minima are given in the format JD(hel) - 2400000.

Epochs and O-C residuals were calculated with respect to the elements:

$$Min.I = JD(hel)\ 39020.4104 + 4.122766 \times E.$$

Method of observation: V = visual, P = photogr. patrol plate, S = series of photographs, E = classical photoelectric, C = CCD camera.

Source:
AAVSO = American Association of Variable Star Observers,
Observed Minima Timings of Eclipsing Binaries,
AcA = Acta Astronomica,
AJ = Astronomical Journal,
AN = Astronomische Nachrichten,
Ann.Belg. = Annales de l'Observatoire royal de Belgique,
ApJ = Astrophysical Journal,
ApJS = Astrophysical Journal, Supplement Series,
Astron.Cirk. = Astronomicheskij Tsirkulyar (USSR),
BAA-VSS = British Astronomical Association, Variable Star Section Circular,
BAC = Bulletin of the Astronomical Institutes of Czechoslovakia
BAVM = Mitteilungen der Bundesdeutsche Arbeitsgemeinschaft
für Veränderliche Sterne,
BBSAG = Bulletin der Bedeckungsveränderlichen Beobachter
der Schweizerischen Astronomischen Gesellschaft,
BRNO = Contributions of the Public Observatory and Planetarium in Brno,

GCVS4 = General Catalogue of Variable Stars, 4th edition,
HA = Annals of Harvard College Observatory,
Hartha BZ = Harthaer Beobachtungs-Zirkular,
JAAVSO = Journal of the American Association of Variable Star Observers,
krakow.pl/ephem/ = http://www.as.ap.krakow.pl/ephem/,
MNRAS = Monthly Notices of the Royal Astronomical Society,
Princ.Cont. = Contributions from the Princeton University Observatory,
SAC = Rocznik Astronomiczny Observatorium Krakowskiego,
VSNET-ECL Jan2006 = VSNET-ECL Archives, January 2006,
VSOLJ V.S.Bull. = Variable Star Observers League in Japan,
Variable Star Bulletin.

Remarks on individual minima:
No.1 8 estimates on descending branch, last one 0.06 day from mid-eclipse
No.2 6 estimates high on ascending branch, first one 0.15 day after mid-eclipse
No.3 4 estimates, two in constant minimum, one each on two branches
No.4 9 estimates on descending branch, last one 0.04 day before mid-eclipse
No.5 4 estimates during constant minimum. Observers: G.van Biesbroeck, L.Casteels
No.6 46 estimates on both branches and bottom
No.7 in original paper the geocentric value of 18604.49 is given. Observers: G.van Biesbroeck, L.Casteels
No.8 15 estimates on both branches and bottom
No.9 initial epoch from elements (normal minimum determined by J.Q.Stewart from observations by G.van Biesbroeck and L.Casteels)
No.10 9 estimates on bottom and ascending branch
No.11 van der Bilt's observations from JD 18567-18736 grouped into normal minimum, time determined by R.S.Dugan
No.12 initial epoch from elements (normal minimum from all observations). Observers: G.van Biesbroeck, L.Casteels
No.13 8 estimates at bottom and both branches
No.14 van der Bilt's observations from JD 18938-19000 grouped into normal minimum, time determined by R.S.Dugan
No.15 normal minimum from all van der Bilt's observations
No.16 normal minimum
No.17 van der Bilt's observations from JD 19272-19437 grouped into normal minimum, time determined by R.S.Dugan
No.18 low accuracy, 17 estimates
No.19 initial epoch from elements determined by M.B.Shapley by subtracting 0.004 d. from epoch in van der Bilt's elements (AN 196:396)
No.20 initial epoch from elements, van der Bilt's observations from JD 19767-20051 grouped into normal minimum, time determined by R.S.Dugan
No.21 initial epoch from elements
No.22 time of minimum determined by P.Molík from photovisual data published by M.B.Shapley (1922, ApJ 56:439)
No.23 time of minimum determined by P.Molík from photographic data published by M.B.Shapley (1922, ApJ 56:439)
No.24 normal minimum
No.25 normal minimum
No.26 normal minimum

No.27 low accuracy, time of minimum determined by P.Molík from data published by R.Szafraniec (1959:Krakow.obs.gwiazd zmien.1920-1950)
No.28 time of minimum determined by P.Molík from data published by R.Szafraniec (1959)
No.29 time of minimum determined by P.Molík from data published by R.Szafraniec (1959)
No.30 normal minimum from observations in JD 25922, 25996, and 26025
No.31 normal minimum determined from a series of patrol plates within the interval JD 25502 - 27334, cited in MNRAS 101:243
No.32 Source: Inf.Cir.As.Inst.USSR 1(1933):6
No.33 time of minimum determined by P.Molík from data published by R.Szafraniec (1959)
No.34 time of minimum determined by P.Molík from data published by R.Szafraniec (1959)
No.38 normal minimum determined from minima 27769.391, 27806.496 and 27827.114, cited also in MNRAS 101:243
No.43 normal minimum determined from minima 28037.372, 28066.229, 28107.456, 28132.198 and 28136.305, cited also in MNRAS 101:243
No.49 normal minimum determined from 7 minima (28466.125 - 28573.327)
No.58 initial epoch from elements
No.60 normal minimum determined from 10 minima (28779.444 - 29117.531)
No.63 initial epoch from elements
No.65 in original paper the incorrect value of 29836.134 is given
No.67 normal minimum from many estimates on Harvard patrol plates
No.70 ascending branch was not observed, published also in BAVM 8 and MVS Vol.1, No.124
No.72 normal minimum
No.73 normal minimum
No.74 published also in BAVM 13
No.75 published also in BAVM 13
No.76 published also in BAC 15:26
No.77 filter V
No.78 filter V
No.79 initial epoch from elements, mean of B and V filters
No.80 filter B
No.82 published also in BAVM 18
No.84 low accuracy
No.85 published also in BAVM 18
No.87 low accuracy, published also in BAVM 23
No.92 published also in BAVM 25
No.96 published also in BAVM 26
No.101 superposition of observations from JD 42631 and 42652
No.102 low accuracy
No.105 the value of 42712.296 given in original paper is incorrect
No.111 initial epoch from elements
No.133 not accepted for publication
No.153 normal minimum, Source: list of Prof. J. M. Kreiner, 2001 (private communication)
No.155 time of minimum determined by P.Molík, low accuracy
No.156 Min.II, time of minimum determined by P.Molík, distorted light curve
No.158 normal minimum (superposition of observations from JD 49211 and 49236)
No.171 low accuracy
No.172 normal minimum (superposition of observations from JD 50007 and 50011)
No.176 method of observation is not given
No.177 superposition

No.179 initial epoch from elements, the time of minimum does not correspond to any observed minimum timing, Source: http://www.as.ap.krakow.pl/ephem/
No.181 superposition