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Y Cam: An Eclipsing System with a Delta Scuti Primary

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Summary. Photoelectric light curves of the eclipsing variable Y Cam in the B and V wavelength regions are presented. The orbital period is studied using all available epochs of primary minimum and the variability of the period is confirmed.
The primary, larger and brighter component turns out to be a δ Sct star with a one and a half hour period and a variable light amplitude. The amplitude variation moreover is not correlated with the phase in the orbital motion. We can conclude therefore that the amplitude variations in δ Sct stars are not necessarily caused by a companion.
Direct photometric solutions are computed and then improved by means of the Irwin method.

Key words: binary system – Delta Scuti

1. Introduction

A complete summary of the many former studies on this Algol type eclipsing variable has been given by Dugan (1924). This author obtained a complete visual light curve with a polarizing photometer, confirmed the change of the period previously noted and observed an apparent displacement of nearly an hour of the secondary minimum toward the following primary. Dugan also computed a solution for the system. It was shown that the dimensions of the two components were nearly the same so it was not evident if the principal eclipse is a transit or an occultation.
A substantial number of epochs of Min I derived after the year 1890 has made it possible to check the trend of the period. Miss Szcepanowska (1955) on the basis of 176 times of minimum found necessary to introduce a sinusoidal term into the elements of Y Cam with a total amplitude of 0^d24 and a period of about 3300 cycles. However according to this author the sixty year interval covered by the observations is too short for deducing that the variation of the period is real and that it is not due to a cumulative effect of random fluctuations of the period itself. Plavec *et al.* (1961), discussing the period variability of six detached systems with undersize subgiants, noted that the sinusoidal term in the ephemeris of Y Cam probably does not represent the whole period variation but only the main part. They concluded moreover that the large periodic term cannot be due to a third body nor to an apsidal advance.
The only spectroscopic research we know was done by Struve *et al.* (1950). Y Cam is a single-spectrum A 7 V system with strong metallic lines. The following results were also given: $f(m)=0.015\,\odot$, $a_1 \sin i = 1.6\ 10^6$ km. These values must be considered as provisional because they were deduced from only four spectra.
No photoelectric light curve for this system has been published, as far as we know.

II. The Observations and the Variation of the Orbital Period

The need for a more detailed photometric analysis of the system and an evaluation of the geometrical and physical elements and for a further study of period variation was obvious. Therefore B and V observations were carried out at the Merate Observatory from 1961 to 1970 by means of the 102 cm Zeiss reflector, a Lallemand photomultiplier, with Schott BG 12 + GG 13 (2 mm) and OG 4 filters and a chart recorder. Altogether about 3700 photoelectric measures were obtained. Owing to the variability of the brighter component of the system it seemed advisable to publish the individual observations (P. Broglia, P. Conconi, Publ. Obs. Merate N° 27, 1973) with a hope it might be of some use for future investigators.
The variable = BD +76°286 was mostly compared with star c($\Delta\alpha = +1.3$ min, $\Delta\delta = +1'.0$ with respect to Y Cam) and in the deepest part of the Min I with star d ($\Delta\alpha = -1.1$ min, $\Delta\delta = +1'.3$) to reduce the difference in colour between the variable and the comparison and the corresponding correction for the differential colour extinction. The measures were then all referred to the star c. Check star was b = BD +76°285. Numerical reduction of the observations were done with the

aid of an IBM 1620 computer. The stars c, b, d appear to be constant in brightness and the standard deviation of a mean Δm, deduced from a hundred values gives the approximate result $\pm 0^m.001$. By means of a comparison to some photoelectric standards made in two nights we obtained moreover:

	c	d	b
V	$10^m.25$	$10^m.94$	$9^m.81$
$B-V$	+ 0.34	+ 0.90	+0.46.

Representing by least squares the two branches of each Min I and estimating their bisection we evaluated fifteen instants of primary minimum. The heliocentric epochs are listed in Table 1 with the corresponding internal deviation of the mean of the B and V values. The epochs are spread over a run of 1008 cycles so that, on account of the variability of the period, a linear ephemeris is not sufficient to represent them. On the contrary, adding a parabolic term, we obtained residuals of the same order as the estimated mean errors of the instants of minimum. The results are:

$$\begin{aligned}\text{Min I} = \text{Helioc. J.D. } &2437375.4923 + 3.3055069\,n \\ &\pm \quad 4 \qquad\qquad 24 \\ &+ 5.3\;10^{-8} n^2 \\ &\quad 5 \text{ m.e.}\end{aligned}$$

The corresponding values for n and for the residuals $O-C$ are listed in Table 1.
The phases for single observations were computed according to the formula:

$$\text{Helioc. phase} = \frac{\text{Helioc. J.D.} - E_0}{P} \cdot \left(1 - A\,\frac{\text{Helioc. J.D.} - E_0}{P}\right)$$

where $E_0 = 2437372.1868$, $P = 3.3055069$ and $A = 5.3\;10^{-8}$.

Table 1. Epochs of Min I

J.D. ⊙ 24...		n	$O-C$
37375.4917 ± 0.0002 e.m.		0	+0.0006
699.4326	1	98	− 1
752.3199	9	114	+ 9
765.5433	2	118	− 4
7785.3764	3	124	− 4
8142.3723	4	232	+ 4
403.5096	3	311	+ 4
436.5623	17	321	+ 31
760.5078	2	419	+ 11
8793.5653	4	429	− 9
9213.3709	2	556	− 5
504.2614	8	664	− 9
593.5119	6	671	− 8
39950.5128	2	779	+ 12
40707.4970	2	1008	− 4

From literature we then collected the following epochs of minimum, besides the previous ones given by Miss Szcepanowska:

J.D. 2432883.309	B.A.C. 12, 127, 1961
33762.577	B.A.C. 12, 127, 1961
34605.577	B.A.C. 12, 127, 1961
38763.816	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 114
39140.648	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 129
39173.702	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 129
39173.706	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 180
39183.612	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 154
39183.617	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 180
39477.815	Comm. 27 I.A.U. Inf. Bull. Var. Stars N° 221 .

As it is now possible to recover an interval about 2200 cycles more extended than the one of 6600 periods considered by Miss Szcepanowska, we thought it useful to check further the variation of the orbital period. We considered, apart from the twenty seven normal epochs calculated by this author, six other normals derived from the above mentioned data and our fifteen photoelectric instants, all with a suitable weight.
A plot of the $O-C$ residuals calculated in comparison with a linear ephemeris proved that the sinusoidal term was partially inadequate (Fig. 1a). An expression of the form:

$$\text{Min I} = E_0 + Pn + A\,n^2 + B\,n^3$$

where A is the rate of the change of the period and B its acceleration, was also shown to be insufficient, yielding a mean residual of $\pm 0^d.033$. Finally as the residuals calculated by means of the sinusoidal term introduced by Miss Szcepanowska display a periodical trend, we tried an empirical fitting of the observed epochs E adding to the linear term two trigonometrical terms:

$$\begin{aligned}\text{Min I} = E_0 + Pn &+ A\sin(A_0 + 2\pi E/P_1) \\ &+ B\sin(B_0 + 2\pi E/P_2)\end{aligned} \tag{1}$$

where the periods P_1 and P_2 were changed step by step in convenient intervals. The solving of the weighted equations by least squares was performed in double precision. We obtained a substantial decrease to $\pm 0^d.005$ of the mean residual in comparison with the above expression, assuming P_1 close to 16000^d and ranging P_2 from 22000^d to about 70000^d (Fig. 1).
Of course, bearing in mind that the values of P_1 and P_2 are of the same order as the interval covered by the observations, we can understand in particular that P_2

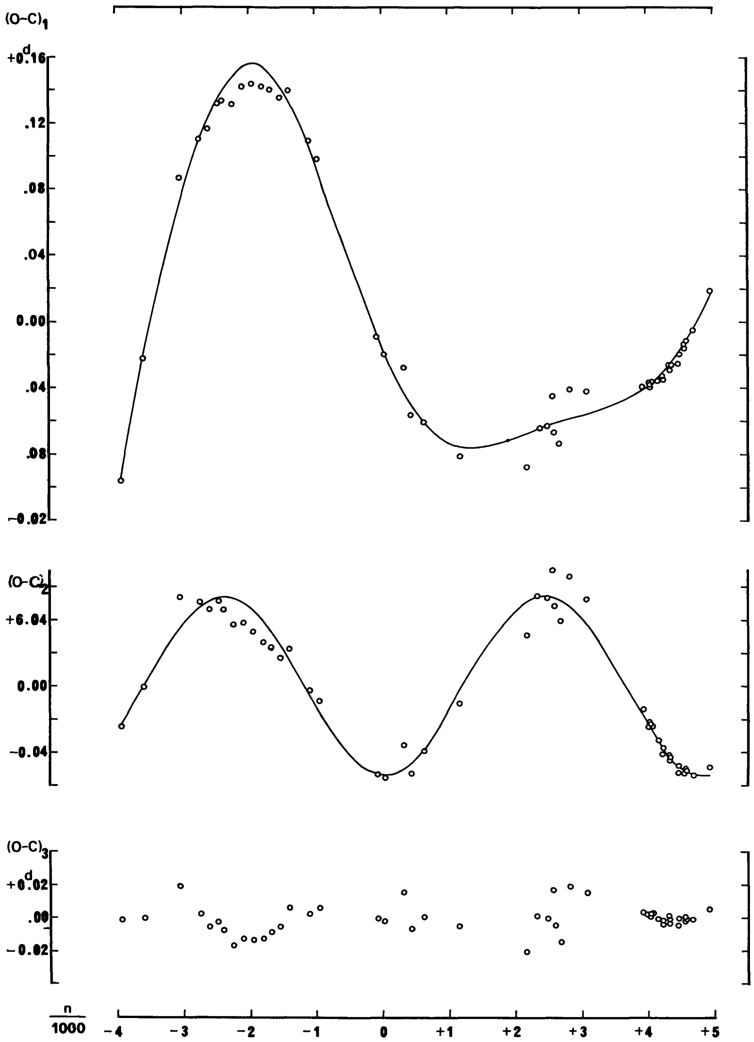

Fig. 1. Residuals of the epochs of Min I with respect: a) A linear ephemeris (upper curve). b) An ephemeris with linear and sinusoidal terms with period $P = 25000^d$ (middle curve). c) An ephemeris like (1) with $E_0 = 24434.4915$, $P_0 = 3^d.30550191$, $P_1 = 25000^d$, $P_2 = 16000^d$ (down curve)

is rather indeterminate. Moreover, for the same reason, we cannot be sure that such periodic variations are a stable characteristic of the system, although we can give a satisfactory representation of the observed epochs by means of the two periodic terms.

III. The Variability of the Primary Brighter Component

An inspection of the observations obtained during the individual nights displays, at times, a slight variation superimposed over the much more conspicuous variation rising from the eclipse phenomenon. In particular we see:

1) The light modulation, a little more marked in B than in V light, is in phase in both the colours and is approximately periodical with a period of one and a half hour. It has an almost sinusoidal form, with a total amplitude of a few hundredths of magnitude at the most, and the colour is more blue at maximum light.

2) The fluctuation is entirely absent in the deepest part of the primary minimum, but it is perceptible during the less advanced phases of the principal eclipse and outside the primary minimum. Therefore the variable star is the brightest component of Y Cam. We note that the steadiness of the comparison c has been tested against the two check stars as we have mentioned earlier. In addition the plot of the Δm between the stars c, d, b, against the phases calculated with the one and a half hour period, during the nights when the fluctuation appears clearly, displays a random scatter around the mean.

3) The amplitude of the fluctuation moreover is not constant. In order to illustrate this behaviour we have plotted in Fig. 2 the observations obtained during the nights J.D. 37760 and J.D. 37998. We see that the light modulation is clearly evident in the first night, on the contrary during the second night it becomes merged with the observational dispersion of the measures.

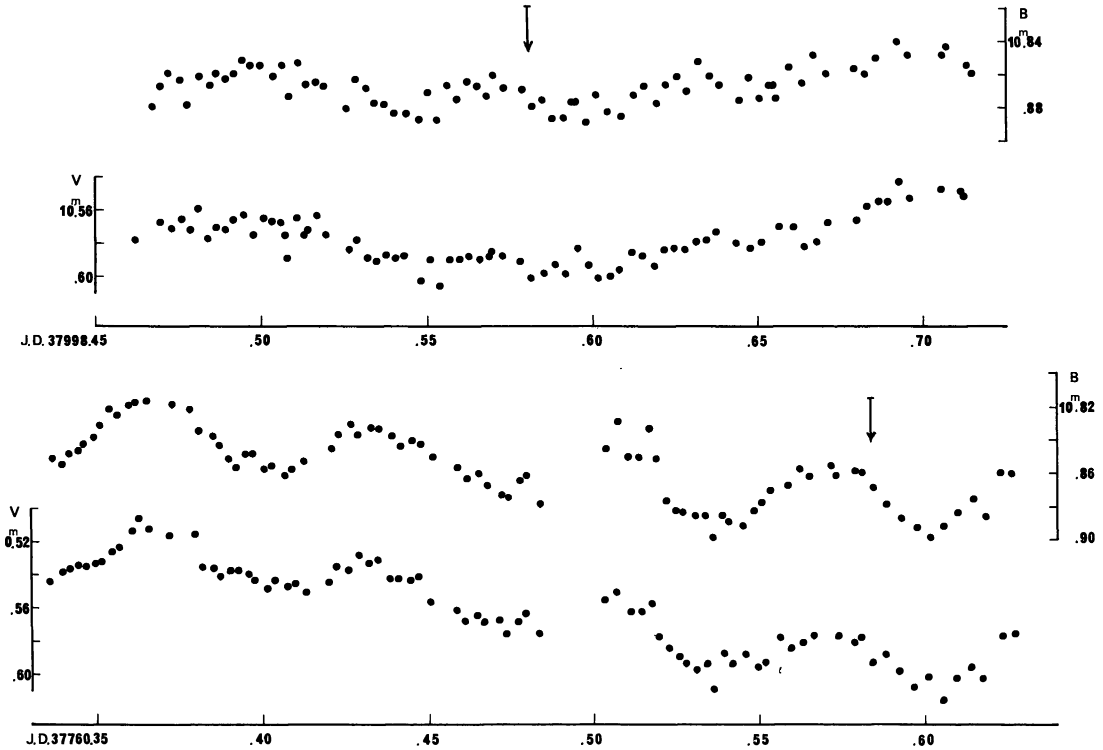

Fig. 2. The light curves obtained during the secondary minimum display the variation in the modulation of the δ Sct component of Y Cam. The arrows indicate the instants of the central secondary eclipse

4) To derive a non subjective estimate of the instants of maximum and minimum of the light fluctuation, when such estimate is possible, we represented the groups of measures around such instants with a parabolic regression. The epochs derived are given in Table 2; the average standard deviation of the mean of B and V values is $\pm 0^d.001$. As appears evident looking at the groups of the consecutive instants and bearing in mind their precision stated above, the light fluctuation is not strictly periodical, but the length of one cycle deviates by $\pm 0^d.01$ also from the mean value $0^d.063$. In order to improve the period we considered at first only the epochs obtained during the nights J.D. 7757 and J.D. 7760. Then, after an evaluation of the most probable number of cycles contained in this interval, a least squares solution calculated for the instants from J.D. 7757 to J.D. 7764 yielded the ephemerides:

$$\text{Min} = \text{Helioc. J.D. } 2437757.358 + 0.0634697\, n$$
$$\pm \quad 1 \qquad\qquad 3 \text{ m.e.}$$

The corresponding residuals are given in the Table 2 for all the 23 epochs obtained. We trust that the cycle number n for the epochs comprised in the above interval is correct. Of course, because of the large number of periods that have elapsed, the values of n are rather uncertain because of the subsequent epochs spaced many nights apart and also for the reason that the 91 min light variation does not seem a stable oscillation and can even disappear.

The computation of the mean period is therefore based on the assumption that the pulsations remain in the same relationship as that prior to their eventual cessation.

5) Bearing in mind the characteristics of the light curves and considering that, in addition, the period, the colour index and the spectral type are within the appropriate range, we conclude that the brighter component of Y Cam is a δ Sct variable. It is known that the variability of the stars of this type is not perfectly regular, but the light and the radial velocity curves are believed to be affected by beat phenomena

Table 2. Epochs of minimum or maximum light of the δ Sct component

J.D. ⊙ 243...	n	$O-C$	J.D. ⊙ 243...	n	$O-C$
7641.522	−1825	$-0^d.004$	7760.538	50	$+0^d.007$
.554	1824.5	− 4	.570	50.5	+ 7
7757.353	0	− 5	.602	51	+ 7
.395	+ 0.5	+ 5	7764.369	110.5	− 2
.421	1	0	7787.449	474	+ 6
.459	1.5	+ 6	7822.385	1024.5	+ 2
.484	2	− 1	7998.545	3800	+ 2
.511	2.5	− 6	.571	3800.5	− 4
7760.366	47.5	− 7	8053.458	4665.5	− 18
.405	48	0	8765.292	15880.5	+ 3
.432	48.5	− 4	.322	15881	+ 2
.477	49	+ 9			

Table 3. *V* normal points

n	Phase	*V*	*n*	Phase	*V*	*n*	Phase	*V*
13	0°1	12^{m}243	15	71°8	10^{m}497	10	229°5	10^{m}506
13	.3	12.233	11	79.5	10.495	11	235.1	10.505
13	.6	12.232	7	85.8	10.487	9	241.4	10.520
14	.9	12.218	6	94.4	10.496	12	250.2	10.510
13	1.2	12.212	9	102.1	10.498	6	257.1	10.513
13	1.4	12.196	6	106.7	10.502	6	263.0	10.509
12	1.6	12.176	6	112.2	10.496	6	269.7	10.504
13	1.8	12.165	14	120.3	10.499	8	276.1	10.505
13	2.1	12.141	5	131.9	10.510	5	287.1	10.498
13	2.3	12.118	6	141.9	10.518	7	293.2	10.526
13	2.6	12.090	8	146.6	10.512	7	300.8	10.504
13	2.8	12.077	8	149.5	10.494	9	306.6	10.513
13	3.0	12.048	10	154.1	10.530	13	315.8	10.515
13	3.3	12.026	11	156.3	10.519	13	320.4	10.524
13	3.5	11.992	10	159.0	10.532	13	331.3	10.538
12	3.8	11.959	10	160.2	10.535	13	333.5	10.573
13	4.1	11.933	9	161.3	10.524	12	334.9	10.594
13	4.5	11.874	10	162.6	10.536	13	336.4	10.623
13	4.7	11.849	10	163.8	10.543	13	338.0	10.672
13	5.1	11.816	10	165.3	10.553	12	339.5	10.721
13	5.3	11.789	9	166.8	10.564	12	340.4	10.759
13	5.7	11.760	10	167.9	10.569	12	341.9	10.816
12	6.1	11.702	10	169.6	10.569	13	343.0	10.869
13	6.7	11.649	10	171.3	10.568	13	343.9	10.907
13	7.3	11.585	10	172.2	10.575	13	344.8	10.952
12	7.9	11.521	11	173.4	10.582	13	345.6	10.997
12	8.3	11.480	10	174.6	10.591	14	346.5	11.066
13	8.9	11.419	10	175.5	10.588	12	347.4	11.125
13	9.5	11.379	10	176.6	10.592	12	348.0	11.177
12	10.0	11.326	10	177.8	10.585	13	348.7	11.224
12	10.7	11.269	10	178.7	10.595	13	349.7	11.307
12	11.3	11.220	10	179.4	10.592	12	350.5	11.376
13	12.1	11.154	10	180.2	10.598	13	351.3	11.443
12	13.4	11.059	11	181.3	10.600	13	352.1	11.527
13	14.5	10.998	10	182.3	10.600	13	352.7	11.602
12	15.5	10.946	10	183.1	10.597	12	353.3	11.655
13	16.5	10.899	10	183.8	10.583	13	353.8	11.717
12	17.5	10.848	10	184.4	10.581	13	354.3	11.769
13	18.4	10.797	10	185.2	10.581	12	354.8	11.809
12	19.4	10.745	10	186.6	10.582	13	355.2	11.864
13	20.2	10.720	10	187.7	10.581	12	355.6	11.909
12	21.0	10.698	11	188.6	10.581	13	356.0	11.952
12	22.1	10.659	10	189.3	10.580	12	356.3	11.995
13	23.1	10.637	10	190.3	10.575	13	356.6	11.026
12	23.8	10.619	10	191.2	10.563	13	356.9	12.050
12	24.5	10.607	10	192.5	10.553	13	357.1	12.070
13	25.4	10.584	10	194.3	10.554	12	357.4	12.106
13	26.4	10.562	10	196.0	10.559	13	357.7	12.125
12	27.6	10.547	10	197.6	10.539	13	357.9	12.147
12	29.0	10.538	10	199.4	10.543	13	358.2	12.168
10	30.3	10.532	11	201.0	10.530	12	358.4	12.193
11	31.9	10.536	10	202.2	10.539	13	358.7	12.209
11	34.0	10.525	10	203.4	10.529	13	359.0	12.226
11	36.3	10.516	11	205.3	10.517	13	359.2	12.230
8	42.6	10.525	11	208.8	10.517	13	359.5	12.234
7	48.5	10.524	11	210.5	10.519	14	359.8	12.243
8	57.6	10.512	17	216.8	10.518			
14	64.1	10.509	11	226.1	10.520			

Table 4. *B* normal points

n	Phase	*B*	*n*	Phase	*B*	*n*	Phase	*B*
10	0°1	12^{m}757	7	85°9	10^{m}797	10	226°0	10^{m}847
10	.4	12.756	6	94.6	10.812	11	229.4	10.827
11	.7	12.738	9	102.0	10.825	11	235.1	10.825
10	1.1	12.714	6	106.7	10.819	7	241.1	10.838
11	1.4	12.700	6	112.1	10.814	12	250.2	10.829
11	1.8	12.669	14	120.3	10.819	6	257.0	10.831
11	2.1	12.628	5	132.1	10.824	6	263.2	10.821
10	2.5	12.589	6	141.8	10.832	7	269.7	10.817
10	2.8	12.560	8	146.5	10.835	8	276.0	10.823
9	3.1	12.504	8	149.6	10.812	5	287.0	10.806
11	3.4	12.473	10	154.1	10.837	6	293.2	10.840
10	3.7	12.443	11	156.4	10.829	6	300.7	10.823
9	4.2	12.373	10	159.0	10.841	9	306.7	10.824
12	4.6	12.329	10	159.9	10.847	11	315.4	10.833
10	5.0	12.270	10	161.3	10.833	12	319.5	10.836
9	5.5	12.208	10	162.8	10.850	10	333.1	10.872
9	6.2	12.127	10	163.9	10.849	10	334.3	10.891
12	6.9	12.034	10	165.5	10.856	11	335.6	10.917
9	7.7	11.937	10	167.0	10.864	11	337.2	10.958
9	8.4	11.863	10	168.2	10.867	10	338.5	10.997
10	9.0	11.786	10	170.0	10.861	10	339.6	11.038
10	9.9	11.700	10	171.5	10.858	11	340.5	11.080
9	10.6	11.635	10	172.8	10.861	10	341.7	11.127
11	11.3	11.575	9	173.9	10.881	10	342.6	11.177
8	12.4	11.471	10	174.9	10.884	10	343.4	11.213
11	13.4	11.398	10	175.8	10.880	10	344.2	11.245
10	14.3	11.337	10	176.8	10.878	11	344.9	11.288
11	15.0	11.301	10	178.0	10.869	9	345.6	11.327
10	15.9	11.253	11	178.9	10.868	11	346.3	11.387
10	16.7	11.215	10	179.8	10.876	10	347.0	11.444
10	17.5	11.169	10	180.6	10.883	10	347.7	11.503
9	18.2	11.128	10	181.6	10.883	10	348.3	11.548
10	18.9	11.086	10	182.6	10.879	10	348.8	11.585
10	19.7	11.057	10	183.6	10.865	11	349.4	11.642
11	20.6	11.023	10	184.2	10.866	10	350.2	11.703
10	21.4	11.001	10	184.7	10.867	9	350.8	11.765
10	22.5	10.961	10	185.8	10.861	11	351.5	11.838
9	23.2	10.941	10	187.2	10.872	11	352.1	11.910
10	23.7	10.931	10	188.0	10.872	10	352.7	11.978
10	24.2	10.927	9	188.7	10.875	10	353.3	12.071
10	25.0	10.912	10	189.5	10.872	10	353.8	12.130
9	25.7	10.886	11	190.5	10.861	10	354.2	12.185
10	26.5	10.868	10	191.5	10.854	10	354.7	12.234
10	27.4	10.857	10	193.1	10.849	10	355.2	12.287
8	28.5	10.848	10	194.7	10.857	10	355.6	12.336
11	29.5	10.841	10	196.3	10.858	10	356.0	12.392
10	31.1	10.848	10	198.3	10.842	10	356.4	12.449
11	32.8	10.851	10	200.0	10.844	10	356.8	12.512
14	34.2	10.837	10	201.7	10.844	10	357.2	12.559
12	36.6	10.828	10	202.8	10.843	10	357.6	12.607
8	42.7	10.838	10	204.4	10.832	10	357.9	12.633
4	49.0	10.842	10	208.2	10.838	11	358.3	12.676
8	57.7	10.818	10	209.7	10.842	10	358.6	12.708
15	64.3	10.821	6	211.1	10.834	11	359.0	12.738
14	72.0	10.814	8	215.8	10.813	12	359.4	12.751
9	79.6	10.815	9	217.7	10.843	10	359.8	12.758

which can bring the amplitude even to zero. Y Cam has a similar photometric behaviour.

However, as the observations were preferentially concentrated on the primary minimum with a view to calculating a photometric solution, we dispose of relatively few observations for studying the δ Sct variability more in detail, over which moreover are superposed reflection, ellipticity and in part eclipse effects, which all distort any periodogram analysis, and so we have considered it unpractical to analyse the beat phenomenon.

IV. Photometric Solution by Means of an Electronic Computer

The single observations were then grouped in the normal points given in Tables 3 and 4. The mean light and colour curves are plotted in Fig. 3.

The results are:

	B	*V*	*B* − *V*
Max	10^{m}815	10^{m}495	+0^{m}32
Min I	12.760	12.245	+0.515
Min II	10.880	10.595	+0.285 .

As the eclipse is nearly grazing, we see that the colour in mid-secondary minimum confirms the spectral type A 7 for the brighter component estimated by Struve *et al.* (1950). Taking into account the uncertainty due to the secondary fluctuation, from Fig. 3 we see also that the secondary minimum occurs at the phase 0.5. Therefore the one hour displacement supposed by Dugan (1924) is not confirmed.

The small brightness fluctuations of the mean light curve out of the deepest part of the primary eclipse are due to the variability of the brighter component. As the

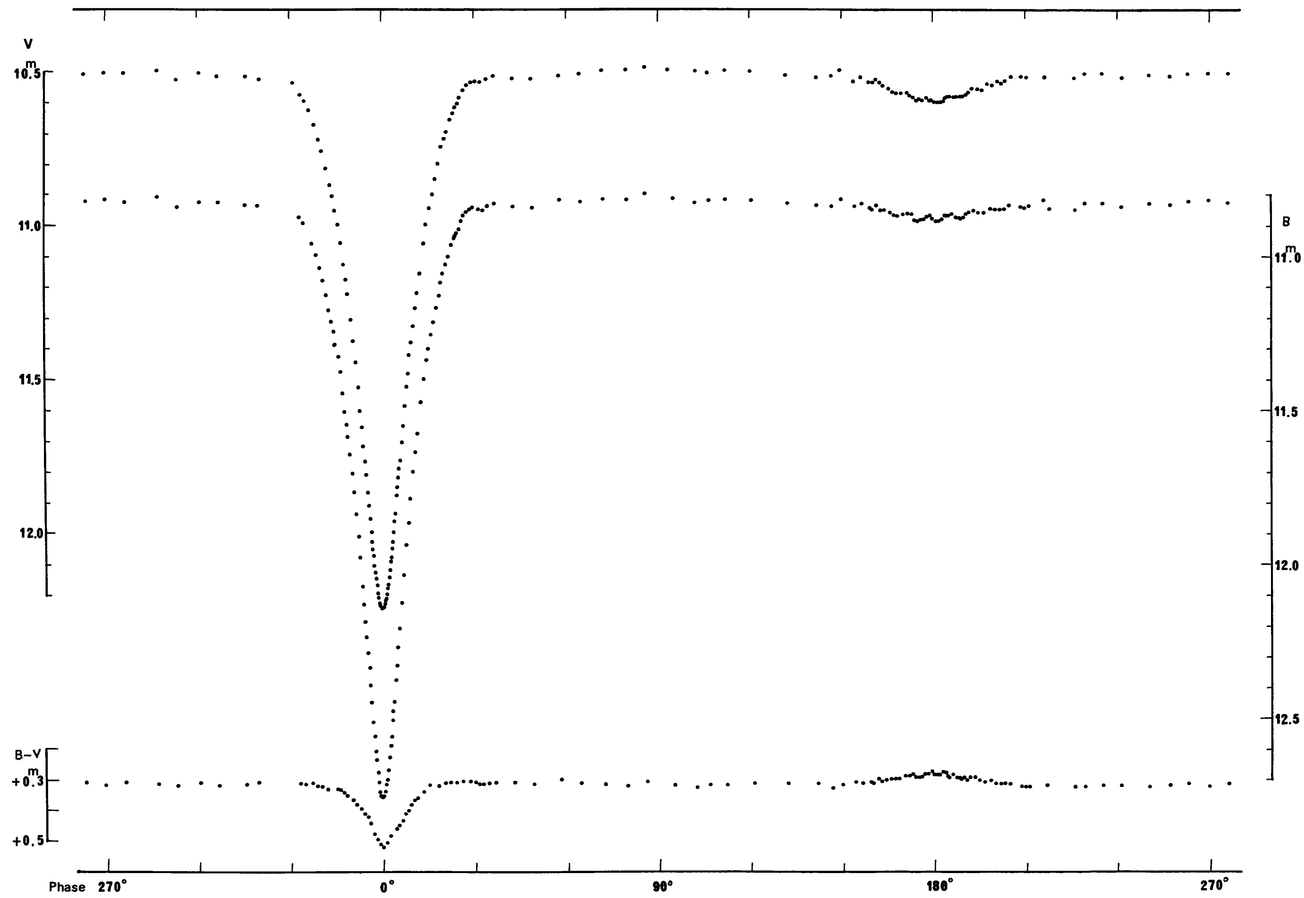

Fig. 3. Mean B, V and colour ligh curves of Y Cam. One should note the modulation, due to the variable bright component, near the shoulders of Min I, outside the eclipses and during the secondary minimum

orbital and the δ Sct periods are incommensurable and considering also that the amplitude of the pulsation is not constant and the distribution of the measures along a revolution is not uniform, the light fluctuations occur variously averaged along the mean light curve. Therefore only the position in comparison with the orbital motion, but not the form of the fluctuation is a stable feature of the mean light curve.

Some different methods have been proposed for the computation of the elements of binary systems by means of an electronic machine. On account of the moderate size of the memory of the computer used, an IBM 1620, we have proved it is advantageous to carry out the calculation in three separate steps:

1) Analysis of the non eclipse regions of the light curve by least squares according to the conventional equation, with terms in $\cos n\vartheta$ and $\sin n\vartheta$ up to $n=4$ at most. For every coefficient the mean error and moreover the mean deviation of a normal in comparison with the Fourier truncated series are calculated, so it is possible to judge how many terms are significant and to repeat the calculation only with these. In this manner, after excluding the terms we do not consider to be consistent, we obtained:

$$\begin{aligned} V\,\ell_{\rm obs} = {} & 0.9548 - 0.0064\cos\vartheta - 0.0129\cos 2\vartheta \\ & \pm\quad 4 \qquad\quad 6 \qquad\qquad\quad 7 \\ & + 0.0042\sin\vartheta \\ & \qquad 2\ \text{m.e.} \end{aligned}$$

$$\begin{aligned} B\,\ell_{\rm obs} = {} & 0.9530 - 0.0041\cos\vartheta - 0.0121\cos 2\vartheta \\ & \pm\quad 5 \qquad\quad 8 \qquad\qquad\quad 9 \\ & + 0.0040\sin\vartheta \\ & \qquad 6\ \text{m.e.} \end{aligned}$$

$$.53\,\mu\ \ell_{\rm obs} = 0.9477 - 0.0102\cos\vartheta - 0.0318\cos 2\vartheta\,.$$

The last line gives the expression obtained by Koch *et al.* (1970) from Dugan's (1924) observations.

The mean deviation in intensity unit of a normal is 0.005 and 0.006 respectively for the V and the B light curves. The influence of the δ Sct oscillation appears therefore small and in account of the very different length of it's period in comparison with the orbital one, we cannot fear a systematic influence on the Fourier coefficients.

2) Rectification for all the normals (light intensity and phase) has been carried out according to the Russell

and Merrill (1952) method. The limb darkening coefficients adopted, the rectification constants calculated and the standard deviations σ from unity of the rectified intensities outside the eclipses are as follows:

V $x=0.6$ $C_0=0.0212$ $C_2=0.0071$
$z=0.0323$ $\sigma=0.0066$

B $x=0.8$ $C_0=0.0212$ $C_2=0.0071$
$z=0.0252$ $\sigma=0.0085$.

In account of the absence of the δ Sct variability in the central parts of the primary eclipse we can expect a better observational accuracy for the normals used in the derivation of the elements. We note also that the "reflection" of the rectified normals around the zero phase displays a good overlapping of the two branches, so no notable asymetry or complication exist in the rectified light curves.

The rectified depths ℓ_0 of primary and secondary eclipses gives the results:

V Min I $=0.764$ Min II $=0.067$
B 0.800 0.038.

According to Russell and Merrill (1952), from these values and from the spectral type A 7 V of the hot star we infer for the cool component the spectral type K 0, which in account of the light added to the opposed emispheres during the rectification is a little earlier than the true mean value.

3) The derivation of the elements was carried out separately for each colour according to a modified Wellmann (1960) method, with assumed values of limb darkening coefficient. Because of the small depth of the secondary minimum the element computation was carried out only from observations of primary eclipse. For each normal the rectification program gives the rectified quantities ℓ, $\sin^2\Theta$ and in addition $\sqrt{w}$, where w is the product of the observational and the intrinsic weights. The program then calculates for each normal the fractional light loss $n=(1-\ell)/(1-\ell_0)$ where ℓ_0 is $\ell_0^{\rm tr}$ or $\ell_0^{\rm occ}$ according to the type of the eclipse, transit or occultation. If it appears during the computation that the adopted hypothesis about the nature of the eclipse is wrong it is necessary to substitute for ℓ_0 the correct value.

By means of the depth relation for mid eclipse (Russell and Merrill, 1952):

$$\alpha_0^{\rm occ}=1-\ell_0^{\rm occ}+(1-\ell_0^{\rm tr})/q_0(k,\alpha_0^{\rm occ}) \qquad (2)$$

where $q_0=\tau\alpha_0^{\rm tr}/\alpha_0^{\rm occ}$ is the ratio of the light loss at corresponding phase in the two minima, starting with the value $q_0=1$, the program gives the corresponding α_0 and $k=k(q_0,\alpha_0)$. Then, through an interpolation in the $\psi(k,\alpha)$ table, for each normal the function is computed:

$$\chi(k,\alpha_0,n)=\frac{\psi(k,n\alpha_0)-\psi(k,\alpha_0)}{(k,\frac{1}{2}\alpha_0)-\psi(k,\alpha_0)}=\sin^2\Theta(n\alpha_0)/\sin^2\Theta(\tfrac{1}{2}\alpha_0)$$

and afterwards from all the normals the most probable values are derived for $\sin^2\Theta(\frac{1}{2}\alpha_0)$ which, according to the least squares method (Wellmann, 1960) is equal to:

$$\sin^2\Theta(\tfrac{1}{2}\alpha_0)=\frac{\Sigma w\chi(k,\alpha_0,n)\sin^2\Theta(n)}{\Sigma w\chi(k,\alpha_0,n)}$$

and the squares sum of the deviations between observed and calculated luminosities:

$$S(k)=\Sigma w\sin^4\Theta-\frac{(\Sigma w\chi\sin^2\Theta)^2}{\Sigma w\chi^2}.$$

The quantities: α_0, k, $\sin^2\Theta(\frac{1}{2}\alpha_0)$, $S(k)$ are then printed, α_0 is increased by a prefixed $\Delta\alpha$, the Eq. (2) gives again q_0 and the whole computation is repeated until the minimum for the function $S(k)$ is reached. The corresponding values for α_0, k, $\sin^2(\frac{1}{2}\alpha_0)$ give the required solution.

As the memory requirements for the $\psi(k,\alpha)$ function, according to Merrill (1953) tabulation, is larger than the whole computer memory, this function is introduced in tabular form only for selected values of α and k, and the values corresponding to each normal are derived by

Table 5. Photometric elements

	V	B	0.53 μ (K.S.)	0.53 μ (K.P.W.)
x (assumed)	0.6	0.8	0.6	0.6
a_g	0.2598 ± .0006	0.2632 ± .0009	0.233 ± .007	0.240
b_g	0.255	0.260	—	0.233
a_s	0.2515 ± .0003	0.2501 ± .0004	0.288 ± .003	0.235
b_s	0.247	0.247	—	0.228
j	85°.93 ± .07	85°.76 ± .09	85°.0 ± .4	85°.0
Θ'	30°.5	30°.6	27°.0	—
p_0	− 0.753	− 0.746	− 0.64 ± .02	—
L_g	0.9234	0.9581	0.952 ± .005	0.952
L_s	0.0766	0.419	0.048 ± .005	0.048
J_g/J_s	11.3	20.6	19 ± 2	—
σ	± 0.0027	± 0.0032	—	—

means of a second order interpolation formula. On the other hand we have found it suitable to represent $k(q, \alpha)$ and $\tau(k)$ by means of suitable polynomials approximating functions.

The above method do not enable the errors in elements to be evaluated; therefore we completed the solution by the differential correction method outlined by Irwin (1947). Since the eclipse is partial and in account of the small δ Sct variability of the eclipsed component, we computed only for the corrections Δr_1, Δr_2 and $\Delta(\cos^2 i)$, for assumed limb darkening coefficients. The results obtained are given in Table 5 together with the solutions reported in their Catalogues respectively by Kopal and Shapley (1956) and by Koch *et al.* (1970).

We note that the standard deviation σ of a normal during the eclipse in comparison with the computed light curve is smaller than the σ derived from the Fourier analysis, as expected, on account of the minor influence of the δ Sct variability during the primary eclipse. This fact proves that the brighter component only is variable. In addition we note that according to its colour the secondary component is too cool to pulsate. To the remaining influence of the variable δ Sct light is probably due the small disagreement between the V and B solutions, which cannot be reduced by repeating the calculations with different values for the darkening coefficient x.

V. Concluding Remarks

The great increase in our knowledge of the Delta Scuti stars during recent years can be emphasized remembering that Seeds and Yanchak (1972) in their Catalogue list fifty-eight stars (and ninety-seven suspected) and that a year later, according to Breger (1973), about seventy δ Sct are known. A few years ago only half a dozen objects were studied. The percentage of these variables among the stars from the Main Sequence A and F region to the RR Lyr one, the so called lower instability strip, seems noteworthy and obviously it depends on the limits of detectable light variability. Breger (1969) indeed, in two hundred and thirteen field stars earlier than F 9, extensively tested for short period variability, found sixteen δ Sct variables. Jorgensen *et al.* (1971) during an analogous search for A and F stars in the southern sky found three certain and further six suspected δ Sct in ninety-four objects tested. The percentage is notably stronger in the groups of stars studied more completely, like some open clusters, where it rises to 40% (Breger, 1972). Jackisch (1972) after a survey on 215 A 0–F 5 stars found that the members of clusters are about twice as often variable as the field stars. Moreover he found about ten percent of the A stars to be variable whereas the percentage of the variable among the F stars, in majority δ Sct, is three times greater.

The binary systems with a δ Sct component are quite common. The Catalogue of Seeds and Yanchak (1972) contains a third of double stars over a total of 155 δ Sct variables or suspected. However, as far as we know, only two eclipsing systems with a δ Sct component are actually recognized, AB Cas observed by Tempesti (1971) and Y Cam.

Up to the present a detailed photometry has been obtained only for few variables of this type. Generally it is admitted that the complex light variations, which seem to be a common feature for these stars, are due to a beat phenomenon, but only for very few objects the beat periods have been derived. When moreover a δ Sct belongs to a binary system we can expect an influence over the normal pulsation due to the near companion through one of the mechanisms quoted by Fitch (1970). An attempt to show an interaction of this type has been made by Hudson *et al.* (1971) for the spectroscopic binary 14 Aur, which has an orbital period of $3\overset{d}{.}789$, a brighter A 9 V component with a δ Sct type fluctuation of $0\overset{d}{.}08748$ and therefore is like Y Cam. According to a suggestion of Chevalier *et al.* (1968), these authors tried to correlate the variable light amplitude with phases in the orbital motion, in order to test if the amplitude variation of the Delta Scuti fluctuation is due to a nonradial pulsation with the pulsation axis possibly directed along the line of the centers of the components of the system. Hudson *et al.* did not reach a definitive conclusion although their fine photometric material is consistent with the hypothesis of Chevalier *et al.* The two sets of light curves displayed in the Fig. 2., both obtained during the secondary minimum, do not prove the above suggestion of a notable gravitational excitation of a nonradial pulsation by the companion, because the light amplitudes of the δ Sct component at the same orbital phases are different.

The changing orbital period moreover proves that it is some mass transfer in the system. It is probable that this phenomenon causes a long term influence over the pulsation mechanism, but it is not possible to prove it by means of our measures which cover a too short an interval.

According to the linear correlation between radial velocity and light ranges obtained by Leung and Wehlau (1967) from six δ Sct: $\Delta R = 62.5\,\Delta m$, the brighter component of Y Cam, with a B amplitude of $0\overset{m}{.}04$ at the most has a $\Delta R = 2.5$ km/s. According to Breger (1969) however the velocity variation caused by pulsation is typically 5 km/s but it can be also greater than 10 km/s. How the component of the radial velocity due to the δ Sct phenomenon can have influenced the value $k_1 = 35$ km/s and the corresponding mass function (Struve *et al.*, 1950) is difficult to evaluate, so it seems that a new spectroscopic study is desirable to obtain a better mass determination for the δ Sct component and to know more about its metallicism.

The photometric elements we give cannot improve substantially the absolute dimensions given by Kopal and Shapley (1956) in account of the meagre radial velocity measures. Lacking a spectroscopic determination of the mass ratio these Authors assume that the primary is a main-sequence star and use the statistical relations which hold for these stars to evaluate the absolute dimensions of the components. The δ Sct nature of the primary don't contradict this hypothesis since the δ Sct strip include the main-sequence and moreover their masses are normal (Breger, 1969). Following Kopal (1959) we obtain: $m_2/m_1 = 0.21$, $m_1 = 2.4\,\odot$, $m_2 = 0.50\,\odot$, $M_1 = 0^m\!.7$, $R_1 = 3.0\,\odot$, $R_2 = 2.9\,\odot$. We note that R_1 is rather large compared to the corresponding mass, for a main sequence star.

It follows that the pulsation constant is $Q = 0^d\!.019$, a value a little small compared to the mean for the δ Sct stars: $\bar{Q} = 0^d\!.026$, but however not unusual (Breger, 1972). On the assumption that the primary rotates in synchronisation with the orbital motion, the equatorial velocity is 46 km/s; the star therefore seems to rotate too rapidly for synchronism.

By means of the correlation between M_V and P, which is believed to exist for the δ Sct (Leung, 1970; Valtier, 1972), the brighter component of Y Cam should have $M_V = +1.8$ instead of $M_V = +0^m\!.7$. A value similar to the latter has 14 Aur, which has some other characteristics common with Y Cam, as we have noted before. According to Leung (1970) 14 Aur falls above the region occupied in the H–R diagram by usual δ Sct stars, as seem to be the case also for Y Cam. The Leung regions however are not securely established because of a lacking statistics.

A direct determination of the absolute dimensions will permit us to remove these uncertainties and will help to understand better the evolutionary phase. According to Roxburgh (1966) the eclipsing systems with undersize subgiant secondaries, like Y Cam, are in the pre-main sequence evolutionary phase. This conclusion does not disagree with the fact that the primary is a δ Sct since the pulsation can occur in stars of all ages (Breger, 1972).

If a more detailed spectroscopy confirms the metallicism, Y Cam will add to HR 5491 and to 32 Vir (Bartolini *et al.*, 1972); these stars prove that metallicism can coexist with pulsation[1]).

Note added in proof. According to M. Breger and M. Smith, which recently evaluated the old Struve spectra (private communication), Y Cam is not an Am star but its spectrum looks absolutely normal and it is approximately A 9 IV.

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[1]) According to the Referee, which we thank for the helpful comments, the variability of HR 5491 has not been confirmed at later dates; 32 Vir moreover, on the basis of a hundred spectra, has at present an extremely variable spectrum and this is very unusual for an Am star.