Eclipsing binaries, Andromeda to Camelopardalis, in 1972-1983

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Report of the Variable Star Section *Director: D. R. B. Saw*

Observations of 34 eclipsing binaries are discussed. Revised elements are derived for five systems. Several anomalies have come to light. RR Ari does not appear to be an eclipsing variable. The secondary eclipses of IM Aur have become progressively shallower.

Introduction

The Association's eclipsing binary programme was first set up in 1972. At the beginning it was confined to systems whose eclipses were observable from the British Isles in the course of a single night with the unaided eye or with binoculars. More recently, the predictions issued to observers have been extended to cover all objects brighter than $10^{m}.0$ at maximum listed in the 1969 *General Catalogue of Variable Stars* (GCVS) and its supplements[1], provided they have an amplitude of at least $0^{m}.4$, and are north of -18° declination; there is no limit on the length of time the eclipse lasts. In addition, observations of stars not included in the predicitions are welcomed.

An earlier account[2] of the eclipsing binary programme may be of interest to potential observers. That paper described a reduction procedure which the observer may follow if it is wished to deduce times of minima and compare them with predictions based on the catalogue elements. Some mathematics is involved, but this need not put anyone off. The writer will be pleased to receive raw observations and to do the reduction.

The first reports of the programme comprised little more than bare listings of timings of minima. But now that, for some systems at least, the Section has a fairly long run of observations, it is appropriate to present reports on the programme in a different form. Timings of minima will continue to be published in the Variable Star Section *Circulars*, but reports in the *Journal* will discuss the results, each report dealing with a group of constellations. The present report covers objects observed in the constellations Andromeda to Camelopardalis, with the omission of Epsilon Aurigae which will be the subject of a separate report when analysis of all observations of its 1982-84 eclipse has been completed.

The main aim of the programme is to detect changes in the periods of eclipsing binaries. Most well-observed systems show such changes, and it is to be expected that the poorly-observed ones will prove to be no different in this respect. The causes of period changes include mass transfer between the components, mass ejection from the system, and the disturbing influence of a third component. The changes are small—usually of the order of a few seconds—but the accumulated error after a year or two is often large enough to be detected by means of visual magnitude estimates during an eclipse. In fact, among the systems discussed in this report, those which are performing in accordance with the catalogue elements appear to be in a minority.

Observations

The following observers contributed series of estimates which yielded timings of minima for stars discussed in this report.

Observer	*Timings*
S. Anderson	2
T. Brelstaff	104
P. Clayton	4
J. Isles	2
R. Miles (photoelectric)	2
M. Taylor	13
10 observers	10
Total	137

One observer, Tristram Brelstaff, has contributed most of the results, and the Association's eclipsing binary programme would not amount to much without his efforts. It is earnestly hoped that he will soon be joined by other keen observers.

The timings have been published in the following places.

Year	*Julian Dates*	*Reference*
1972	2441318-1683	*J. Brit. astron. Assoc.*, **83**, 452 (1973)
1973-74	2441684-2413	*J. Brit. astron. Assoc.*, **85**, 443 (1975)
1975	2442414-2778	*J. Brit. astron. Assoc.*, **87**, 79 (1976)
1976-78	2442779-3874	VSS *Circular* 58 (1984)
1979-81	2443875-4970	VSS *Circular* 59 (1985)
1982-83	2444971-5700	VSS *Circular* 60 (1985)

The report for 1975 was compiled by P. W. Hornby, the others by the present writer. Observations up to 1975 were reduced by the tracing-paper method, but since then computer programs described elsewhere[3] have been used. There is no evidence of any systematic difference between the two methods of reduction, nor in fact of any significant gain in accuracy as a result of computerisation. The accuracy of a timing is still limited by the accuracy of the original observations. The gain is rather a saving of the analyst's time. A printout listing the timings used in the present report may be obtained from the writer.

Findings

Table 1 presents revised elements for five systems with at least four minima observed by the Section, and showing a significant deviation from the elements in both the new Moscow catalogue[4] and the Cracow yearbook[5]. In calculating these revised elements, photoelectric determinations have been given ten times the weight of a visual determination. A few less-certain timings have been given half weight.

The following notes, on each of 34 stars observed, begin with the latest details from the catalogue: the type (EA = Algol, EB = Beta Lyrae, EW = W UMa); the magnitude range (v = visual, p = photographic, V = photoelectric yellow, B = photoelectric blue); and the approximate period. If the catalogue gives a magnitude for secondary minimum, this is quoted in parenthesis. The following additional abbreviations may be found within the notes:

D = total duration of eclipse, expressed either in units of time or as a fraction of the period

d = duration of constant phase at mid-eclipse

JD = Julian Date

Min I = primary minimum

Min II = secondary minimum

O - C = difference between the observed time of eclipse and the calculated time according to the published elements, negative if early and positive if late.

P = period

Stars appearing in table 1 are distinguished below by an asterisk following the name.

RT And

EA, 8.6-9.5 (8.9) V, $0^d.63$

One minimum was observed photoelectrically by Miles on JD 2445630 (see figure 1). The individual measurements suggest that there may have been a short period of constant brightness at minimum, lasting about 20 minutes (d = 0.02P), whereas according to the catalogue there is no constant phase. The O - C is zero against the linear elements and $+0^d.003$ against the quadratic elements of the catalogue; and $-0^d.003$ against those of Cracow.

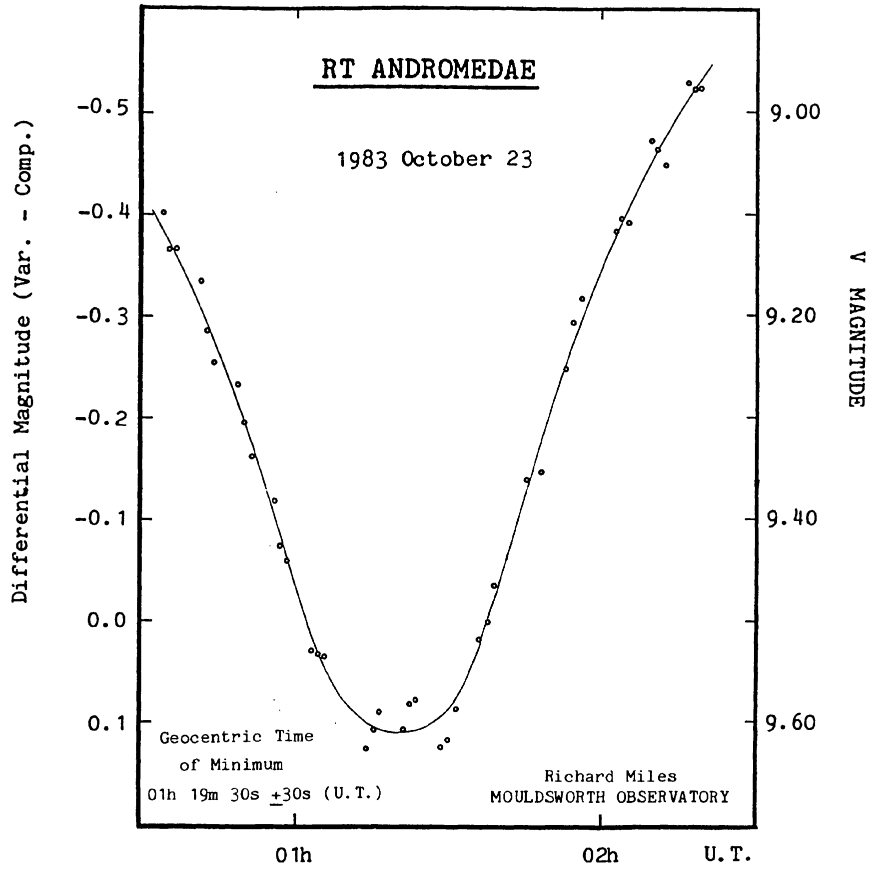

Figure 1. RT And. Photoelectric light curve of Min I. Note the possible constant phase shown by the observations plotted at mid-eclipse.

Table 1

Revised elements for five eclipsing binaries

Star	*Elements*			
AD And	2445226.328 (0.008)	+	0.98617 (0.00004)	E
V822 Aql	2441899.83 (0.04)	+	5.2949 (0.0002)	E
AR Aur	2441358.464 (0.008)	+	4.13467 (0.00002)	E
IM Aur	2441539.587 (0.004)	+	1.247282 (0.000003)	E
AY Cam	2445175.446 (0.007)	+	2.7348 (0.0002)	E

(Standard errors given in parenthesis)

TW And

EA, 8.8-10.9 (8.9) V, $4^d.12$

One minimum by Brelstaff in 1983 gives O - C = $+0^d.03$ against the catalogue elements, but is in close agreement with Cracow.

WW And

EA, 10.3-11.4 v, $23^d.29$

Observed by Brelstaff in 1981-83. D = 39 hours, so observations on several nights need to be pieced together to deduce the phase of minimum. The O - C against the catalogue elements (which are repeated by Cracow) is not significantly different from zero, and the catalogue value for D is approximately right, but the observed amplitude is only $0^m.7$, rather than the $1^m.1$ given in the catalogue.

WZ And

EB, 11.6-12.7 (11.9) p, $0^d.70$

Three minima by Brelstaff in 1981-83 are in satisfactory agreement with both the catalogue and Cracow elements.

AB And

EW, 9.5-10.3 (10.2) V, $0^d.33$

Four minima by Brelstaff in 1983 are in agreement with both the catalogue and Cracow elements.

AD And*

EB, 10.9-11.6 (11.6) p, $0^d.99$

Four Min I observed by Brelstaff in 1982-83 give a significant O - C of $-0^d.015$ against the catalogue elements, and $-0^d.036$ against Cracow. One Min II was also observed.

BX And

EW, 8.9-9.6 (9.2) v, $0^d.61$

Seven minima by Brelstaff in 1977-79 agree fairly well with the catalogue elements (repeated by Cracow). The mean O - C of $+0^d.007$ is not significantly different from zero.

DS And

EB, 10.4-10.9 (10.7) V, $1^d.01$

Four minima by Brelstaff in 1981-83 indicate a significant O - C of $+0^d.10$ against the Cracow elements but agree well with the catalogue.

SU Aqr

EB, 10.2-10.8 (10.5) p, $1^d.04$

One minimum by Brelstaff in 1983 gives O - C = $-0^d.01$ against the catalogue elements, and $-0^d.02$ against Cracow.

EE Aqr

EB, 8.3-8.9 (8.5) p, $0^d.51$

One minimum by T. Gough in 1973 gives O - C = $+0^d.01$ against the catalogue elements (repeated by Cracow).

OO Aql

EW, 9.2-9.9 (9.8) v, $0^d.51$

Eight minima by Brelstaff in 1981-83 give a significant O - C of $-0^d.008$ against the Cracow elements but agree well with those of the catalogue.

V822 Aql*

EB, 6.9-7.4 (7.1) V, $5^d.29$

Five minima have been reported between 1973 and 1979, by Anderson, Brelstaff and Taylor. They are somewhat discordant, but agree in showing a large positive O - C, averaging $+0^d.23$, against the catalogue elements (repeated by Cracow). Agreement with the issued predictions, which use the elements of the 1974 Supplement, is better (O - C = $+0^d.05$). Four of the observed eclipses were Min II, which according to the catalogue have a depth of only $0^m.2$, so the visual results are inevitably uncertain. Further observations are needed to confirm the elements given in table 1.

V889 Aql

EA, 8.5-9.1 (9.0) V, $11^d.12$

Two minima by Brelstaff in 1982 give a significant O - C of $+0^d.15$ against the catalogue elements, which are repeated by Cracow. This large residual is confirmed by another, incompletely observed minimum in 1981. Further observations are needed to determine the current value of P.

RR Ari

EA?, 6.4-6.8 (6.8) p, $47^d.9$?

This object was identified as an eclipsing binary by Archer[6]. Brelstaff, however, reports 52 observations made during the 1979-80 apparition (JD 2444113-302) which cover four of the supposed cycles and show no eclipses. The mean visual magnitude was 5.74 with standard deviation $0^m.09$.

SS Ari

EW, 10.4-10.9 (10.8) V, $0^d.41$

Five minima by Brelstaff in 1982 give a significant O - C of $-0^d.027$ against the catalogue elements but are in reasonable agreement with Cracow. Cracow gives the photographic range as $1^m.0$, but the observed visual range (figure 2) is at most $0^m.5$, as in the catalogue.

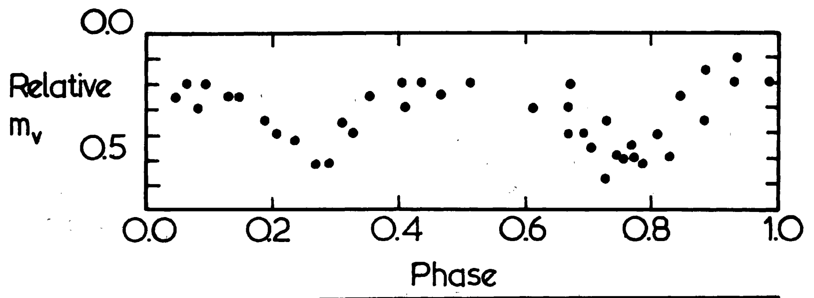

Figure 2. SS Ari. Visual estimates by T. Brelstaff in 1983, plotted against phase according to the 1969 catalogue elements. As accurate comparison star magnitudes are not known, the scale is based on the observer's step estimates. The 1985 elements imply that the minimum shown at about phase 0.28 is Min I, and that at phase 0.78 is Min II.

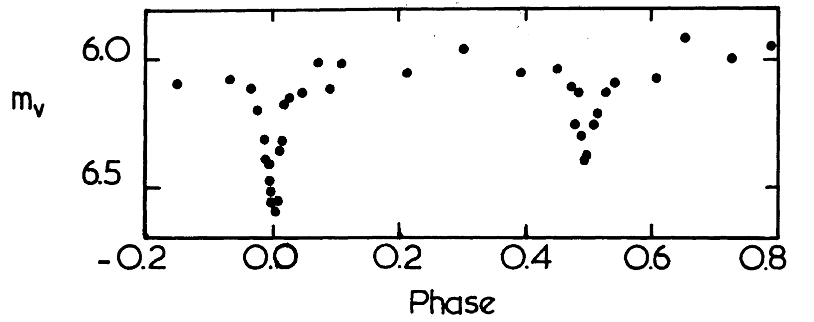

Figure 3. AR Aur. Mean light curve from visual estimates 1972-83. Each point is the mean of five or six visual estimates. Phases are against the revised elements given in table 1.

SX Aur

EB, 8.4-9.1 (8.9) V, $1^d.21$

One minimum observed by Brelstaff in 1979 gives O - C = $+0^d.01$ against Cracow, but agrees well with both the linear and quadratic elements of the catalogue.

TT Aur

EB, 8.6-9.5 (9.0) B, $1^d.33$

A minimum by Taylor in 1977 gives O - C = $+0^d.02$ against the catalogue and $+0^d.01$ against Cracow.

WW Aur

EA, 5.8-6.5 (6.4) V, $2^d.53$

Five minima in 1973-79 fit both the catalogue and Cracow elements well. Observers were Brelstaff, Hornby and Taylor.

AM Aur

EA, 10.9-12.0 (11.0) p, $13^d.62$

Two minima by Brelstaff in 1982-83 indicate the remarkably large O - C of $+0^d.58$ against the catalogue, and $+0^d.08$ against Cracow. Further observations would be particularly welcome.

AR Aur*

EA, 6.2-6.8 (6.7) V, $4^d.13$

Nine visual minima in 1972-78 give a mean O - C of $-0^d.038$ against the linear elements of the catalogue but agree closely with the quadratic elements. Against Cracow the mean O - C is $+0^d.007$ but this is not significantly different from zero. The observers were Brelstaff, Clayton, M. Currie, R. McNaught, P. Swift and Taylor. A photoelectric minimum by Miles on JD 2445629 (1983 October 21) gives O - C = $-0^d.057$ against the linear elements and $+0^d.010$ against the quadratic elements and those of Cracow. Miles' light curve was reproduced in VSS *Circular* 56. Combining the visual and photoelectric data yields the revised elements in table 1, which are significantly different from both catalogue and Cracow.

This system appears on the VSS Binocular Group chart for AE Aur, and a number of additional estimates of AR Aur have been made at random times by observers of AE Aur. These, together with the visual observations of minima referred to above and some further series of estimates which did not yield timings, enable the complete curve to be constructed (figure 3). Additional observers were S. Albrighton, M. Bell, N. Bone, R. Dryden, A. Gardner, P. Heppenstall, A. Hollis, A. Horton, M. Houchen, I. Nartowicz, M. Poxon, and C. Swan. The comparison star magnitudes used agree closely with published photoelectric V measures. Within the likely limits of observational error, the curve agrees with the catalogue data, except that it is a quarter of a magnitude brighter.

BF Aur

EB, 8.8-9.5 (9.5) V, $1^d.58$

Two minima by Brelstaff in 1979 are in satisfactory agreement with both the linear and quadratic elements of the catalogue, and with those of Cracow.

HL Aur

EB, 10.8-11.9 (11.0) p, $0^d.62$

Two minima by Brelstaff in 1983 give a significant O - C of $+0^d.02$ against the catalogue elements, which are repeated by Cracow.

IM Aur*

EA, 7.9-8.5 (8.1) V, $1^d.25$

This object is easy to find, being only half a degree away from Capella, though this means observation with binoculars is difficult. Nevertheless, as many as 26 minima have been timed visually in 1972-83, and we also have one photoelectric minimum in 1983. The observations show a significant departure from the catalogue elements, which gave P = $1^d.247296$, and from Cracow which gives P = $1^d.2472906$. The eclipses occur progressively earlier, compared with prediction. Our observations would best fit a shorter P of

$1^{d}.247282$. Photoelectric observations by Gülmen *et al.*[7] indicate a further shortening of P to $1^{d}.2472681$ occurring in 1980. Our photoelectric minimum, by M. Peel on JD 2445675 (1983 December 6), gives O - C = $-0^{d}.033$ against the catalogue elements and $-0^{d}.004$ against those of Cracow; but $+0^{d}.014$ against those of Gülmen *et al.* Visual timings were by Anderson, Brelstaff, A. Brown, J. Carey and Clayton.

The magnitude of Min II is given as 8.3 in the 1969 GCVS, but as 8.05: in the 1976 Supplement and 1985 GCVS. Were the depth of Min II only $0^{m}.15$, as the more recent data imply, it would be somewhat surprising that our observers had succeeded in timing as many as seven Min II visually. Mean light curves for 1972-76 and 1977-83 are shown in figure 4, from which it appears that Min II has in fact become shallower over the period of this report. These plots include further observations by Hollis and Isles, as well as by some of the observers mentioned earlier, which did not yield timings. The last series of observations at the phase of Min II was by Isles on JD 2444870 (1981 September 21), when no variation could be discerned.

A photoelectric light curve[8] for 1980-81 shows that Min II was then $0^{m}.1$ deep. An earlier, incomplete curve[9] indicates that Min II was appreciably deeper in 1969.

The most likely explanation for this phenomenon would appear to be that IM Aur has an elliptical orbit which is in apsidal motion, causing the magnitude of the partial secondary eclipse to be reduced. The apsidal motion may be due either to the gravitational influence of a third component, or to the components being not perfectly spherical. The eclipses should eventually deepen again.

LY Aur
EB, 6.7-7.4 (7.3) V, $4^{d}.00$
Three minima in 1978-79 give O - C values averaging $+0^{d}.03$ against both the catalogue and Cracow, but in view of the difficulty of timing this system's eclipses this may be not be a real discrepancy. The timings were by Brelstaff and Taylor.

SS Boo
EA, 10.3-11.0 (10.4) V, $7^{d}.61$
Three minima by Brelstaff in 1982-83 are in reasonable agreement with the Cracow elements (P = $7^{d}.606133$). The catalogue gives P = $7^{d}.603133$, which is evidently a transcription error.

UW Boo
EA, 10.4-11.4 (10.5) p, $1^{d}.00$
Two minima by Brelstaff indicate an O - C of $-0^{d}.01$ against the catalogue elements, which are repeated by Cracow.

ZZ Boo
EA, 6.8-7.4 (7.4) V, $4^{d}.99$
Two minima observed, in 1974 and 1978, respectively give O - C values of zero and $+0^{d}.02$, against both the catalogue and Cracow. Observers Brelstaff and D. Pickup.

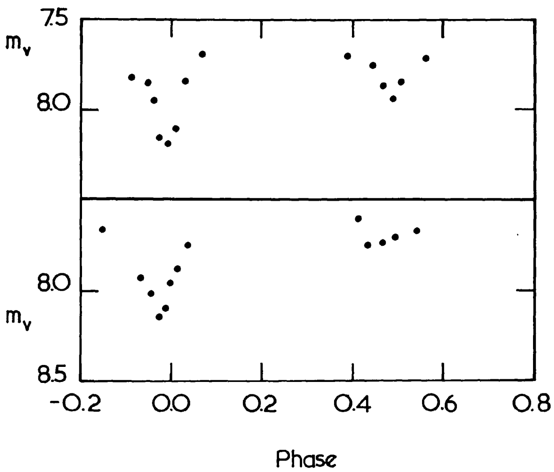

Figure 4. IM Aur. Mean light curves from visual estimates in 1972-76 (above) and 1977-83 (below). Phases are against the 1969 GCVS elements. Each point is the mean of about ten visual estimates, except in the lower plot where points around Min II are means of about five estimates. The amplitude of Min II has decreased over the period of observation.

AC Boo
EW, 10.0-10.6 (10.6) v, $0^{d}.35$
Five minima in 1978-83 by Brelstaff and Isles are in reasonable agreement with both the 1969 and 1976 elements.

SV Cam
EA, 8.4-9.1 (8.6) V, $0^{d}.59$
Seven minima by Brelstaff in 1982-83 indicate a significant O - C of $+0^{d}.009$ against the catalogue elements, but fit those of Cracow quite well.

XZ Cam
EA, 11.4-14.4 p, $11^{d}.01$
A timing by Brelstaff, derived from estimates in 1982 and 1983, gives O - C = $+0^{d}.07$ against both the catalogue elements and those of Cracow. The observations (figure 5) indicate D = 0.08P, or 21 hours, in agreement with the catalogue against Cracow which gives D = 30 hours.

AL Cam
EA, 10.5-11.3 p, $1^{d}.33$
Three minima by Brelstaff in 1982 indicate an O - C of $-0^{d}.005$ against the catalogue elements and $+0^{s}.006$ against Cracow.

AN Cam
EA, 10.4-11.2 p, $21^{d}.00$
Two minima by Brelstaff in 1982 and 1983 both give the remarkably large O - C of $-4^{d}.9$ against the catalogue elements (repeated by Cracow). A large change in P appears to have occurred, and further observations would be of value.

AW Cam
EB, 8.2-8.7 (8.4) V, $0^{d}.77$
Three minima by Brelstaff in 1978-79 agree well with the catalogue elements, which are essentially the same as those of Cracow.

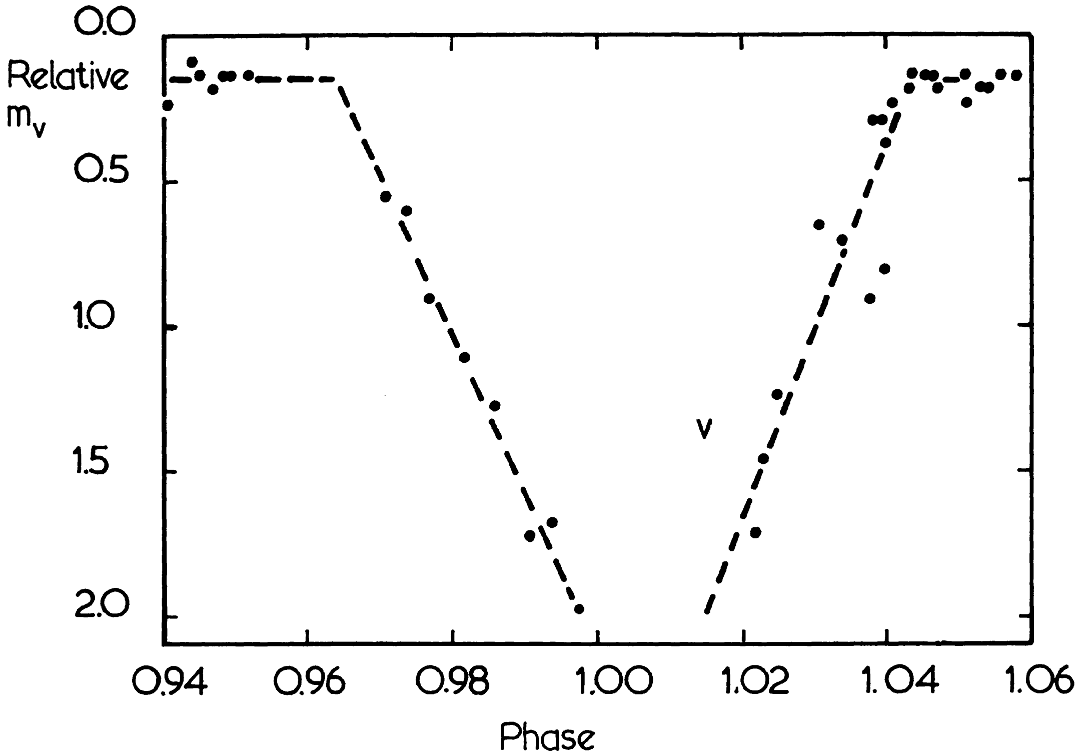

Figure 5. XZ Cam. Visual estimates near Min I by T. Brelstaff in 1981-83, plotted against phase according to the 1985 catalogue elements. The magnitude scale is based on the observer's step estimates. D is about 0.08 P, rather than about 0.11 P as implied in the Cracow yearbook.

AY Cam*

EA, 9.7-10.3 (10.2) V, $2^d.73$

Four minima by Brelstaff in 1982-83 give a significant O - C against the catalogue elements of $+0^d.010$, whereas against the Cracow elements (which use the halved P of $1^d.37$) they give $+0^d.013$.

Further observations were reported for the following stars, but were either too few in number or showed too small an amplitude to enable any useful conclusions to be drawn: SY And, CD And, GZ And, ST Aqr, V342 Aql, AD Boo, 44i Boo, AZ Cam.

Concluding remarks

This report shows that eclipsing binaries are by no means the clockwork variables they are sometimes represented to be, and that a great deal may be deduced from visual estimates. Photoelectric measurements may be expected to yield even more useful results. More observations by both methods will be welcome.

The increasing use of instrumental photometry does not put the visual observer out of business, since there are about 5000 eclipsing binaries in the catalogue, most of them within reach of amateur telescopes. But it is necessary for the visual observer to become more adventurous. Many fainter systems have never been observed with photoelectric equipment; and many relatively bright binaries with longer eclipses are also neglected. Such objects are likely to prove more profitable to observe than the binocular objects with short eclipses. The recent extension of the programme to cover some such systems should help. But the observer who strikes out on his own with the aid of the catalogue can make an especially great contribution.

Acknowledgements

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