T Vulpeculae:

Maximum Times covering 120 years show a slight, continuous Period Decrease

US astronomer Benjamin Apthorp Gould (1824...1896) studied in Germany, namely mathematics in Göttingen from Prof. Gauss and astronomy in Bonn from Prof. Argelander. Back home Gould started a visual sky survey to complete Argelander's Bonner Durchmusterung. After Gould had departed to observe in Argentina his assistant Seth Carlo Chandler jr. (1846...1913) in 1876 recruited the Boston bank clerk Edwin F. Sawyer to contribute with own visual observations. It seems, that Sawyer observed at least until about 1900. During these 25 years with the visual comparison methods of his time Sawyer discovered a remarkable number of variable stars, among them (Sawyer, 1885) the bright, classical cepheid T Vulpeculae.

T Vul is about the 10th in apparent magnitude of all classical cepheids. A modern database (DDODB, ca. 1996) reports a mean magnitude of 5,75mag and an amplitude of 0,64mag. The period is 4,4 days. The lightcurve (figure 1) produces the typical smooth, asymmetric pattern of classical cepheids with periods between 3 and 6 days. Around 1900 the term "cepheid" had not yet been introduced. Researchers designated variables with asymmetric lightcurves and periods shorter than 50 days as short period variables. Karl Schwarzschild (1900) discovered, that brightness and brightness variation of a star on photographic plates can be much different from visual ones. In the following years scientists recognized, that short period variables show this phenomenon to an especially marked amount. Authors of the 1920ies and 1930ies continued to study this by comparing visual magnitudes or magnitudes on panchromatic, sensitised ("photovisual") plates on one with magnitudes on unsensitised, blue sensitive ("photographic") plates on the other side. The period of T Vul can be compared to the one of δ Cephei, however because of his brightness and a close companion δ Cephei is difficult to observe. Therefore among the cepheids with shorter periods T Vul always has been a favourite object in these studies. Out of the great number of reported observations I adopted 221 maximum times and built an O-C-diagram (figure 2). I give details of each data point in the appendix and some general technical remarks how to read old observations in the key to the appendix. The diagram is based on the ephemeris of Szabados (1977), which is given in the figure.

The Danish astronomer Axel Nielsen around 1930 suspected a variable period, reviewed all observations of T Vulpeculae (Nielsen 1931, corresponding to epoch −3800 in figure 2) and could not establish a change. 46 years later Szabados (1977) in his investigation of T Vul found a definite period change, but still hesitated to state, that it was continuous. Turner (1998) finally reported a continuous period decrease of T Vul amounting to 0,25 sec/year. Applying a quadratic fit to the premium quality part of my data set (red in figure 2, see key to column 5 at the end of the appendix) I find a similar value and a mean error of 0,05 sec/year. The probability is 68%, that the true, but unknown value of the rate of period change will be found between −0,25 ±0,05 s/y. The probability is 99%, that it will be found between −0,25 ±0,13 s/y. A rate of 0,25 s/y is unspectacular and ongoing observations are likely to unveil similar rates of period change in many other cepheids. On some well known cepheids Turner (1998) for comparison gave the following rates of period decrease and increase:

SV Vul	-	226	s/y	T Mon	+	13	s/y
RW Cas	-	13	s/y	Y Oph	+	11	s/y
ζ Gem	-	3,4	s/y	RU Sct	+	10	s/y
W Gem	-	1,5	s/y	SZ Aql	+	5,7	s/y
V Lac	-	0,8	s/y	TX Cyg	+	4,4	s/y
T Vul	-	0,2	s/y	TT Aql	+	0,3	s/y
δ Cep	-	0,1	s/y	η Aql	+	0,2	s/y

Figure 1: Three lightcurves of T Vulpeculae (same ephemeris as in figure 2):

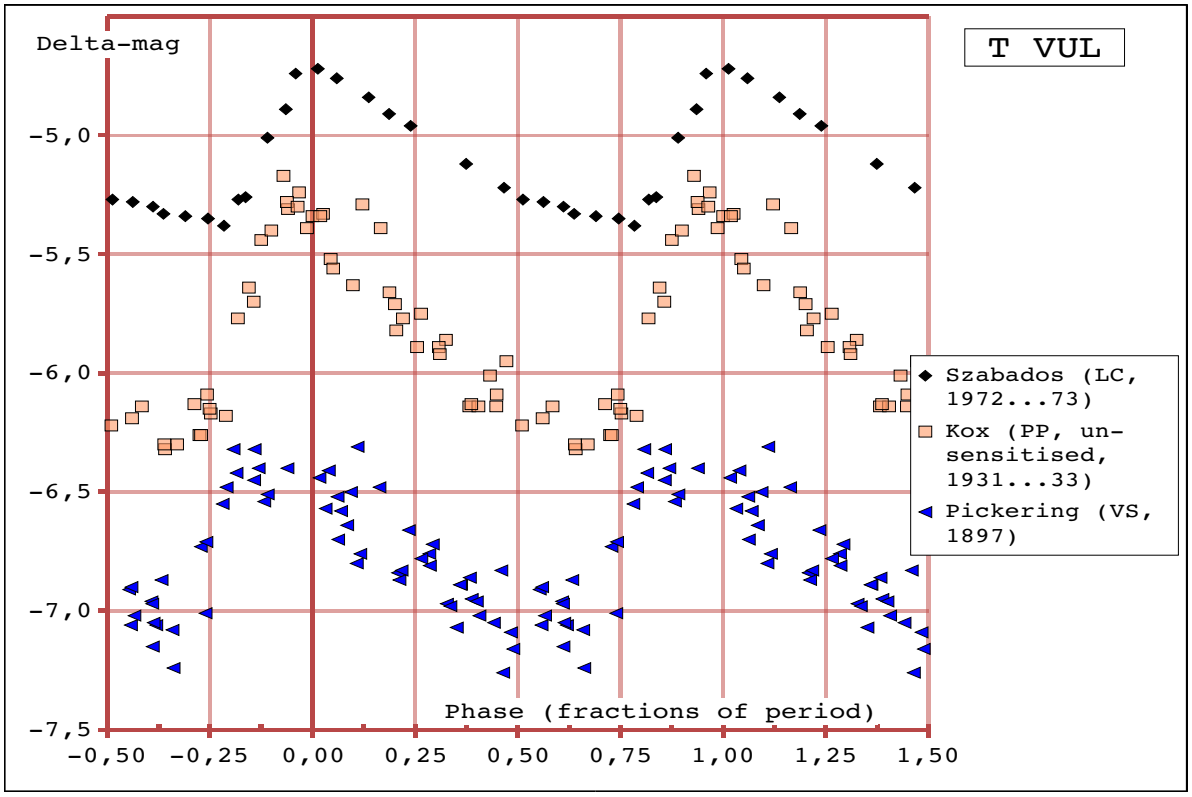
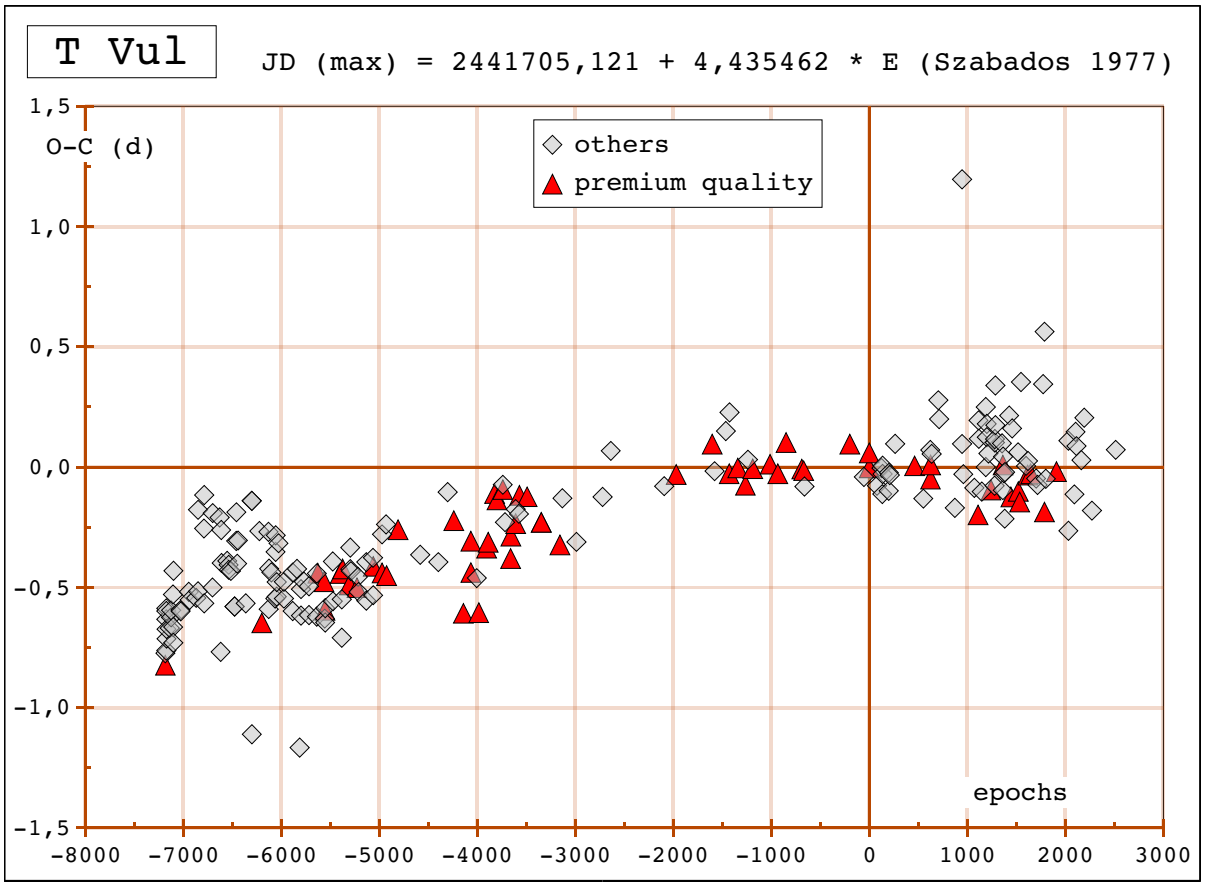


Figure 2: The O-C-diagram of T Vulpeculae (1885 until 2003):



Using Szabados' (1977) ephemeris I reduced three sets of observations, each separated from the other by at least 30 years, into one standard epoch (figure 1). The curves have been shifted up- and downwards to graphically convenient places, but the ranges of values have been left unchanged. The middle lightcurve consists of photographic estimates on unsensitised plates (Kox 1934, ref. in the appendix). The brightness range of this set is greater than the range Szabados' photoelectric-(V) set covers. The diagram furthermore illustrates, that the phase shift from Szabados' (1977) precise data set on top to Pickering's visual one on bottom is inconspicuous. Unprecise data sets display such a shift only, if they cover time intervals longer than 30 years.

Remarks: The three papers of Szabados (1977, 1980, 1981, see also: http://www.konkoly.hu/) give comprehensive collections of historical observations of all long known cepheids. These collections are an excellent starting point for every investigation in period changes of cepheids. For other papers I used the astronomical library of Bamberg Observatory and the service CDS/ADS Strasbourg (http://cdsads.u-strasbg.fr/article_service.html). Dr. Ulrich Bastian from Astronomisches Recheninstitut in Heidelberg supplied the Puebla/Mexico paper.

DDODB	David Dunlap Observatory Database of Galactic Classical Cepheids http://www.astro.utoronto.ca/DDO/research/cepheids/cepheids.html
Nielsen (1931)	Astron. Nachr. 244, 331
Sawyer (1885)	Astron. Journ. 7, 3
Schwarzschild (1900)	Publ.d. von Kuffner'schen Sternwarte in Wien (Austria) Nr. 5
Szabados (1977)	Mitteilungen d.Sternw.d. Ungar.Akad.d.Wiss., Budapest, Nr. 70
Szabados (1980)	Mitteil. ... as above or: Commun. Konkoly Obs., Budapest, Nr. 76
Szabados (1981)	Mitteil. ... as above or: Commun. Konkoly Obs., Budapest, Nr. 77
Turner (1998)	Journal of the AAVSO, 26, 101

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Appendix

Maximum Times of T Vulpeculae

1 Nr.	2 JD -2400000	3 Meth Obs	4 Type Max	5 Wgt	6 reporting Observer(s)	7 referring Author(s)	8 Reference
1	09848,81	VS	LM	1	CHANDLER		AJ 7, 1
2	09848,86	VS			CHANDLER		AJ 7, 1
3	09884,53	VS			SAWYER	SZABADOS	MBS Nr.70
4	09888,79	VS			CHANDLER	LUIZET	AN 192, 193
5	09888,92	VS			SAWYER	LUIZET	AN 192, 193
6	09893,39	VS			CHANDLER	LUIZET	AN 192, 193
7	09897,71	VS			CHANDLER	SZABADOS	MBS Nr.70
8	09897,75	VS			SAWYER	LUIZET	AN 192, 193
9	10048,56	VS			CHANDLER	LUIZET	AN 192, 193
10	10101,83	VS			CHANDLER	SZABADOS	MBS Nr.70
11	10110,73	VS			CHANDLER	LUIZET	AN 192, 193
12	10195,07	VS			SAWYER	LUIZET	AN 192, 193
13	10199,37	VS			SAWYER	SZABADOS	MBS Nr.70
14	10203,74	VS			SAWYER	LUIZET	AN 192, 193
15	10212,91	VS			GORE	PRAGER/SZABAD	MBS Nr.70
16	10532,10	VS	X		SAWYER		AJ 16, 113
17	10536,53	VS	N		SAWYER		AJ 16, 113
18	10909,19	VS	X		SAWYER		AJ 16, 113
19	10944,64	VS	N		SAWYER		AJ 16, 113

20	11246,26	VS	N		SAWYER		AJ 16, 113
21	11321,69	VS	X		SAWYER		AJ 16, 113
22	11330,90	VS	X		YENDELL		AJ 9, 137
23	11596,95	VS			YENDELL	LUIZET	AN 192, 193
24	11605,51	VS			YENDELL	LUIZET	AN 192, 193
25	11605,96	VS			YENDELL	SZABADOS	MBS Nr.70
26	11982,59	VS			YENDELL	LUIZET	AN 192, 193
27	11991,77	VS			YENDELL	SZABADOS	MBS Nr.70
28	12306,67	VS	X		YENDELL		AJ 13, 81
29	12346,03	VS	N		YENDELL		AJ 13, 81
30	12373,15	VS	N		SAWYER		AJ 16, 113
31	12395,19	VS	X		SAWYER		AJ 16, 113
32	12648,02	VS	N		YENDELL		AJ 14, 11
33	12710,10	VS	X		YENDELL		AJ 14, 11
34	12718,95	VS	X		SAWYER		AJ 16, 113
35	12812,09	VS	N		SAWYER		AJ 16, 113
36	12980,49	VS			YENDELL	NIELSEN	AN 244, 331
37	12980,49	VS			YENDELL	NIELSEN	AN 244, 331
38	13051,73	VS	X		YENDELL		AJ 15, 39
39	13060,72	VS	N		YENDELL		AJ 15, 39
40	13095,99	VS	X		SAWYER		AJ 16, 113
41	13131,57	VS	N		SAWYER		AJ 16, 113
42	13481,71	VS			SAWYER	NIELSEN	AN 244, 331
43	13752,70	VS	X		YENDELL		AJ 17, 67
44	13760,60	VS	N		YENDELL		AJ 17, 67
45	13761,57	VS			YENDELL	SZABADOS	MBS Nr.70
46	14098,54	VS			YENDELL	SZABADOS	MBS Nr.70
47	14213,48	VS	LM	1	PICKERING		HA 46, 127
48	14515,47	VS	X		LUIZET		AN 153, 79
49	14524,02	VS			LUIZET		AN 192, 193
50	14541,93	VS			LUIZET		AN 192, 193
51	14643,93	VS	X		LUIZET		AN 153, 79
52	14821,24	VS	N		YENDELL		AJ 21, 23
53	14834,74	VS	X		YENDELL		AJ 21, 23
54	14843,68	VS	X		LUIZET		AN 153, 79
55	14887,78	VS			LUIZET		AN 192, 193
56	14887,84	VS			LUIZET		AN 192, 193
57	14967,84	VS	X		LUIZET		AN 153, 79
58	15211,56	VS			LUIZET		AN 192, 193
59	15211,63	VS			LUIZET		AN 192, 193
60	15610,70	VS			LUIZET		AN 192, 193
61	15610,86	VS			LUIZET		AN 192, 193
62	15801,60	VS			TASS	SZABADOS	MBS Nr.70
63	15925,05	VS			YENDELL	SZABADOS	MBS Nr.70
64	15983,26	VS			LUIZET		AN 192, 193
65	15983,37	VS			LUIZET		AN 192, 193
66	16120,90	VS			TASS	SZABADOS	MBS Nr.70
67	16346,97	VS			LUIZET		AN 192, 193
68	16347,09	VS			LUIZET		AN 192, 193
69	16701,80	VS			LUIZET		AN 192, 193
70	16701,98	VS			LUIZET		AN 192, 193
71	16741,90	VS	LM	1	TERKAN		AN 168, 33
72	17030,17	VS	LM	1	LUIZET		AN 192, 193
73	17065,50	VS			LUIZET	SZABADOS	MBS Nr.70
74	17069,97	PP	LM	1	WILKENS		AN 172, 305
75	17078,79	VS			LUIZET		AN 192, 193
76	17078,85	VS			LUIZET		AN 192, 193
77	17425,01	VS			LUIZET		AN 192, 193
78	17429,28	VS			LUIZET		AN 192, 193
79	17757,62	VS	LM	1	VON ZEIPEL		AN 177, 379

80	17828,32	VS			LUIZET		AN 192, 193
81	17828,48	VS			LUIZET		AN 192, 193
82	17864,09	VS	LM	1	NIJLAND		UTRR 8, 239
83	18170,07	VS	LM	1	NIJLAND		UTRR 8, 239
84	18214,49	VS			LUIZET		AN 192, 193
85	18214,58	VS			LUIZET		AN 192, 193
86	18245,53	VS			NIJLAND		UTRR 8, 239
87	18520,46	VS	LM	1	NIJLAND		UTRR 8, 239
88	18564,86	VS			LUIZET		AN 192, 193
89	18591,41	VS			LUIZET		AN 192, 193
90	18937,34	VS			LUIZET		AN 192, 193
91	18937,50	VS			LUIZET		AN 192, 193
92	19248,00	VS			LUIZET		AN 192, 193
93	19252,28	VS			LUIZET		AN 192, 193
94	19252,400	LC		1	GUTHNICK	HELLERICH	AN 228, 113
95	19656,00	PP	LM	1	ROBINSON		HA 90, 27
96	19656,16	PP			ROBINSON		HA 90, 27
97	19833,62	VS			DZIEWULSKI		WILNO 7, 28
98	19860,02	PP	LM	1	HERTZSPRUNG		AN 208, 51
99	20379,16	VS	LM	1	DZIEWULSKI		WILNO 7, 28
100	21381,47	VS			LUYTEN	NIELSEN	AN 244, 331
101	22202,00	VS			LUYTEN	HELLERICH	AN 228, 113
102	22623,66	VS			DOBERCK		AN 221, 305
103	22898,54	VS	LM	1	DOBERCK		AN 221, 305
104	23332,83	VS	LM	1	HELLERICH		AN 228, 113
105	23674,53	VS	LM	1	HELLERICH		AN 228, 113
106	23674,66	VS	LM	1	HOPMANN		AN 221, 337
107	23945,07	VS			HELLERICH		AN 228, 113
108	24029,20	VS	LM	1	HELLERICH		AN 228, 113
109	24379,87	VS	LM	1	HELLERICH		AN 228, 113
110	24459,733	LC	LM	1	HUFFER	STEBBINS	PWAS 15, 127
111	24748,24	VS	LM	1	KUKARKIN		PSMO 13, 118
112	24859,10	VS	LM	1	KUKARKIN		PSMO 13, 118
113	25116,40	PP	LM	1	HELLERICH		AN 256, 221
114	25116,42	PP			HELLERICH		AN 256, 221
115	25218,28	VS			LAUSE		AN 264, 229
116	25470,95	VS	LM	1	KUKARKIN		PSMO 13, 118
117	25484,35	VS	LM	1	ZVEREV		PSMO 8(1), 125
118	25701,74	VS	LM	1	DZIEWULSKI EA		WILNO 13, 25
119	25701,80	VS			DZIEWULSKI EA		WILNO 13, 25
120	25848,15	VS			ZVEREV		PSMO 8(1), 53
121	25874,84	VS	LM	1	ZVEREV		PSMO 8(1), 125
122	26220,80	VS	LM	1	KUKARKIN		PSMO 13, 118
123	26859,40	PP	LM	1	KOX		AN 256, 21
124	26859,40	PP	LM	1	KOX		AN 256, 21
125	27706,48	VS	LM	1	MICZAIKA		AN 262, 347
126	27817,56	VS			MICZAIKA		AN 262, 347
127	28451,65	VS			KEPINSKI	SZABADOS	MBS Nr.70
128	29631,67	VS			MANDRE	SZABADOS	MBS Nr.70
129	30004,44	VS			CONCEICAO SIL	SZABADOS	MBS Nr.70
130	32421,62	VS			NN	BERDNIKOV EA	AVSJ 31, 146
131	32967,230	LC	LM	1	EGGEN		APJ 113, 367
132	34595,171	LC		1	DETRE	SZABADOS	MBS Nr.70
133	34701,51	VS			WROBLEWSKI		AAC 9, 51
134	35216,19	VS			MARKS		AAC 9, 51
135	35362,383	LC		1	WALRAVEN EA	SZABADOS	MBS Nr.70
136	35380,38	VS			AZARNOVA	SZABADOS	MBS Nr.70
137	35757,163	LC		1	PROKOFYEVA	SZABADOS	MBS Nr.70
138	36098,622	LC		1	SVOLOPOULOS	SZABADOS	MBS Nr.70
139	36214,05	VS			LATYSHEV	SZABADOS	MBS Nr.70

140	36431,350	LC	LM	1	MITCHELL EA		BOTT 3, 153
141	37212,010	LC		1	MITCHELL EA	SZABADOS	MBS Nr.70
142	37562,372	LC		1	JOHANSEN	SZABADOS	MBS Nr.70
143	37939,516	LC		1	WILLIAMS	SZABADOS	MBS Nr.70
144	38649,080	LC		1	JOHANSEN	SZABADOS	MBS Nr.70
145	38733,347	LC		1	WISNIEWSKI EA	SZABADOS	MBS Nr.70
146	38773,20	VS			NN	BERDNIKOV EA	AVSJ 31, 146
147	40822,560	LC	LM	1	FELTZ&MCNAMAR		PASP 92, 609
148	41461,13	VS			NN	BERDNIKOV EA	AVSJ 31, 146
149	41705,118	LC		1	SZABADOS		MBS Nr.70
150	41705,180	LC	LM	1	SZABADOS		MBS Nr.70
151	42051,01	VS			NN	BERDNIKOV EA	AVSJ 31, 146
152	42259,55	VS			NN	BERDNIKOV EA	AVSJ 31, 146
153	42290,49	VS			NN	BERDNIKOV EA	AVSJ 31, 146
154	42303,88	VS			NN	BERDNIKOV EA	AVSJ 31, 146
155	42308,35	VS			NN	BERDNIKOV EA	AVSJ 31, 146
156	42587,68	VS			NN	BERDNIKOV EA	AVSJ 31, 146
157	42592,19	VS			NN	BERDNIKOV EA	AVSJ 31, 146
158	42632,10	VS			NN	BERDNIKOV EA	AVSJ 31, 146
159	42876,18	VS			NN	BERDNIKOV EA	AVSJ 31, 146
160	43754,310	LC	LM	1	MOFFETT&BARNE		APJS 55, 389
161	44148,93	VS			WEIDLICH		BAVM Nr.38
162	44464,05	VS			WEIDLICH		BAVM Nr.38
163	44472,800	LC	LM	1	BERDNIKOV		MCMDB
164	44477,294	LC	LM	1	BERSIER EA		AAPS 108, 9
165	44526,13	VS			WEIDLICH		BAVM Nr.38
166	44832,40	VS			WEIDLICH		BAVM Nr.38
167	44863,37	VS			WEIDLICH		BAVM Nr.38
168	45577,11	VS			BRAUNE		BAVM Nr.38
169	45905,60	VS			GECKELER		BAVM Nr.39
170	45906,70	VS			GECKELER		BAVM Nr.43
171	45958,70	VS			SCHMIDT		BAVM Nr.39
172	46459,85	VS			NN	BERDNIKOV EA	AVSJ 31, 146
173	46623,850	LC	LM	1	BERDNIKOV		AAPT 2, 1
174	46646,42	VS			STURM		BAVM Nr.46
175	46659,65	VS			ALTEWEIER		BAVM Nr.46
176	46796,93	VS			NN	BERDNIKOV EA	AVSJ 31, 146
177	46974,45	VS			GECKELER		BAVM Nr.50
178	46974,70	VS			MALINOWSKI		BAVM Nr.52
179	47023,42	VS			STURM		BAVM Nr.50
180	47027,80	VS			ALTEWEIER		BAVM Nr.50
181	47098,70	VS			THOMAS		BAVM Nr.60
182	47213,870	LC	LM	1	BERDNIKOV		AAPT 2, 31/43
183	47378,00	VS			DAHM		BAVM Nr.56
184	47387,05	VS			MALINOWSKI		BAVM Nr.52
185	47391,50	VS			STURM		BAVM Nr.52
186	47409,30	VS			RINGE		BAVM Nr.52
187	47413,90	VS			ALTEWEIER		BAVM Nr.52
188	47706,40	VS			GECKELER		BAVM Nr.56
189	47750,56	VS			SEIFERT		BAVM Nr.56
190	47755,100	LC	LM	1	BERDNIKOV		AAPT 2, 107
191	47759,57	VS			DAHM		BAVM Nr.56
192	47799,42	VS			STURM		BAVM Nr.56
193	47830,28	VS			STRUEVER		BAVM Nr.56
194	47843,78	VS			SCHUBERT		BAVM Nr.56
195	48034,74	VS			DAHM		BAVM Nr.59
196	48114,240	LC	LM	1	BERDNIKOV		AAPT 2, 157
197	48167,75	VS			KRIEBEL		BAVM Nr.59
198	48442,65	VS			GECKELER		BAVM Nr.60
199	48446,922	LC	LM	1	TYCHO (ESA)		HIP Nr.102949

200	48513,410	LC	LM	1	BERDNIKOV		PISM 18, 325
201	48571,57	VS			DAHM		BAVM Nr.60
202	48797,43	VS			GECKELER CARS		BAVM Nr.62
203	48877,230	LC	LM	1	BERDNIKOV		PISM 19, 210
204	48886,16	VS			RAETZ		BAVM Nr.62
205	49010,300	LC	LM	1	BARNES		PASP 109, 645
206	49254,23	VS			NN	BERDNIKOV EA	AVSJ 31, 146
207	49316,30	VS			STRUEVER		BAVM Nr.68
208	49569,54	VS			RAETZ KERSTIN		BAVM Nr.79
209	49626,670	LC	LM	1	BERDNIKOV		PISM 21, p.nn
210	49636,29	VS			STURM		BAVM Nr.79
211	49693,34	VS			RAETZ		BAVM Nr.79
212	50172,400	LC	LM	1	KISS		MNRAS 297, 825
213	50713,28	VS			MEYER		BAVM Nr.113
214	50718,09	VS			MAINTZ		BAVM Nr.113
215	50988,43	VS			NN	BERDNIKOV EA	AVSJ 31, 146
216	51037,48	VS			MEYER		BAVM Nr.122
217	51077,34	VS			RAETZ KERSTIN		BAVM Nr.122
218	51303,49	VS			NN	BERDNIKOV EA	AVSJ 31, 146
219	51436,73	VS			STURM		BAVM Nr.143
220	51782,31	VS			MEYER		BAVM Nr.143
221	52860,37	VS			MEYER		BAVM Nr.171

Key:

column 3 method of observations: VS = visual, including the traditional visual "photometers" PP = all kinds of photographic observations LC = photo-electrical or CCD

column 4 type of maximum time: no entry, X, N or LM; no entry designates, that I took a reported maximum time as given in the reference, but sometimes rounded to a smaller number of decimals; X designates, that I (present paper) reduced a number of reported maximum times based on few single observations into a standard epoch and took the mean as maximum time; N designates an analogous procedure on reported minimum times, applying additionally a given M-m value to get a maximum time; LM designates, that I won an own subsequent maximum time from single observations. The archaic habit of the 19th century to derive maxima and minima from few observatons (sometimes only 2 or 3) devaluates these reports. I urgently warn today's researchers of cepheid period changes against overstressing such data, especially if they scatter to positive O-C values!

column 5 weight: no entry or “1” (= premium quality, marked red in figure 2); I regard as premium quality all LC data, VS and PP data only on the condition, that original single observations have been reported and can be used to determine subsequently a maximum time (LM in col.4)

column 8 reference: AAC = Acta Astronomica Series C, AAPS = Astronomy and Astrophysics Supplement Series, AAPT = Astronomical and Astrophysical Transactions, AJ = Astron.Journ., AN = Astron.Nachr., APJ = Astrophysical Journal, APJS = Astrophysical Journal Supplement Series, AVSJ = Journal of the AAVSO (USA), BAVM = BAV-Mitteilungen (Berlin, D), BOTT = Boletín de los Observatorios de Tonantzintla y Tacubaya (Puebla, Mexico), HA = Annals of the Harvard College Observatory (USA), HIP = Hipparcos Catalogue (ESA, via Simbad: http://simbad.u-strasbg.fr/), MBS = Mitteilungen der Sternwarte der Ungarischen Akademie der Wissenschaften (Budapest, H), MCMDB = loci diversi taken from the McMaster Cepheid Photometry ... Archive (http://crocus.physics.mcmaster.ca/Cepheid/), MNRAS = Monthly Notices of the Royal Astronomical Society, PASP = Publications of the Astronomical Society of the Pacific, PISM = Pisma Astronomitsky Zhurnal (USSR, RUS), PSMO = Publications (Trudy) of the Sternberg Astronomical Institute/Observatory (Moscow, USSR), PWAS = Publications of the Washburn Observatory of the University of Wisconsin (Madison, USA), UTRR = Recherches Astronomiques de l' Observatoire d' Utrecht (NL), WILNO = Bulletin de l'Observatoire Astronomique de Vilno, Wilno-Bulletin (Poland).