THE CLASSICAL CEPHEID PROGRAM
JD 2,441,000 - 2,442,000

by

THOMAS A. CRAGG
The Hale Observatories
Mt. Wilson, CA 91023

This paper is a study of the second 1000-day interval of data on long-period classical cepheids. Reference to the first study (Cragg 1972, hereafter "Ref. 1") will provide continuity in the reports on individual stars.

All observations of a star in the 1000-day interval are reduced to two cycles in order to increase the accuracy of the times of minimum and maximum and decrease the "noise." Phases computed from maximum according to GCVS linear elements were divided in one-day intervals and estimates within each interval were averaged. Thus, each estimate enters twice into the plots, once before maximum and once after maximum. Slight differences in grouping occurred because the periods are not integral numbers of days, and these account for the slight differences in the positions of the points before and after maximum.

Table I lists the observers, the stars that were observed, and how many estimates were made of each star. Landis is listed separately because all of his measures were photoelectric. Various observers were reduced to a common mean by the use of "k-factors," and these were largely based on Landis's observations. Landis's improvement of the magnitude sequence (especially for the regions of SZ Aql and TT Aql) was a further major contribution to this project.

I wish to thank Pat Mahnkey for getting more observers going on the project. His efforts have resulted in a large increase in the data. I also wish to thank him for his excellent reduction of the X Cyg data.

Anyone interested in more details of the program may write to me.

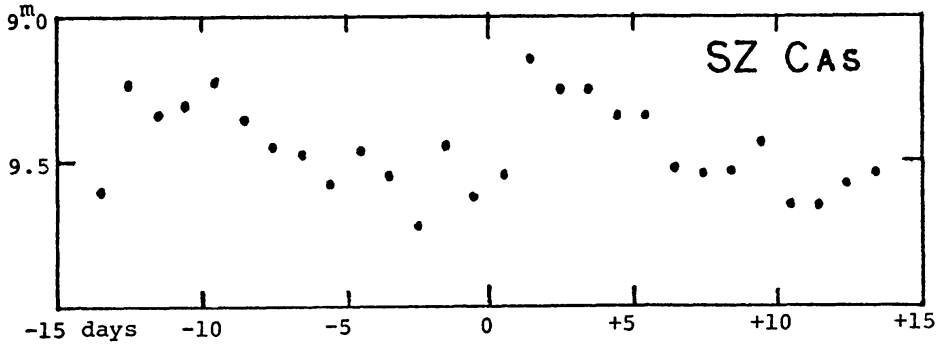
INDIVIDUAL STARS

020057 VX Per ($10^{d}.9$) Cδ

Insufficient data for a meaningful commentary.

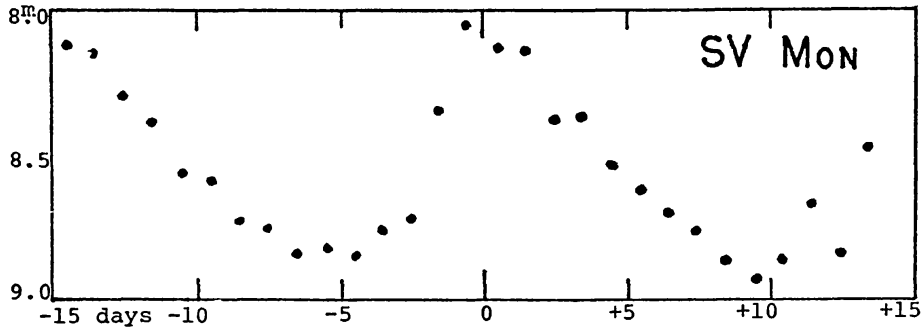
021959 SZ Cas ($13^{d}.6$) CW

The data produced a very rough curve which resembles the W Vir type with a range of about 0.5 magnitude. It is atypical in that the minimum phase lasts some 8 days (60% of the period). The GCVS (2nd Supplement) gives a V range of 0.4 magnitude. This data set indicates that the inclusion of this star in the program is dubious.



061606 SV Mon ($15^d.2$) Cδ

With a larger number of observers, k-factors were feasible. Four data points were eliminated as obvious errors. With proper k-factors applied, means of the data produced the curve below. The difference between this curve and that for the previous 1000-day period (Ref. 1) is largely the inclusion of k-factors. Little meaningful change in the O-C (observed minus calculated: when plus, maximum is occurring late; when minus, maximum is occurring early) is found between the two intervals under discussion. M-m (max. date minus min. date) derived from this data set would be ∿.33P (.35P according to GCVS).



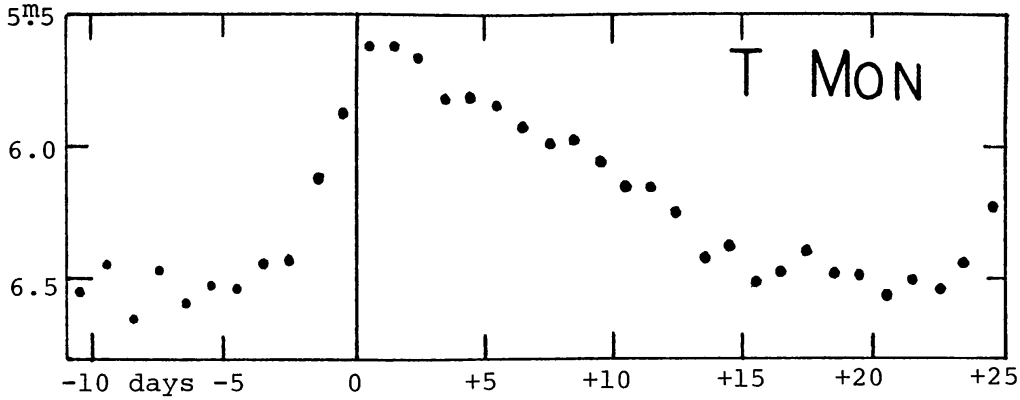
061907 T Mon ($27^d.0$) Cδ

This was one of our heavily observed stars, and fortunately a good PEP curve was furnished by Landis. Individual means showed little scatter, but were nearly all under the PEP curve. This could be attributed to a zero-point error in the sequence used by visual observers, or a transfer error in the sequence used. Landis checked some of the sequence stars on two dates with the following results:

	JD	
Comp. Star	2441725	2441754
6.1	6.23	6.23
6.7	6.73	6.74
6.4	6.53	6.56
5.9	6.04	6.08
5.8	6.69	5.71

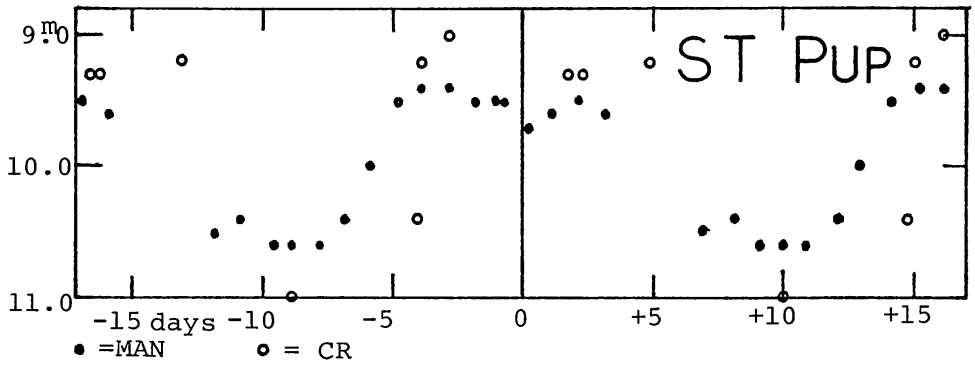
The differences of the PEP measures for the 5.8 star are almost certainly an error as no such variation has been observed during the last couple of years. The others check rather well for HD magnitudes.

All the visual data were reduced to Landis's PEP curve. The resulting mean curve is depicted below. The resulting O-C is ∿+1^d. Those concluding from the previous 1000-day data set (Ref. 1, p. 14) whose O-C was ∿+$2^d.5$, that a change has taken place must remember that the current curve is a simple daily mean and the previous curve was a 5-day running mean. These are not mutually comparable since running means shift the position of a maximum for an asymmetric curve. With this in mind, little shift, if any, in O-C was encountered. The mean curve seems brighter than before, as the current data were reduced to Landis's PEP values, which were brighter than the references used in the last data set. The current curve indicates roughly an M-m of 9^d or .33P (.29P in GCVS).



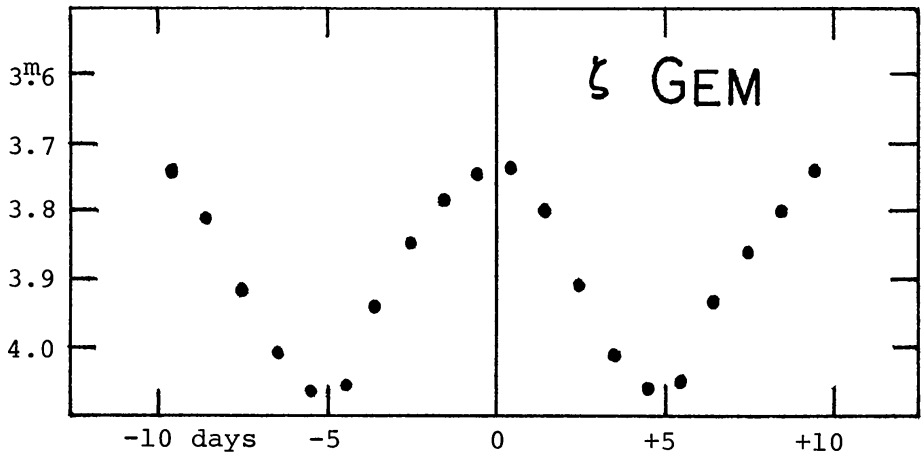
064537 ST Pup (18d9) CW

Although not heavily observed, the daily mean curve generated by the primary observer (MAN) shows a basic W Vir type; O-C of ∿-3d5, and an M-m = ∿5d5 or ∿.29P (.13P in GCVS). The descending branch hump on this one seems more exaggerated than most W Vir stars.



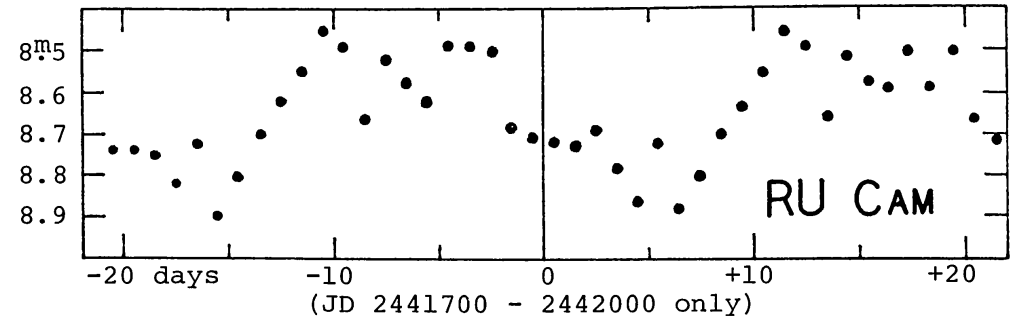
065820 Zeta Gem (10d2) Cδ

The combined daily curve of all observers confirms CR's curve of the previous 1000-day interval quite well. Within the data accuracy, no change in O-C was noted. The current curve shows the peculiarity of a longer rise than fall. The pertinent data for this 1000-day interval appear to be O-C = ∿0d and M-m = ∿.55d (.5d in GCVS). Observer k-factors were computed and found to be negligible for these data.



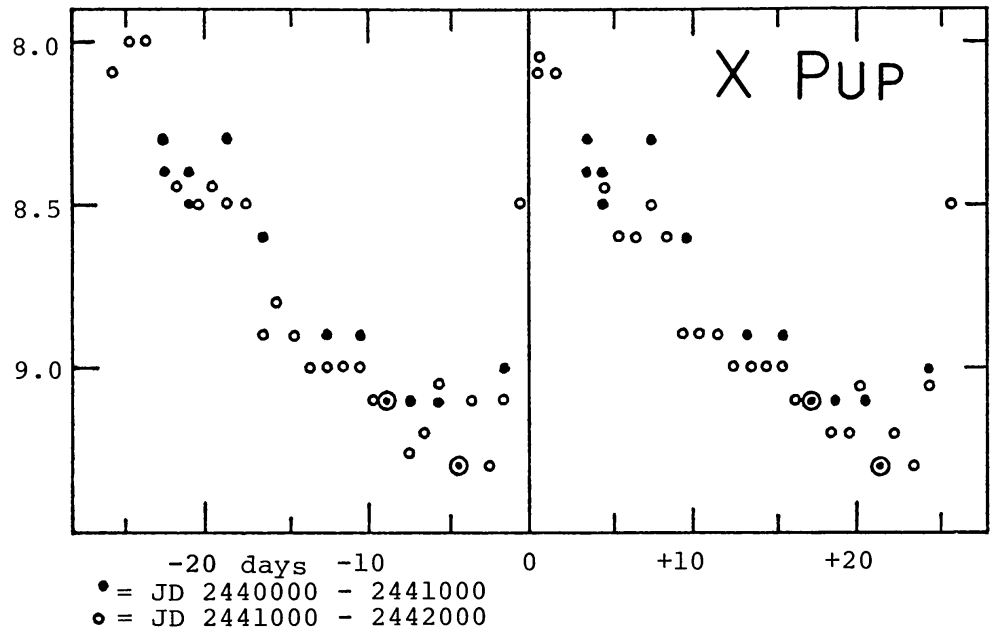
071069 RU Cam ($22^d.1$) CW

This most irregular cepheid was found essentially constant for the first 700 days of the included interval. Variations during the last 300 days confirmed (via minima) the 22^d period. A double max was found, and an M-m (to the first max) of $\sim 5^d$ or .23P. The amplitude of the mean curve is $\sim$0.5 magnitude. O-C (min) with this data set looks like $\sim +5^d.5$. It is not surprising to find the poorly indicated O-C significantly different from that reported last time (Ref. 1, p. 10). Phases are computed from minimum for this star.



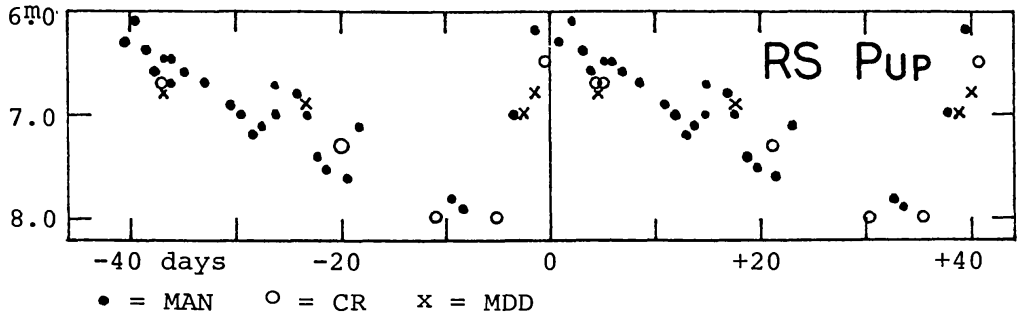
072820a X Pup ($26^d.0$) Cδ

More estimates would have been useful, but those obtained this time, combined with those of the last 1000-day interval make a fairly good curve. An O-C of $\sim +1^d$, and an M-m of 4-5 days, .15 - .18P (.27P according to GCVS) seem indicated. The large range and good sequence make this a very good star to work, but evidently the -20° declination scares everyone.



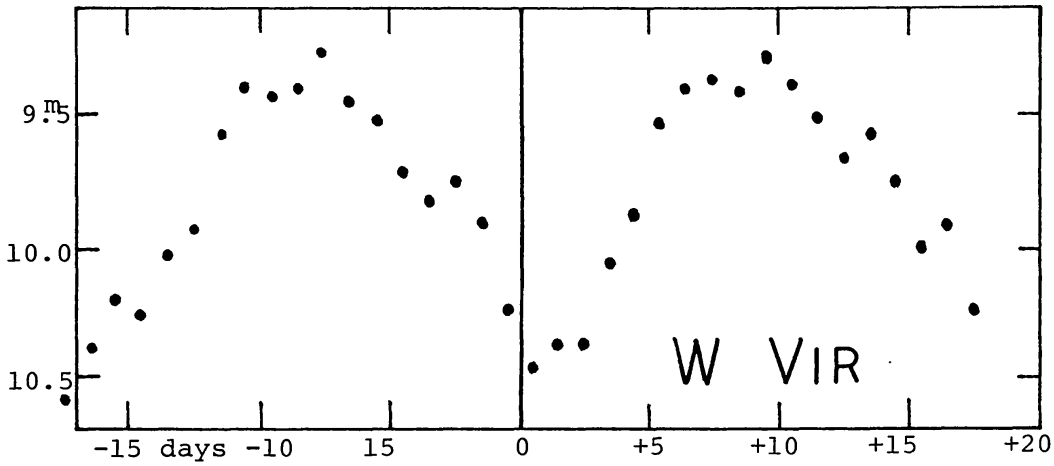
080934 RS Pup ($41^d.4$) Cδ

The individual observation plot on this star describes the curve reasonably well, the scatter being surprisingly small for a star so far south. The cardinal points (max and min) are not accurately defined, but it seems reasonable to say O-C is $\sim 0^d$, and M-m is $\sim$6 to 11 days, .14-.26P (.24P according to GCVS). Its large range and very long period make this one of the best stars for our program.



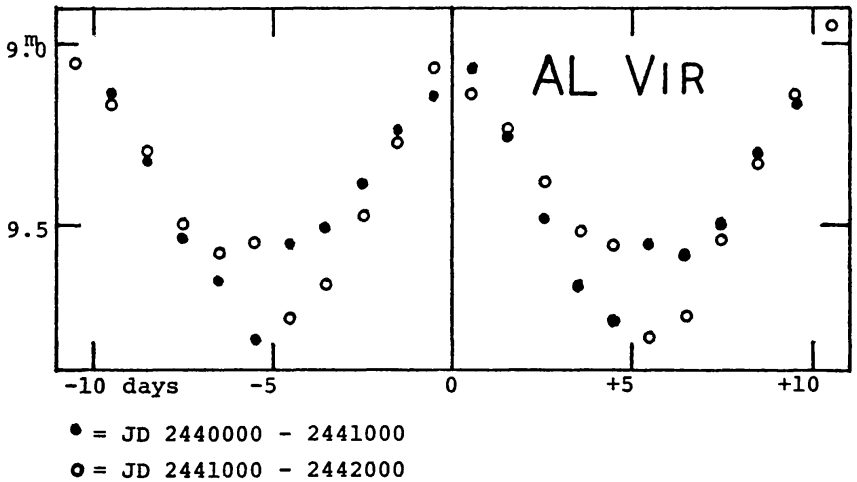
132002 W Vir (17d.3) CW

Observational scatter hides the characteristic W Vir type curve. The wide max is what one expects when the true max and the descending branch hump are merged. At the risk of grossly overinterpreting the data, an O-C of ∿+7d seems indicated. Scatter is surely increased by the fact that the sequence is somewhat distant. Individual k-factors were computed but no appreciable observer differences were noted.



140512b AL Vir (10d.3) CW

The curve is similar to that of the last 1000-day interval, but it bears little resemblance to the classical W Vir star. O-C continues to be zero with a longer rise than fall. A parallel to Zeta Gem is surprisingly close.

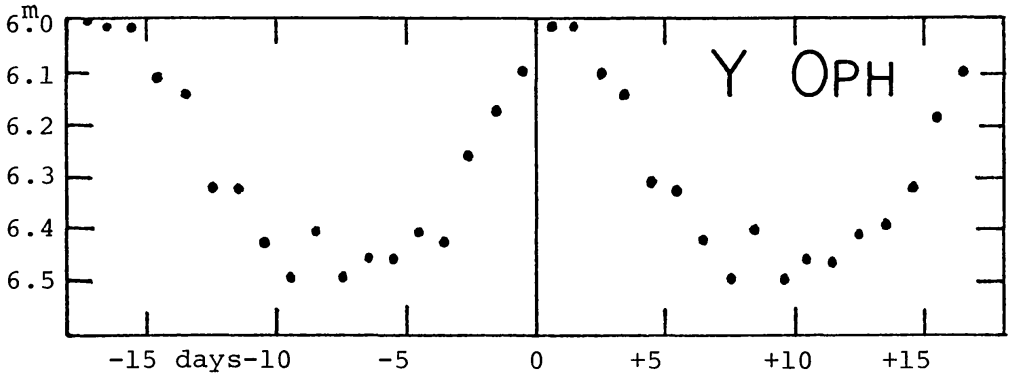


153620b RX Lib ($24^d.9$) CW

No sensible conclusions can be drawn from the data using the accepted period from GCVS.

174706 Y Oph ($17^d.1$) Cep

During the previous 1000-day interval, the few available estimates generated a good scatter diagram! During this 1000-day interval observers OV and AYT hit it hard and produced a very good curve. It is rather symmetrical and remarkably smooth for the indicated range. An O-C looks like $\sim+1^d$. All observations were reduced to OV and the daily means plotted.

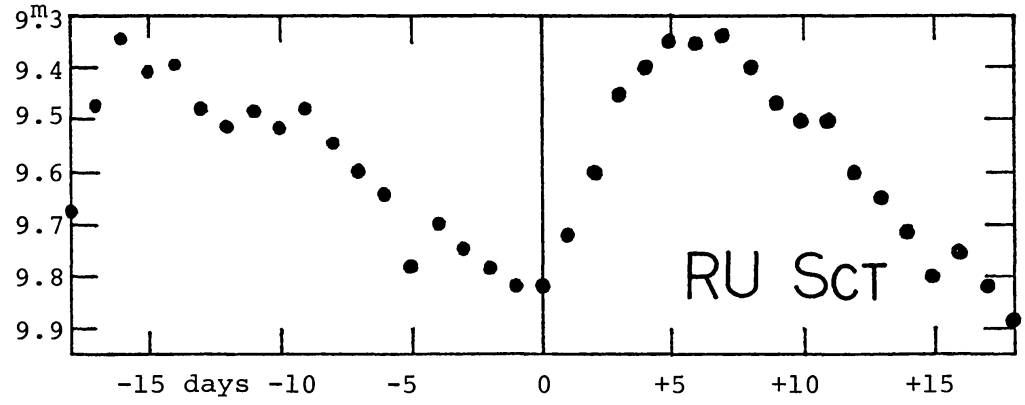


175822 AV Sgr ($15^d.4$) Cδ

No useful information can be gleaned from the small amount of data using the accepted period.

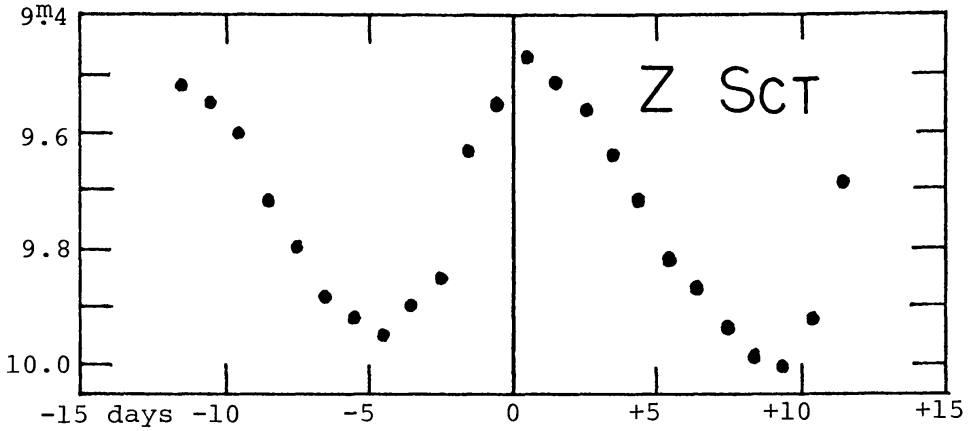
183604 RU Sct ($19^d.7$) Cδ

Because of the distant sequence, the estimates on this star have more scatter than normal. A 4-day running mean of the daily means yields a fairly good curve. An O-C of about +5 to +6 days is indicated showing little or no shift from the previous 1000-day interval. M-m appears to be on the order of 6 days, or .3P (.38P according to GCVS).



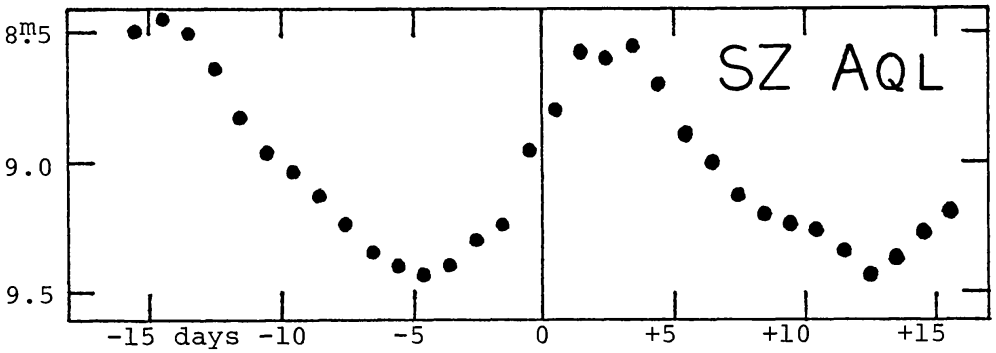
183705 Z Sct ($12^d.9$) Cδ

The data had a larger scatter than expected, but the sequence used was nearly 1° away. Three-day running means of the individual means generate a fairly good curve. Note the O-C is essentially zero, and the M-m is $\sim 5^d.5$, or .39P (.39P according to GCVS). During the previous 1000-day interval, a mean O-C of $-5^d.5$ was indicated (Ref. 1, p. 14). This phase change could be explained by a period change of only $\sim 0^d.005$. Unfortunately, the data do not appear good enough to break down into significantly smaller intervals (200 - 300 days) and still yield usable results showing a phase shift of maxima during the 1000-day interval. This star should be a primary target for observers during the current 1000-day interval.



185901 SZ Aql ($17^d.1$) Cδ

Although fewer observations were available during this 1000-day interval, they must have been of better quality since a good curve was derived. A 3-day running mean of the daily means indicates an O-C of $\sim +3^d$, and an M-m of $\sim 7^d$, or .41P (.33P according to GCVS).

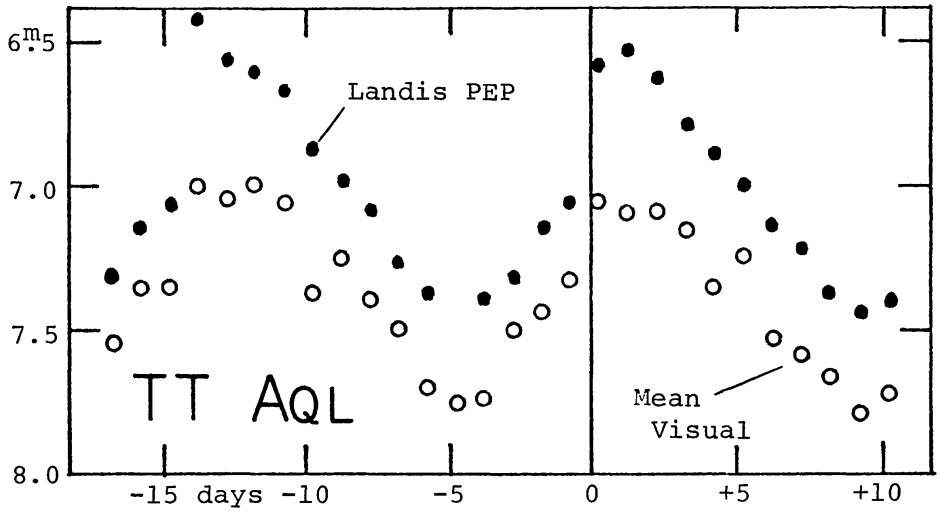


190301 TT Aql ($13^d.8$) Cδ

An excellent PEP data set was furnished by Landis, but it differs significantly from the mean visual data. The two curves are so different that it is not easy to force one to fit the other with a simple correction. From both the visual and PEP data one derives an O-C of essentially zero, and an M-m of $\sim 5^d$, or .36P (.34P according to GCVS). Landis measured several of the comparison stars with the results listed in the table below.

Comp Star	Mean PEP	No. of Measures	Adopted Magn.	Comp Star	Mean PEP	No. of Measures	Adopted Magn.
5.7	5.85	6	5.8	8.1	7.63	2	7.6
6.4	6.59	6	6.6	8.4	8.00	2	8.0
7.4	7.55	7	7.6	10.1	9.90	2	9.9
7.7	7.74	6	7.7	8.9	8.53	2	8.5
7.6	7.55	4	7.6	9.4	9.27	2	9.3
9.1	9.02	2	9.0	7.1	7.71	2	7.7
8.7	8.92	3	8.9				

It is hoped a new chart will be issued soon reflecting these changes, but in the meantime observers should note the differences on their charts and this should bring the visual and PEP data closer in agreement.



194727 SV Vul (45d.0) Cδ

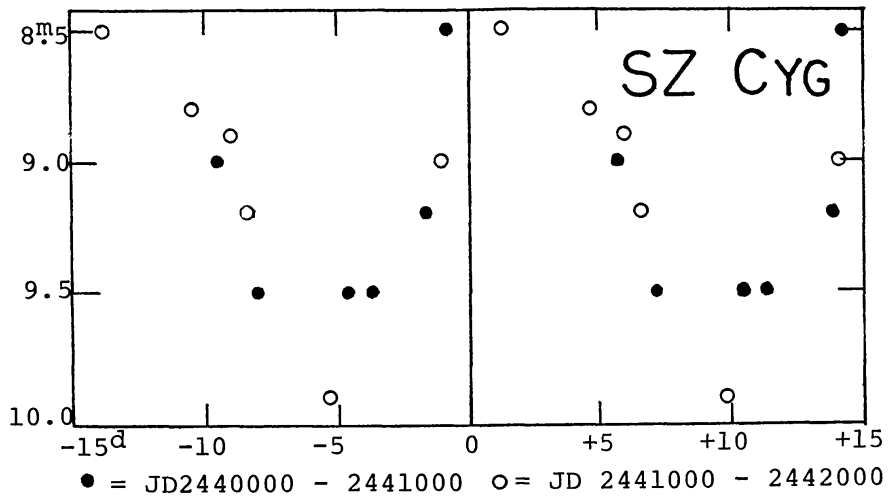
Well observed this time. Notice that the secondary max indicated in the previous 1000-day data set (ref. 1, p.15) is absent this time. OV's visual data set is the best single effort submitted. It is plotted here to show what visual observers should strive for! The second curve is a daily mean of all observations reduced to OV. The final curve is a 5-day running mean of the second curve. This can be compared with the last curve published (Ref. 1, p.15). From this curve, an O-C of no more than -1d is derived, and an M-m of some 10 days is indicated, or .20P (.19P according to GCVS). (See Figure 1 for light curves.)

200814 TW Cap (28d.6) CW

Not enough observations were made to produce a good curve, however what is available looks somewhat similar to the curve for W Vir.

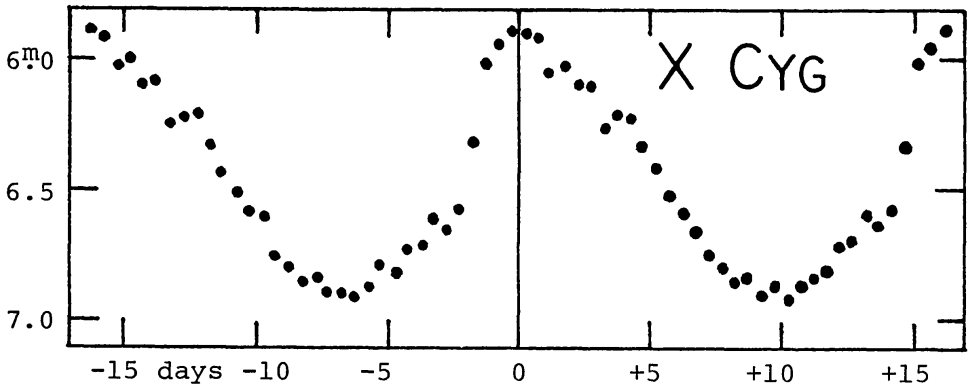
202946 SZ Cyg (15d.1) Cδ

This star is quite distant from the sequence and is therefore difficult to observe. So few observations were available, meaningful conclusions are difficult. However, combining the last 1000-day interval with this one shows a surprisingly good curve for so small a data set. O-C seems very close to zero, and M-m is of the order of 5 days, or .33P (.38P according to GCVS). With a range of some 1.4 magnitudes, this should be one of our better stars.



203935 X Cyg, (16d.4) Cδ

All of the analysis on this star is due to Pat Mahnkey (MAN) and he did an excellent job. To discuss adequately all his work would be a major paper in itself! Excellent PEP data were furnished by Landis, and all the visual data were reduced to these. Mahnkey's one-half day curve (below) shows an O-C of zero within the limits of the data set, M-m of 6d.5, or .40P (.35P according to GCVS), indicating no change from the last 1000-day interval. The visual and PEP curves show very close agreement over the part of the curve used to derive the k-factors. Surprisingly, the visual data also show the pre-max rise at -3.25 and +13.25 days, although its amplitude is far below what is normally considered in the range of visual detection.



204244 BZ Cyg (10d.1) Cδ

Not enough material for a useful discussion.

A number of new stars are being investigated currently and charts are being prepared for those which merit being added to the program (See J.A.A.V.S.O., 4, No. 1., p.47). We hope these will be available for distribution so observers can get working on them by JD 2443000. Observers are reminded that to participate in this program they must send their observations of the classical cepheids to the Committee chairman as well as including them in regular monthly reports to Headquarters. The observations should be sent to the chairman at the end of the observing season for the star, rather than in small batches.

REFERENCES

Cragg, T.A. 1972, J.A.A.V.S.O., 1, 9.
Kukarkin, B. V. et al. 1969, General Catalog of Variable Stars, Moscow.
_____ 1974, General Catalog of Variable Stars, Second Supplement, Moscow.

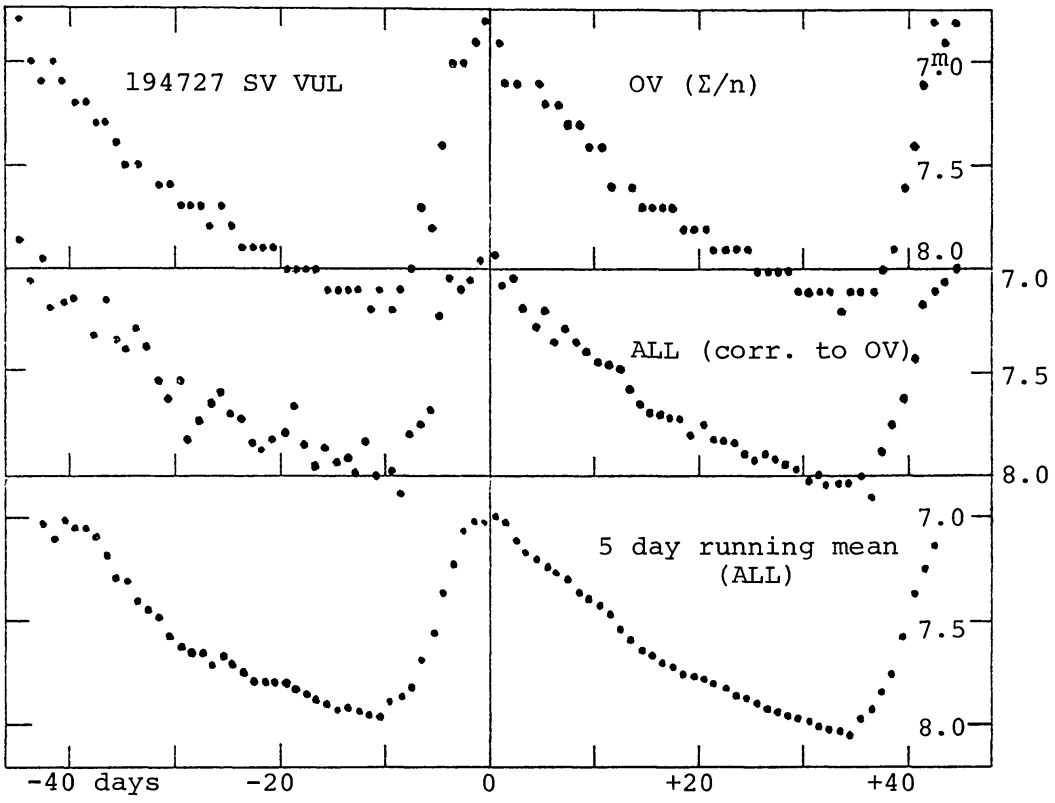


Figure 1. Light curves of SV Vul compared.

TOP: Data from a single observer (OV).
MIDDLE: All observers' data corrected to OV.
BOTTOM: 5-day running mean derived from middle curve.

TABLE I

DESIG.	NAME	AC	ANN	AYT	BRJ	CR	CST	GB	GLF	GLW	HAM	HMR	HY	MAN	MDD	MM	OCN	OV	SCE	SL	SLB	SLE	THS	TJ	VBN	WSN	LND	Total Est.
020057	VX Per																								5			5
021959	SZ Cas		51	3		9			1	1	4											45				12		132
061606	SV Mon	21	29			21	7				3			35		1	1									5		123
061907	T Mon	20	74			36	3	12	1	1	16			59			1			5			44			38	30	394
064537	ST Pup					7								22				55										29
065820	ζ Gem	15	77			10	2	5						52	20			1			60							267
071069	RU Cam		30			3	8		3	3				38			25	146										232
072820a	X Pup		28			18	4							48		1	1											99
080934	RS Pup					5								27	4													36
132002	W Vir	10	54	44		11	10							14														143
140512b	AL Vir	10	50	43		12								3														118
153620b	RX Lib		25	1		13																						39
174706	Y Oph	11		41									2					115						10				179
175822	AV Sgr					15																						15
183604	RU Sct	31		13		10																						54
183705	Z Sct	32		13		12								11					34							15		117
185901	SZ Aql			1		11	8							9			8									19		56
190301	TT Aql			1		12	7				4			21			8	78								19	48	198
194727	SV Vul	80			69	12	4		8	10				18				143	67							5		416
200814	TW Cap					16																						16
202946	SZ Cyg					7																						7
203935	X Cyg		123	25		39			19	19		13		41	35			112	152	5	138					26	?	747+
204244	BZ Cyg					7																						7
Observer Totals:		230	541	185	69	286	53	17	32	34	27	13	2	398	59	2	44	650	253	10	198	45	44	15	5	139	78+	3454
Number of Stars:		9	10	10	1	21	9	2	5	5	4	1	1	14	3	2	6	7	3	2	2	1	1	2	1	8	3	

TABLE II

Desig.	Name	O-C	Mean Date	Observed M-m
021959	SZ Cas	+1^{d}.5		.29
061606	SV Mon	-0.5	1500	.33
061907	T Mon	+1	1500	.33
064537	ST Pup	-3	1750*	.29
065820	ζ Gem	0	1500	.55
071069	RU Cam	+5.5(Min.)	1850†	.23
072820a	X Pup	+1	$(^{0500}_{1500})$+	.16
080934	RS Pup	0	1765**	.26
132002	W Vir	+7	1500	.38
140512b	AL Vir	0	$(^{0500}_{1500})$	.49
174706	Y Oph	+1	1500	.47
183604	RU Sct	+6	1500	.3
183705	Z Sct	0	1500	.39
185901	SZ Aql	+3	1500	.41
190301	TT Aql	0	1500	.36
194727	SV Vul	0	1500	.20
202946	SZ Cyg	0	$(^{0500}_{1500})$+	.33
203935	X Cyg	0	1500	.40

* Most (∿80%) of the estimates were made between JD 2441735 and 2441785

† Significant variation noted only during the last 300^{d} of this 1000-day data group.

+ Two 1000-day data sets, individually computed, are combined into one curve.

** Most (∿80%) of the estimates were between JD 2441735 and 2441795.