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PHOTOELECTRIC TIMES OF MINIMUM LIGHT COLLECTED BY A COMPUTER-CONTROLLED TELESCOPE

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Abstract

Thirty times of minimum light have been measured photoelectrically for 27 eclipsing binary systems: AN And, QS Aql, V889 Aql, ι Boo, AW Cam, R CMa, RZ Cas, TW Cas, EM Cep, U CrB, RV Crv, Y Cyg, AI Dra, YY Eri, RX Her, SZ Her, μ Her, δ Lib (2), V566 Oph, ER Ori, AG Per (2), IZ Per, DM Per, CD Tau, V471 Tau, Z Vul (2), and RS Vul. No times of secondary minima are reported. The Δmagnitude at mid-eclipse is reported, along with comparison stars used. All minima occured between May 1980 and June 1982. Approximately 35 percent of these timings are of lesser quality, but are included in case there has been an observational gap for these stars. The heliocentric time of mid-eclipse for V471 Tau was JD 2444645.58611. These minima were gathered using a computer-controlled telescope, and the advantage of freeing the observer from the task of collecting data on eclipsing binary stars has been demonstrated.

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1. Introduction

During the first two years of photometry with a computer-controlled telescope (Skillman 1981), photometry of variable stars was obtained on approximately 280 nights. Of these nights, about 80 were devoted to timing minima of eclipsing variables. Of those 80 nights, 30 yielded data useful enough to obtain a time of minimum light. Of the other 50 nights, clouds were the main cause of data loss, with poor ephemerides also contributing substantially. The equipment consists of a 32-cm reflecting telescope with an uncooled 1P21 phototube, standard filters for **V** and **B**, and a 30 arc-sec diaphragm.

2. Description of Telescope and Photometry

About 50 Δmagnitudes were collected on each of the 30 successful nights. The observing sequence was always comparison star, sky, and then variable star. Each observation was a 25-second integration after centering. All centering, movement between stars, and data collection were performed automatically. Extreme air masses were avoided, and all comparison stars were within a degree of the variable, with typical separations of 15 to 30 arc-minutes. Differential extinction and color corrections were calculated when significant, and all reduced data were stored in disk files as UT and Δmagnitudes, along with header information.

The Δmagnitude files were fitted with low order polynomials, and the best-fit polynomial was evaluated to find the geocentric time of minimum light. The same data were then analyzed with Kwee-van Worden (K-W) technique. As this method did not provide a graphical representation of its time of minimum, I have chosen to report the times of minima obtained by the polynomial method. The difference between the two methods is reported in Table I for those who wish to use the K-W time of minimum. Those who have more sophisticated methods may want to revert to the original data and perform the analyses themselves.

The heliocentric corrections were calculated and added to the geocentric times of minimum light. The eccentricity of the Earth's orbit was always included, but was critical only for the case of V471 Tau, whose unique light curve allows timings to within a few seconds.

Table I also indicates the best-fit Δmagnitude at minimum light, for those who are either keeping track of the long-term luminosity changes in these systems, or who are concerned with variability in the comparison stars.

A quality indicator, q, is listed in Table I as a guide to the self-consistency of the time of minimum light. An indication of "1" implies a reasonable number of points around minimum, low scatter, and symmetrical shapes. An indication of "2" shows that the minimum is of lesser quality because of too few points, large scatter, data gaps, or asymmetrical light curves. An indication of "3" shows that the time of minimum was synthesized from data taken on different nights. The separation of the data sets is usually less than 14 days, so these timings should be acceptable if the stars are regular in their light curves. The data are presented in graphical form, with the polynomial solution superimposed. Tabular data are available from the AAVSO.

Other information in Table I includes magnitudes at maximum and minimum and period, as given in the third edition of the General Catalogue of Variable Stars, as well as filter, number of readings, and heliocentric correction.

3. Comments on Individual Stars

ι Boo is a classic W UMa-type system with constantly changing brightness. ι Boo sounds like an easy star to observe until one finds out that there is a second star, twice as bright as the variable, 1.2 arc-sec away. This means that the variability is highly suppressed, making the observations more difficult. ι Boo is included only because it was the first one obtained with the automated system.

TW Cas has a minimum assembled from three separate runs over a two-week span. The asymmetries in the composite curve lower the credibility of this minimum, so it is placed in category "2."

EM Cep has a poor data set but this star is included because of the low amplitude of the light curve.

U CrB has a data set taken on a windy and hazy night. The light curve shows asymmetries which one would not expect from an Algol-type variable. This minimum carries less weight since the data seem imperfect.

RV Crv when first observed had a maximum instead of a minimum. After about a week I was able to find a real minimum several hours away from the ephemeris. The data set is not very good, with asymmetries showing that probably should not be there. This star is reported since the ephemeris was so far off.

RX Her is supposed to have one hour of totality which the data do not show. This minimum is therefore suspect and is included in the lower quality data set.

SZ Her was chosen to test the faint-end ability of the star detection and centering software. With the uncooled 1P21 used in the analog mode, no filter, and about 0.1 second time-constant, the limit seems to be about 11.2 magnitudes. Enough data points were collected near the shoulders to give a low-quality time of minimum. The comparison star was an anonymous star 8 arc-minutes earlier and 2.5 arc-minutes south of the variable.

V566 Oph had the points around totality removed for the polynomial fit.

IZ Per did not have very good coverage, with only two points on the ascending branch, making this a lower quality timing.

DM Per has a minimum classed as lower quality because of large scatter and data gaps.

V471 Tau has an eclipse of its white dwarf companion which lasts about 45 minutes, but the ascending and descending branches are each only about a minute long. This precludes simple differential photometry, so the ascending and descending branches must be done in absolute intensity rather than magnitudes. The disappearance of the 12.5 magnitude dwarf caused about a 15 percent drop in intensity. The descending and ascending branch plots were least-squares-fitted with a 3-segment approximation. Mid eclipse was defined as the mid time of the times of the half power points. WWV time was accurately correlated with computer time, and each data point was recorded to the nearest second. This star allows timing of mid-eclipse to within a few seconds, which means that its variation can be studied in detail even though the star has been known for only about ten years. In this paper only the timing of the mid-eclipse is given. The light curve is not shown.

RS Vul is unusual because it has a light curve that is constantly changing with phase, like an EW type, but has a long period, meaning that the stars are well separated. The comparison star was SAO 087036 (BD +22° 3648). A second comparison star was also measured, SAO 087102 (BD +21° 3740), and its brightness was 1.108 magnitudes fainter in V than SAO 087036. This secondary reference star was measured on three nights, each a month apart, and this brightness difference was found to be constant.

4. Conclusion

A review of the data used for these times of minima reveals the usefulness of having a computerized telescope-pointing and data-collection system for the photometry of variable stars. The relief provided by having the telescope do all the simple-minded work is a great advantage because it frees up time for data reduction and analysis, and in general, makes it easy to work up enthusiasm for observing. At one point, during some runs on V471 Tau, my records show that 80 hours of photometry required about one hour of observer's time.

The automatic centering algorithm has proven quite reliable. In ten-hour runs of absolute photometry (one integration per minute), the power spectra reveal no frequencies from the motors or gearing. If a star were occasionally positioned near the edge of the diaphragm, one would expect the periodic errors in the drive system to creep into the data.

If the telescope time had been devoted completely to collecting times of minima and better ephemerides had been used, approximately 120 minima would have been collected, about 60 per year. It seems that this method for photometry should have much appeal to both the amateur and professional astronomer.

REFERENCES

Kukarkin, B. V. et al. 1969, General Catalogue of Variable Stars, Moscow.

Skillman, D. 1981, Sky & Telescope 61, 71.

TABLE I

30 Photoelectric Times of Minimum Light

Star	Magn. max-min	Period (days)	JD min. (hel.)	Filter	n	q	Hel. corr.	Δm (v-c)	Poly-KW (sec.)
AN And	6.0 - 6.16	3.22	2444518.1040	Y	83	1,3	0.00432	0.31	183
QS Aql	5.8 - 5.95	2.51	2444439.6649	Y	43	2	0.00483	-0.17	-190
V889 Aql	8.7 - 9.3	11.12	2444803.6557	Y	22	1	0.00460	2.04	11
ι Boo	6.5 - 7.1	0.27	2444375.6326	Y	12	2	0.00224	-0.73	-1
AW Cam	8.0 - 8.6	0.77	2444569.8400	Y	36	1	0.00336	0.08	1
R CMa	6.05- 6.66	1.14	2445018.6451	Y	35	1	0.00368	-1.45	-98
RZ Cas	6.38- 7.89	1.20	2445020.6674	Y	11	1	0.00270	-0.07	80
TW Cas	8.3 - 8.9	1.43	2444543.7813	Y	66	2,3	0.00360	-0.15	384
EM Cep	7.0 - 7.13	0.80	2444502.7002	Y	45	2	0.00225	0.46	30
U CrB	7.04- 8.35	3.45	2445145.6708	Y	34	2	0.00202	2.05	-
RV Crv	9.0 -10.0	0.75	2445084.7077	Y	35	2	0.00531	0.85	-
Y Cyg	7.2 - 7.8	3.00	2445148.7695	Y	65	1	0.00230	1.28	-70
AI Dra	7.2 - 8.2	1.20	2445113.8224	Y	54	1	0.00165	1.01	15
YY Eri	8.8 - 9.5	0.32	2444996.7034	B	25	1	0.00178	0.88	-109
RX Her	7.26-7.89	1.78	2444421.6513	Y	28	2	0.00477	-0.25	-54
SZ Her	10.20-12.15	0.82	2445108.8739	-	36	2	0.00296	-	-86
μ Her	4.6 - 5.3	2.05	2444440.6109	Y	30	1	0.00234	0.04	135
δ Lib	4.9 - 6.0	2.33	2444403.6758	Y	43	1	0.00462	-0.82	91
δ Lib			2445143.7759	Y	77	1	0.00402	-0.82	5
V566 Oph	7.60- 8.09	0.41	2444801.7034	Y	38		0.00463	0.55	38
ER Ori	9.3 -10.0	0.42	2445014.6669	Y	23	1	0.00168	0.72	-157
AG Per	6.5 - 6.8	2.03	2444519.6637	Y	36	2	0.00353	0.33	150
AG Per			2444584.5860	Y	42	1	0.00542	0.34	117
IZ Per	7.8 - 9.0	3.69	2444577.5874	Y	20	2	0.00383	0.57	164
DM Per	7.7 - 8.5	2.73	2444574.5482	Y	41	2	0.00431	2.35	230
CD Tau	7.0 - 7.6	3.44	2444566.7546	Y	22	1	0.00543	-0.38	-390
V471 Tau	10.5 -10.65 B	0.52	2444645.58611	B	-	1	0.00065	-	-
Z Vul	7.4 - 9.2	2.45	2444405.8408	Y	48	1	0.00338	1.38	0
Z Vul			2444783.7657	Y	36	1	0.00376	1.41	-2
RS Vul	6.9 - 7.6	4.48	2444539.7401	Y	70	1,3	0.00202	-	68

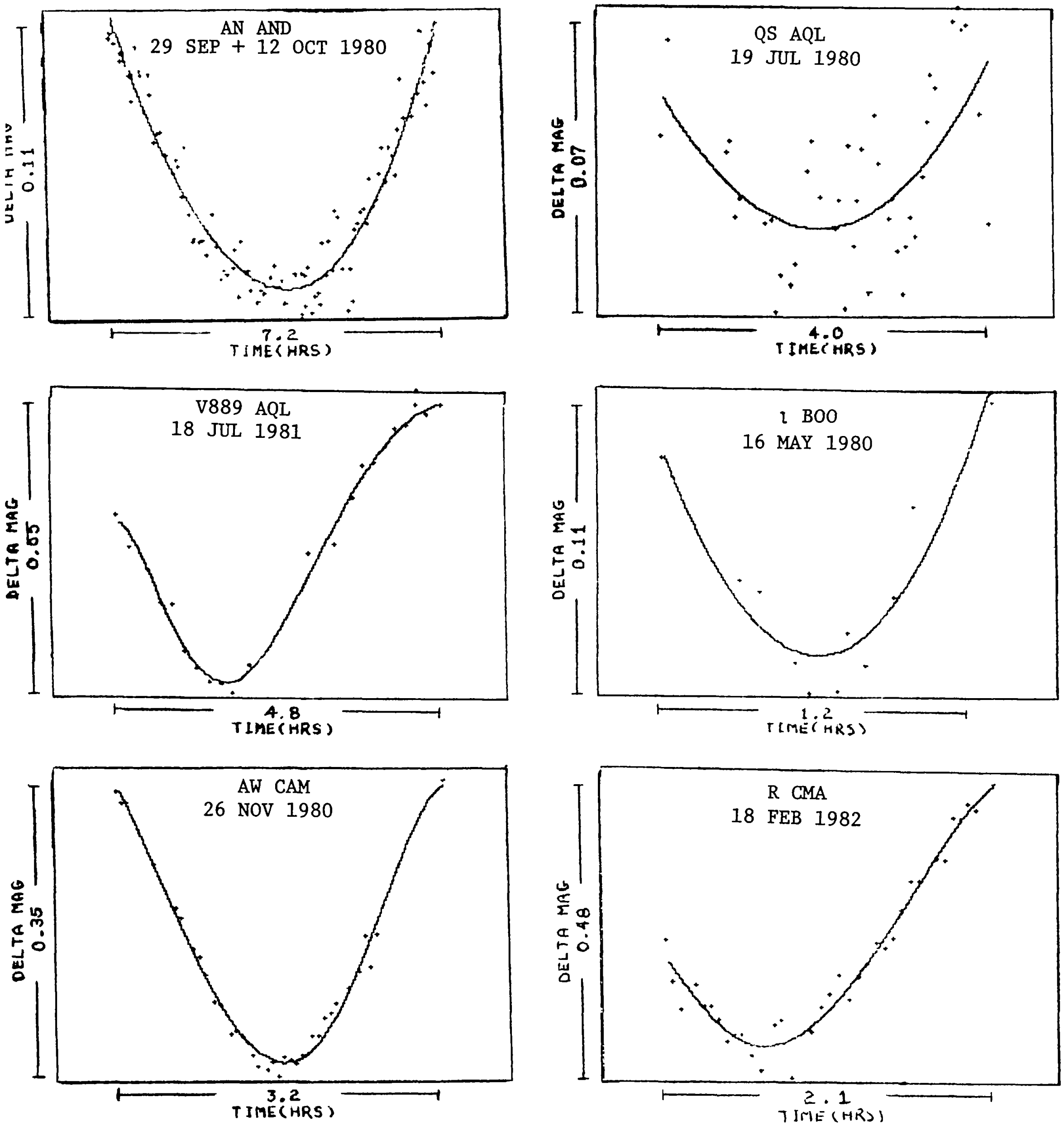


Figure 1. Photoelectric light curves of times of minimum for the systems AN And, QS Aql, V889 Aql, ι Boo, AW Cam, R CMa, RZ Cas, TW Cas, EM Cep, U CrB, RV Crv, Y Cyg, AI Dra, YY Eri, RX Her, SZ Her, u Her, δ Lib, V566 Oph, ER Ori, AG Per, IZ Per, DM Per, CD Tau, Z Vul, and RS Vul. All data are plotted Δmagnitude versus time in hours.

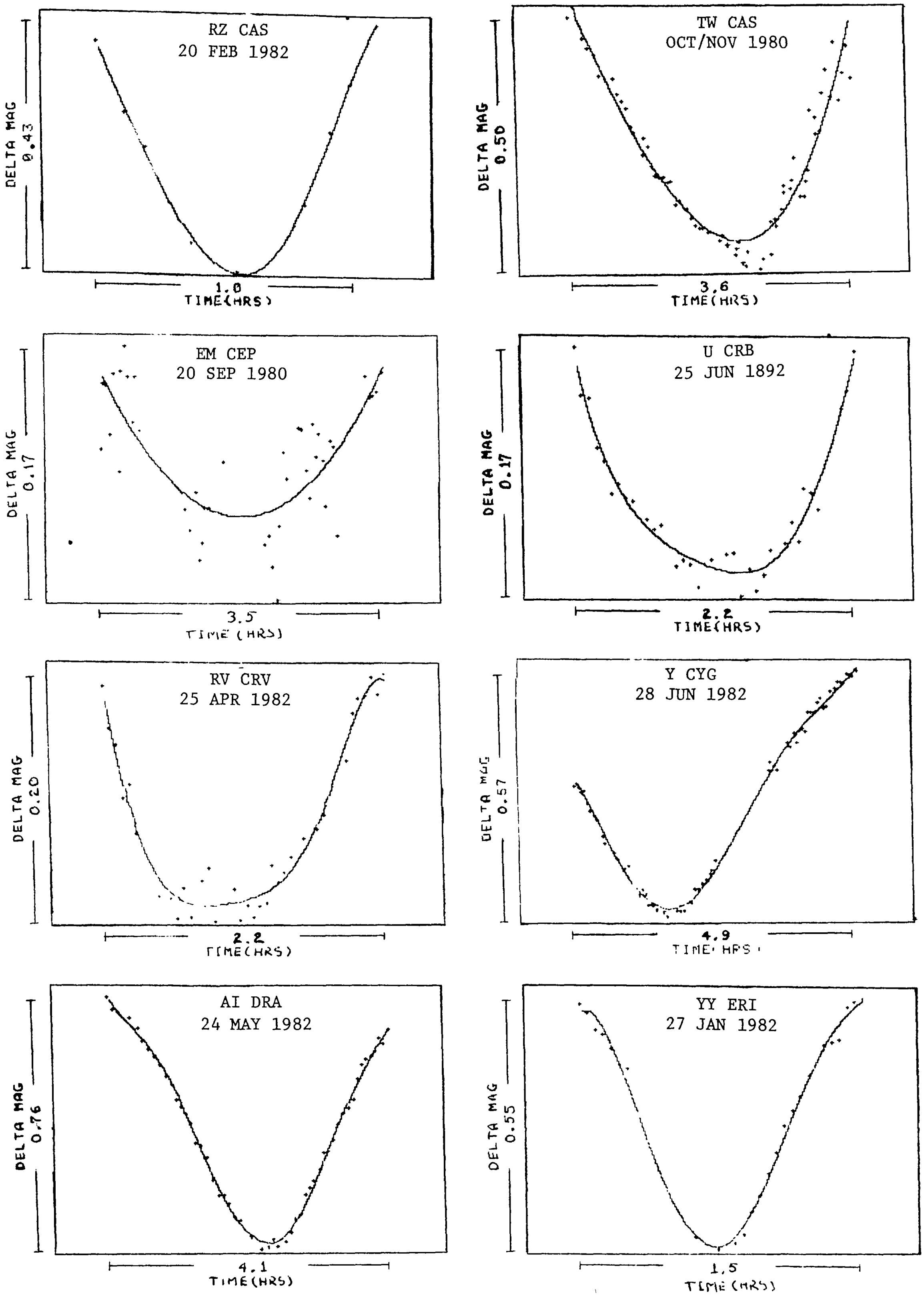
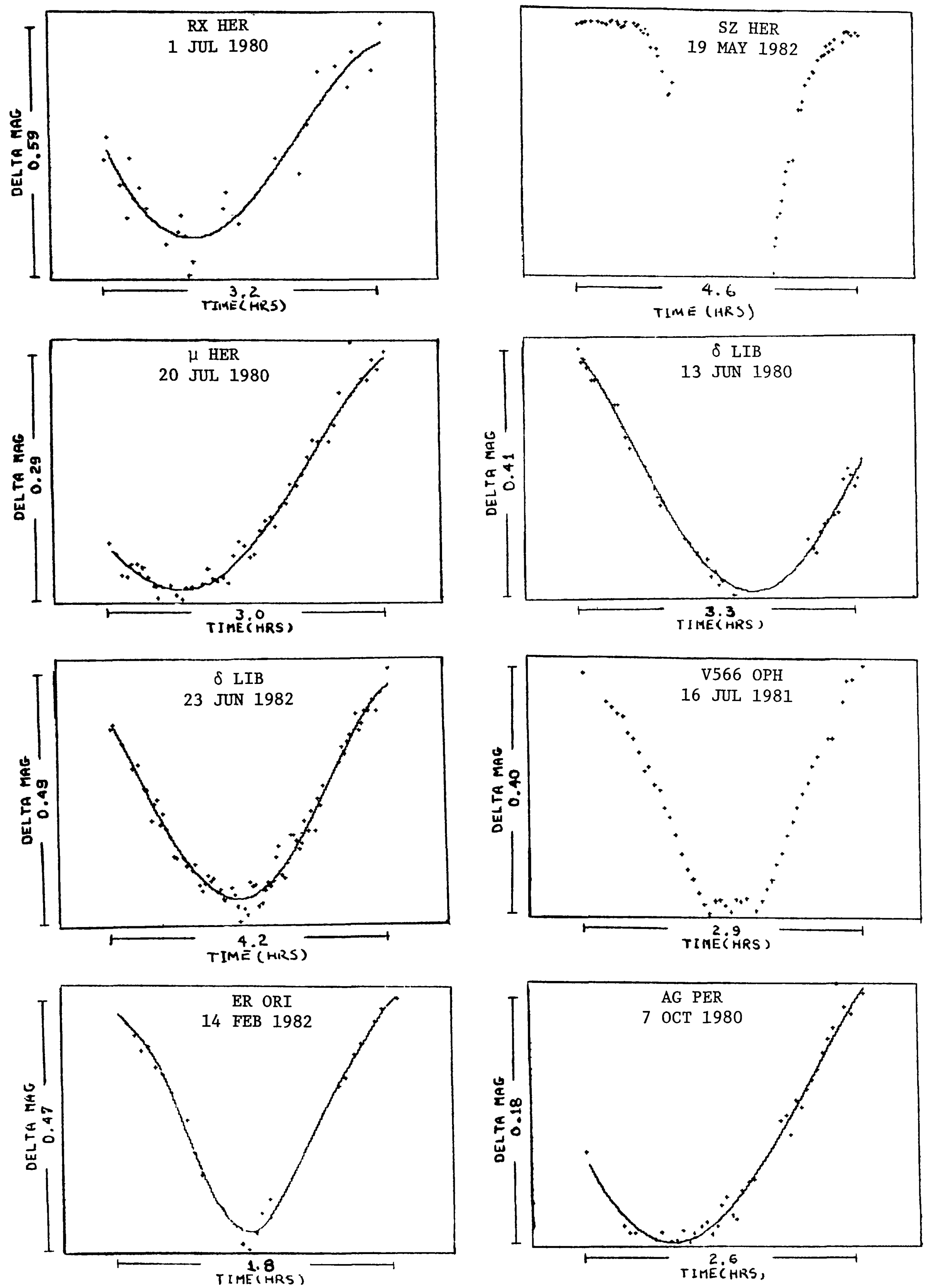


Figure 1 (cont'd)



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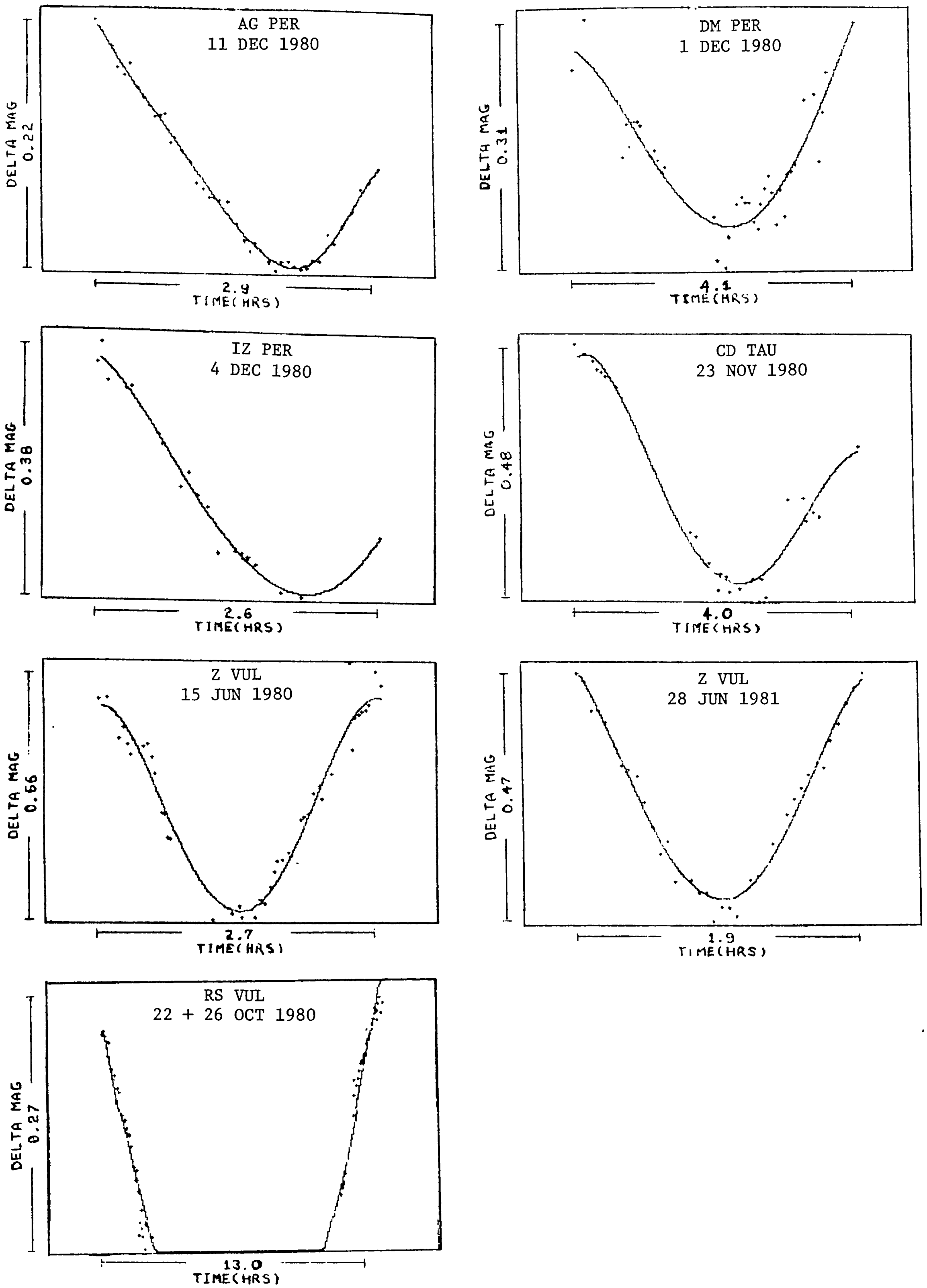

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