1984A&A...138..443B

Astron. Astrophys. 138, 443–450 (1984)

ASTRONOMY AND ASTROPHYSICS

Non-radial pulsator in the binary system Y Cam

P. Broglia and P. Conconi

Osservatorio Astronomico di Brera, I-22055 Merate (Co), Italy

Received February 7, accepted April 10, 1984

Summary. On the basis of new *B* and *V* observations the large variation in the orbital period of the eclipsing system Y Cam is studied along an interval over ninety years. An explanation of the minimum time residuals in terms of a third or a fourth body is discussed. Photometric solutions are calculated according to the Roche model.

Multiperiod analysis of the Delta Scuti-type primary component of the binary system gives a period ratio of 0.97 consistent with non-radial pulsations. This ratio moreover seems to conform to the linear relation between rotational velocity and period ratio proposed for non-radial pulsators. The oscillation with larger amplitude has a period constant over at least an interval of 120,000 cycles.

Key words: eclipsing binary – δ Scuti stars

Introduction

The eclipsing binary Y Cam (= BD +76°286) belongs to the small group of systems at present known to have a Delta Scuti variable as one of its components. In a previous note (Broglia and Marin, 1974) photoelectric *B* and *V* light curves of Y Cam were given. The variation of the orbital period was determined on the basis of minimum timings covering an eighty year interval. Two sinusoidal components with periods approaching 16,000^d and 25,000^d were proposed to represent the epochs of minimum; accordingly the mean residual of an epoch of minimum was reduced to an acceptable value of $\pm 0\overset{d}{.}005$. Because the derived periods are of the same order as the interval covered by observations these values were considered provisional. Further observations seemed necessary to confirm if such cyclic variations are a stable characteristic of the system and therefore to give a more sound indication about the causes of period changes.

Evidence was given moreover that the A9 component undergoes small cyclical light variations of δ Sct type. These oscillations moreover did not turn out to be strictly periodical, but changes on the period of $\pm 0\overset{d}{.}01$ in relation to the mean value $0\overset{d}{.}063$ were noted. Some epochs of minimum or maximum light of the δ Sct fluctuation were evaluated and a representation of these instants with a linear ephemeris along an interval of about 18,000 cycles was possible. The light amplitude also appeared to be variable from one night to another, but an analysis of the probable beat phenomenon was considered unpractical because the superposition of eclipse effects on the δ Sct variation. The amplitude variations moreover do not turn out to be correlated with the orbital phase. This fact imposes some restrictions on the hypothesis of a gravitational excitation of a non-radial pulsation of the A9 star by the companion. Finally photometric solutions were calculated in accordance with the Russell model by means of the Irwin differential correction method.

Quite recently Frolov et al. (1980) obtained new photoelectric observations and confirmed the variability of the brighter component of Y Cam. The period was found to vary from $0\overset{d}{.}056$ to $0\overset{d}{.}073$ during few cycles, but its mean value derived on the basis of the out of eclipse measurements given by Broglia and Conconi (1973) appeared to be constant over 13,000 pulsations and the mean value $0\overset{d}{.}066458$ was deived. These authors noted that in binary systems with a pulsating component (δ Sct, β CMa, cepheid) a synchronisation between pulsational and orbital motion is a probable state. They note however that for Y Cam the poor synchronisation they find, the changing light amplitude and instantaneous period may be the evidence of an unusual pulsation in the presence of a close companion.

Observations

For all these reasons further observations of Y Cam seemed useful, so during the last few years *B* and *V* measurements were performed again at the Merate Observatory using the same photometer and telescope as for the measurements referred to above. The same comparison and check stars were used and no evidence for variability between them appeared by as much as 0.01 mag in any colour. This value, which is the standard deviation of a Δm between the two stars, can be assumed as precision of a measurement of Y Cam. In particular we obtained some primary eclipse timings to monitor the orbital period. At the present the time span useful for the study of this period is thirteen years longer than in previous study. After the findings of Frolov et al. (1980) it seemed convenient to check also the δ Sct variability with some observations out of primary eclipse. Some of them are represented in Fig. 1. Moreover because of the present larger computing facilities it also became convenient to study all the photoelectric observations previously given to obtain both photometric solutions and more insight into the δ Sct pulsation.

The new epochs listed in Table 1 are the following:

a) Nine photoelectric timings of Min I. In view of possible difficulties to be encountered in the evaluation of times of lighty asymmetric minima caused by the superimposed δ Sct variation,

---

Send offprint requests to: P. Broglia

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

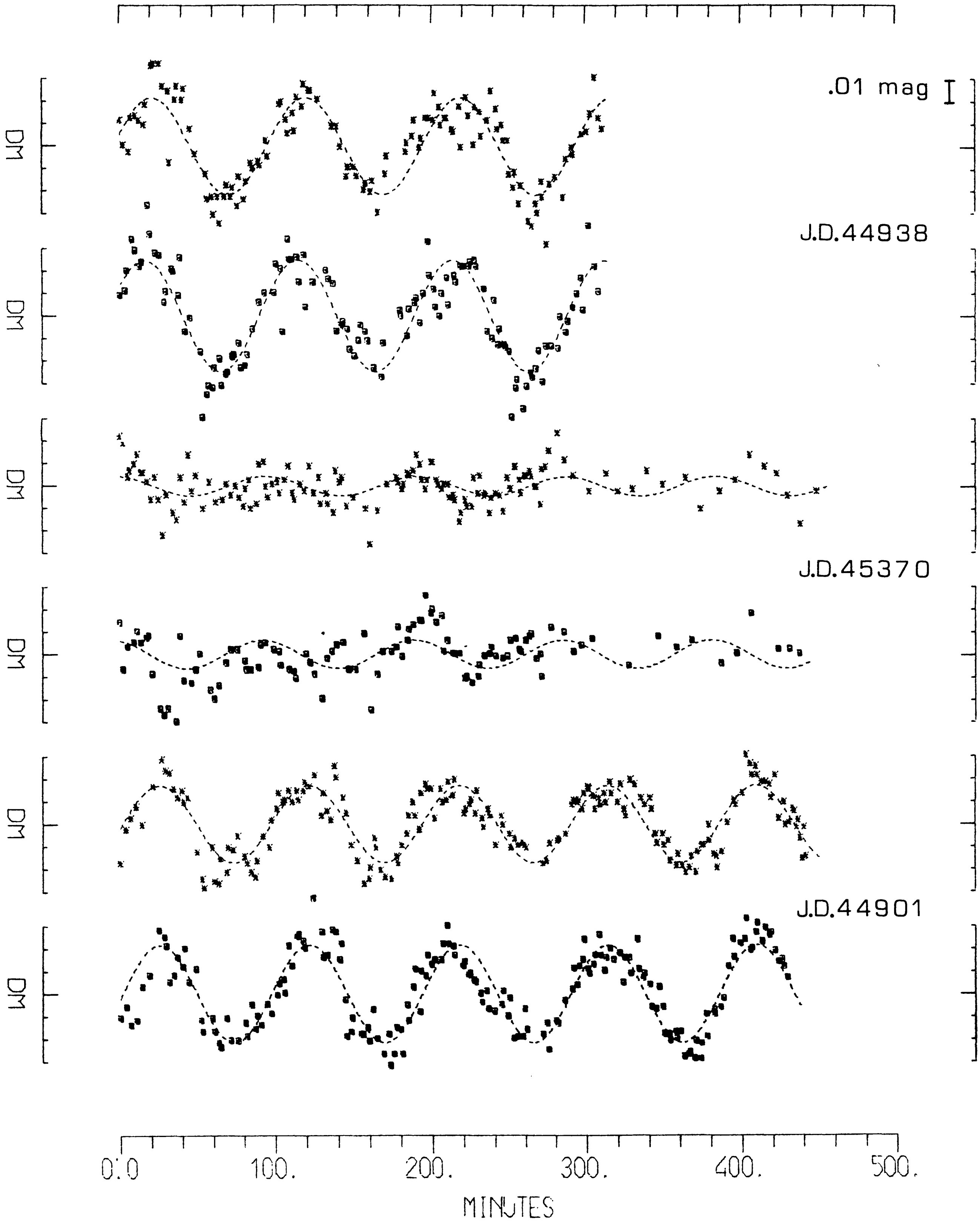

Fig. 1. Nightly plots of observations of Y Cam. The sine-curves have been calculated by means of the period P_0

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

Table 1. Timings of Min I and Min II

Helioc. J.D. 24...	n	$\sqrt{w}$	
37641.587	3995.5	1	pe
37760.587	4031.5	1	pe
37998.577	4103.5	1	pe
39940.594	4691.	1	v
41421.5068	5139.	10	pe
41540.517	5175.	2	v
41960.325	5302.	1	v
42396.6642	5434.	10	pe
42578.476	5489.	2	v
42803.2561	5557.	10	pe
42859.456	5574.	2	v
43216.4567	5682.	5	pe
43259.4335	5695.	10	pe
43517.284	5773.	1	v
44016.4274	5924.	10	pe
44223.031	5986.5	1	pe
44581.697	6095.	1	v
44902.3477	6192.	10	pe
44968.448	6212.	2	v
45054.402	6238.	1	v
45325.4740	6320.	10	pe
45345.3082	6326.	5	pe
45368.452	6333.	2	v

both the methods of chord bisection and of parabola fitting were used. Groups of observations around the bottom of minimum comprised in different time intervals were also checked. The incertitude of an epoch of weight $\sqrt{w}=10$ was estimated to be about half a minute.

b) Because of the apparent displacement of secondary minimum towards the following primary eclipse noted by Dugan (1924) we again performed a time determination of Min II using the Dugan's measurements. The result however was doubtful because of unfavourable distribution of observations which hindered the δ Sct fluctuation, comparable to the eclipse effect, from being subtracted and because of the moderate precision of observations compared to the very shallow secondary eclipse. Two normal epochs of Min II were then evaluated from the old photoelectric observations (Broglia and Conconi, 1973) dated JD 37608 to 37641 and JD 37757 to 37760 and one epoch for JD 37998. The values were derived by a least squares fitting to the observations of a parabola and a sinusoid representing the δ Sct variation, with the appropriate period. One timing more was derived on the basis of measurements obtained by Frolov et al. (Frolov, private communication). Because these observations cover one branch only of minimum, the epoch was derived by forcing the data to agree along the branch of synthetic light curves computed according to the derived photometric solutions. Moving the phase axis and the magnitudes axis of the Frolov data step by step, the best fit to theoretical light curves was obtained and the corresponding instant of secondary minimum was derived. The uncertainties of timing of secondary minima deduced by comparing B and V epochs and by comparing the values obtained with both methods described above are estimated to be ten times larger than for primary eclipse, i.e. $0^d.003$.

c) Thirty-three visual epochs of primary eclipse determined by Bortle (1973), Peter (1972, 1975), Locher (1973–1983), Germann (1978, 1982, 1983), and Kreiner and Mistecka (1980). One epoch was disregarded because of its large discordance. From the remaining determinations some normal timings were deduced, given in Table 1, where the corresponding weights $\sqrt{w}$ were assigned according to the estimated precision.

Orbital period and third body hypothesis

Adding the twenty three epochs listed in Table 1, where n is the cycle number according to the formula (1), to the instants referred to in the previous study, the material we now dispose of consists of 71 timings spanning over an interval of 93 years or ten thousand orbital revolutions. Following the previous finding an ephemeris was searched by a least squares fitting two since-curves to the observed epochs E, with adjustable amplitudes and phases but with preselected periods. A programme tested, step by step, useful pairs of values of periods. The best fit was obtained with the dominant period $P=32{,}570^d$ practically twice the other. The ephemeris was then derived:

$$E_c = 2424434{,}4806 + 3.30552340\,n + 0.1564\sin(0^\circ.011052E + 225^\circ.8) + 0.0452\sin(0^\circ.022105\,E + 65^\circ.49)\,. \quad (1)$$

In Fig. 2 the $O–C$ computed using formula (1) and using the linear term only are plotted. The period changes appear to be represented satisfactorily by the ephemeris (1). However the mean residual $0^d.0014$ of an epoch with $\sqrt{w}=10$ turns out to be four times larger than internal precision quoted before.

It is well known that regular period changes in a binary system can be explained as due to one or to more of the following mechanisms operating jointly:

1) Mass transfer between the components, or a mass loss from the system, or a change in the structure of one or both components.

2) Rotation of the line of apsides in an eccentric orbit.

3) Light time effect due to the orbital motion of the eclipsing binary around a third star.

A representation of the observed epochs of minimum by means of a parabolic term and a sine term, besides the linear one, is unsatisfactory. The sum of squares of the residuals derived is indeed four times larger than these computed according to formula (1). A secular mass loss or mass exchange phenomena, usually referred to a parabolic term, appears to be unlikely in Y Cam. This is supported also by the fact that no distortion has been observed in accurate photoelectric light curves, apart from the δ Sct oscillation. Both components moreover are some distance inside their Roche lobes (Fig. 3) and the photometric solutions do not require a third light contribution.

Of the three effects caused by the apsidal motion only the displacement of the secondary minimum in relation to 0.5 phase position could be observable in Y Cam. The δ Sct variation hinders greatly the study of the other effects: unequal length and distortion of the minima. The four epochs of secondary minimum listed in Table 1 are half-way between the adjacent primary ones within observational incertitude. Because these timings have an unfavourable distribution as they are practically confined to two dates, a further test was performed. All the epochs of primary and secondary minima were represented by means of the expression which gives the minimum when it is an apsidal motion (see Martynov, 1973, formula 9.34). A least squares fitting to minima was performed accordingly, varying the apsidal period step by step. The best fit gives a period larger than the interval covered by the measurements and an eccentricity $e=0.3$. The sum of squares

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

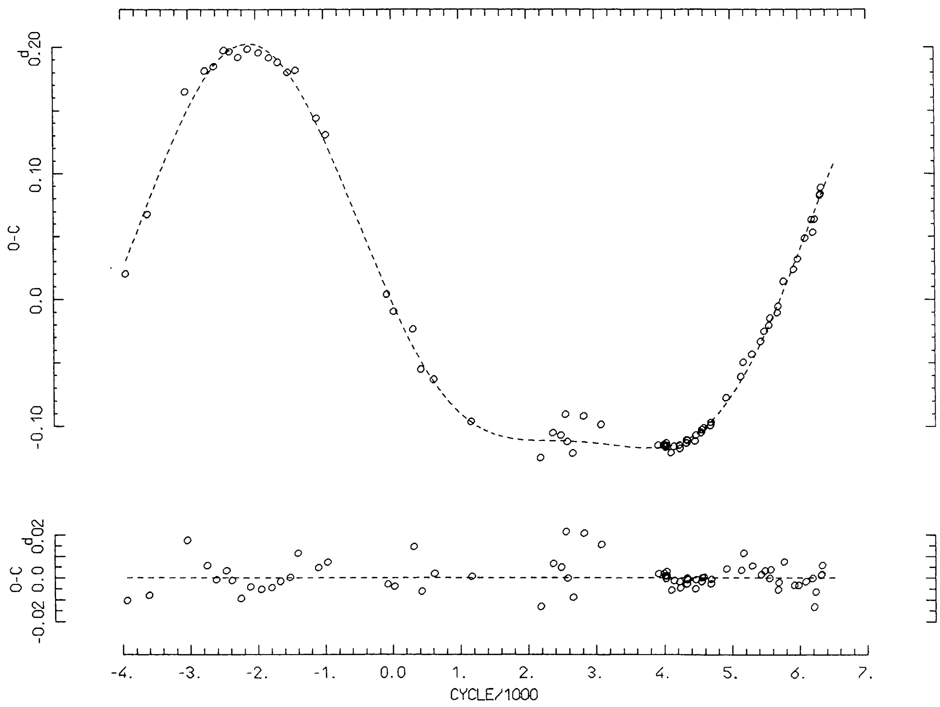

Fig. 2. Variation of the orbital period of Y Cam in the interval 1890–1983. The upper diagram depicts the trend of the $O–C$ computed by means of the linear part of formula (1), which is represented by the smooth curve. The residuals calculated by means of the whole ephemeris (1) are plotted at the bottom

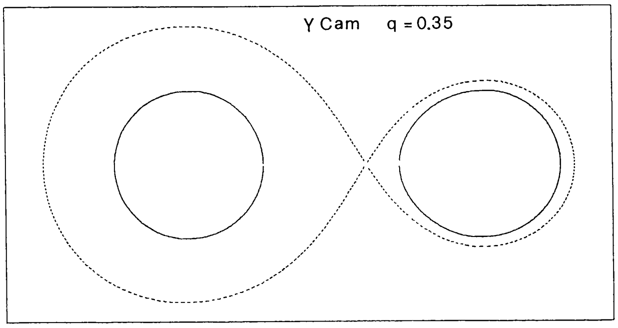

Fig. 3. Roche lobes of Y Cam in the orbital plane

of residuals turns out to be fifteen times larger than the value calculated by means of the formula (1). This result and the constant 0.5 P phase lag between primary and the few secondary minima disproves an apsidal motion as the unique factor responsible for the $O–C$ diagram.

We assume now that the residuals $O–C$ can be explained in terms of a third body. A least squares fitting to the epochs was tried accordingly (see Martynov, 1973, formula 9.43) and the best values were obtained: $a \sin i/c = 0^{d}.1697$; orbital period $P_3 = 31{,}850^{d}$; orbital eccentricity $e_3 = 0.56$. The corresponding sum of squares of residuals, however, turned out to be four times larger than the value obtained with the formula (1).

A further possibility is a combination of a light time effect in a triple system and a rotation of apsidal line of Y Cam moving in an eccentric orbit. Keeping the period P_3 of the third body and the apsidal period P_{aps} close to the values given in formula (1), a representation of data of Table 1 was searched using together the formulas (9.34) and (9.43) referred to above. Iterative differential corrections were computed for the zeroth epoch E_0, for period, eccentricity and longitude of the periastron of orbit of the binary system, for the light term and the longitude of periastron of the third body. The computations were repeated for a series of values of the orbital eccentricity and of the zeroth anomaly of the third body. The observations were represented satisfactorily with an accuracy like that obtained by means of the formula (1).

Assuming $P_{aps} = 89.2$ yr and $P_3 = 44.6$ yr the eccentricity of Y Cam turns out to be too great ($e \geqq 0.14$) and the mass of the third body gives the result $m_3 = 1.9\, m_0$. If instead we assume $P_{aps} = 44.6$ yr and $P_3 = 89.2$ yr we have: $e = 0.02$ and $m_3 = 5.5\, m_\odot$ (for $i_3 = 90°$).

Because for the masses of the components of Y Cam the values 2.33 and 0.50 $m_\odot$ are given (Giannone and Giannuzzi, 1974), the light of a third body should be easily noticeable, when computing photometric solutions.

We meet the same difficulty if the periods and the amplitude coefficients given in formula (1) are ascribed to a third and to a fourth orbiting body. The corresponding masses turn out in fact to be respectively $m_3 = 1.7$ and $m_4 = 6.7\, m_\odot$ (for $i_3 = i_4 = 90°$).

Photometric solutions

The elements of the system have been derived referring to Roche geometry. We intended moreover: a) to settle an upper limit for the light of a possible third body. b) The spectroscopic material on Y Cam is poor. Because the Wilson-Devinney (1971) method for solving light curves permits a mass-ratio to be evaluated, provided that the degree of contact is considerable, we thought useful to try an evaluation of q, although Y Cam is moderately distorted.

Normal points have been derived: altogether 364, and B and V measurements were used together when solving. The 1977 updated version of Wilson computing code was used, operated in mode 0 (Leung and Wilson, 1977). The differential correction program was used. The following parameters were kept fixed at assumed values: gravity coefficients $g_1 = g_2 = 1$; albedos $A_1 = A_2 = 0.5$; darkening

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

Table 2. Photometric elements of Y Cam

$i = 86°.0$	$L_{1V} = 0.934$	$r_{1,pt} = 0.255$	$r_{2,pt} = 0.281$
$q = 0.35 \pm 0.05$	$L_{2V} = 0.066$	$r_{1,s} = 0.252$	$r_{2,s} = 0.251$
$\Omega_1 = 4.343$	$L_{1B} = 0.961$	$r_{1,b} = 0.254$	$r_{2,b} = 0.269$
$\Omega_2 = 2.732$	$L_{2B} = 0.039$	$r_{1,pl} = 0.250$	$r_{2,pl} = 0.244$

coefficients $x_1 = x_2$ equal to 0.8 and to 0.6 respectively for B and V colours; temperatures $T_1 = 7300$ K and $T_2 = 4600$ K.

To prevent difficulties in convergence arising from correlations between parameters, a grid of solutions was performed with assumed values for the mass-ratio $q = m_2/m_1$ ranging from 0.2 to 0.6 at covenient steps. Each solution corrects for the parameters: inclination i, both surface potentials Ω_1 and Ω_2, luminosities of primary and secondary components L_1 and L_2. Moreover the solutions were calculated by separating the most correlated parameters in two subsets (Wilson and Biermann, 1975): i, Ω_1, Ω_2 and L_1, L_2. The adjusted parameters of the best solution (giving the minimum in the sum S of squares of residuals) are listed in Table 2. The incertitude assigned to q corresponds to an increase in S of about five percent over the value of the adopted solution.

To experiment on a possible third light in the system and to avoid correlation difficulties, solutions were then calculated starting from the elements listed in Table 2, after a given third light was added to the normal points. The derived S becomes five percent larger than S of the best solution when the assumed third light is 0.025 (with $L_1 + L_2 + L_3 = 1$). In other words on the basis of available photometry 0.025 is the upper limit for the light of a possible third component in Y Cam.

Frequency analysis of the δ-Scuti pulsation

The new observations confirm that the behaviour of the δ Sct oscillation is as depicted by previous measurements. The light curves are almost sinusoidal in shape although slightly distorted on some nights. On visual inspection the instantaneous period appears to change a little in relation to the average length of a cycle. According to Frolov et al. (1980) the period was calculated to be $P = 0^d.066458$, five percent greater than the value derived previously. The amplitude changes very little during consecutive cycles (Fig. 1), but undergoes certain variations from night to night ranging from some hundredths of magnitude to noise level. Thus a possible modulation period has to be larger than one day.

To settle these questions all available photoelectric data have been analysed, including the Frolov et al. measurements. Because the observations are spread along a twenty-two year interval, the aliasing problems are particularly severe when analysing with spectrum power techniques. Moreover some δ Sct stars are known to have non-constant periods. We performed therefore the analysis in two steps. First we tested for the constancy of the main oscillation along the 22-year interval we now dispose of. The nightly sets containing a complete oscillation at least were studied. To obtain a more uniform coverage in studying the fundamental period, observations during primary eclipses, where δ Sct changes are outpowered by eclipse changes, were considered too. Eclipse and proximity effects were removed from individual observations

Table 3. Times of maximum light of the δ-Sct star

Helioc. J.D. 24...	n	O–C X 1000 d
37375.455	0	- 3
37380.376	74	0
37382.306	103	3
37398.388	345	2
37608.391	3505	0
37641.286	4000	- 2
37696.313	4828	- 2
37699.307	4873	1
37757.322	5746	- 2
37760.370	5792	-10
37764.369	5852	1
37765.493	5869	- 4
37785.505	6170	4
37998.502	9375	4
38053.319	10200	- 6
38314.375	14128	5
38400.309	15421	9
38403.285	15466	- 5
38760.303	20838	3
38765.290	20913	6
44222.178	103024	- 2
44224.176	103054	2
44901.439	113245	- 3
44911.403	113395	- 8
44938.396	113801	4
44940.250	113829	- 3
44999.395	114719	- 6
45028.378	115155	2
45370.300	120300	0
45383.397	120497	5

on the basis of the photometric solutions. Then the δ Sct pulsations observed during eclipses were normalized as if all the pulsating star was visible. A sine-curve was then fitted separated for B and V data of each night, changing the period step by step to find the best fit. The corresponding mean epoch of maximum light was derived at last.

To derive the correct period of main pulsation avoiding errors in cycle counting number n, we computed as follows. Given a period, the values of n for the normal epochs were derived and the corresponding sum of squares of residuals S was calculated. The period was then changed by a convenient step and the computation repeated until a minimum for S was found. We obtained the ephemeris for the pulsation with larger amplitude:

$$\text{Max helioc. JD} = 2437375.458 + 0.066457537\, n \qquad (2)$$

In Table 3 normal epochs, cycle numbers n and residuals pertinent to the above ephemeris are listed, The period P_0 appears to be stable along a twenty-two year interval or 120000 cycles. The mean residual 0.004 days relies in part on observational incertitude and in part on the influence of secondary pulsation, which has a period very close to P_0 and a smaller amplitude, as reported later. This fact justifies the procedure used to derive P_0.

Corrections to the times of observations due to the light time effect of orbital motion were evaluated to be negligible.

An analysis to view other periods was then performed using method of fitting sinusoids by least squares to measurements. A window spectrum of a noiseless constant signal sampled according to the instants of observations gave evidence of severe aliasing difficulties, because of the unfavourable distribution of data and

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

the insufficient fractional coverage of the variability. Therefore only the data comprised in two relatively short intervals, JD 37582–760 (Group I) and JD 44901–45028 (Group II) were analysed separately, disregarding the measurements performed in the deepest part of primary eclipse. There the corrections for the eclipse and the corresponding normalisation are much more ticklish, although the determination of the instants of δ Sct maximum is practically unbiased. Moreover the frequency grid needed (typically the inverse of the length of a data block) is much smaller than for the complete 22 year interval, with a notable saving in computer time. Periodograms were derived separately for B and V data of each set.

The large alias structure associated to P_0 hinders any period near P_0 from being detected (see Fig. 4). Therefore the analysis was performed by fitting a double sine-curve to measurements. The count-cycle period P_0 given in formula (2) was kept fixed and P_1 was changed step by step to find the best fit. The corresponding reduction factor: $RF = 1 - S_1/S$, where S and S_1 are the sums of squares of residuals before and after the fitting of sine-curves to data, are given in Fig. 4 for one set of data. It can be seen in the bottom panel that the larger peak does not correspond exactly to the count-cycle period P because of alias effect. Moreover when the double sinusoid is subtracted from measurements no significant peaks remain in the new calculated periodogram (top panel of Fig. 4).

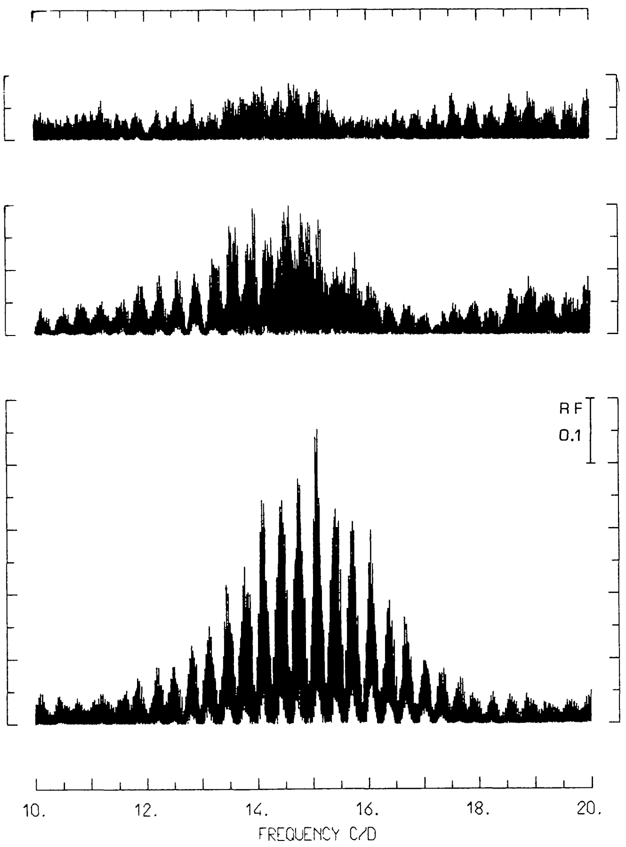

Fig. 4. Periodogram of the group I, B data (bottom). Periodograms after prewhitening of component P_0 (middle) and after the P_0 and P_1 sine-curves have been subtracted (top)

The results of the analysis are given in Table 4. In Fig. 5 the same data analysed as depicted in Fig. 4 (group I, B) are folded modulo the periods P_0 and P_1, after the sine-waves respectively with periods P_1 or P_0 have been removed. The two sine-components clearly appear in spite of certain observational noise. It is of interest to note that the shorter period has the larger amplitude.

Because the ratio of two periods $P_0/P_1 = 0.972$ cannot be identified with ratios of radial pulsators, non radial pulsations in Y Cam are proposed. The analysis gives evidence of a small change of P_1 from one season to the other. We have some doubt if this small frequency splitting is real or if it is due to an observational incertitude. According to the computed mean residuals listed in Table 4 the data precision in the second group is a little inferior to the first one. Moreover the amplitude ratios of two pulsations, equal for B and V data of first group, are different in the second one. Only further observations can help to clear up the question of the stability of P_1.

Discussion

The following comments can be made:

a) The four epochs of secondary minimum follow the primary ones closely in phase and the orbit of Y Cam can be assumed to be circular when computing the photometric elements. The large periodic terms in the O–C diagram cannot be due only to apsidal advance. At most, to give acceptable residuals for the shallow secondary minima, the orbital eccentricity should be very small.

b) The long series of observed moments of minimum is represented satisfactorily by means of a double sine-curve (Fig. 2). However, because the interval covered by observations is of the same order as the periods derived, a further long series of timings is necessary to prove that the supposed periodicities are real. For most eclipsing systems it has often happened that a supposed periodic behaviour was later disproved or was followed by period jumps (Frieboes-Conde and Herczeg, 1973).

Table 4. Results of periodogram analysis of the δ-Sct star

Group	Measurement number	P_0 (days)	A_0 (mmag)	P_1 (days)	A_1 (mmag)	mean residual (mmag) (1)	(2)
I,B	413	0.066457	14.5	0.068542	7.2	10.2	6.5
I,V	407	.066457	12.2	.068545	6.0	9.7	6.8
II,B	531	.066457	16.2	.068216	9.6	15.8	7.9
II,V	537	.066457	11.9	.068216	10.3	13.5	7.9

(1) and (2) are the mean deviations of a single observation before and after the two sine-curves with amplitudes A_0 and A_1 have been subtracted.

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

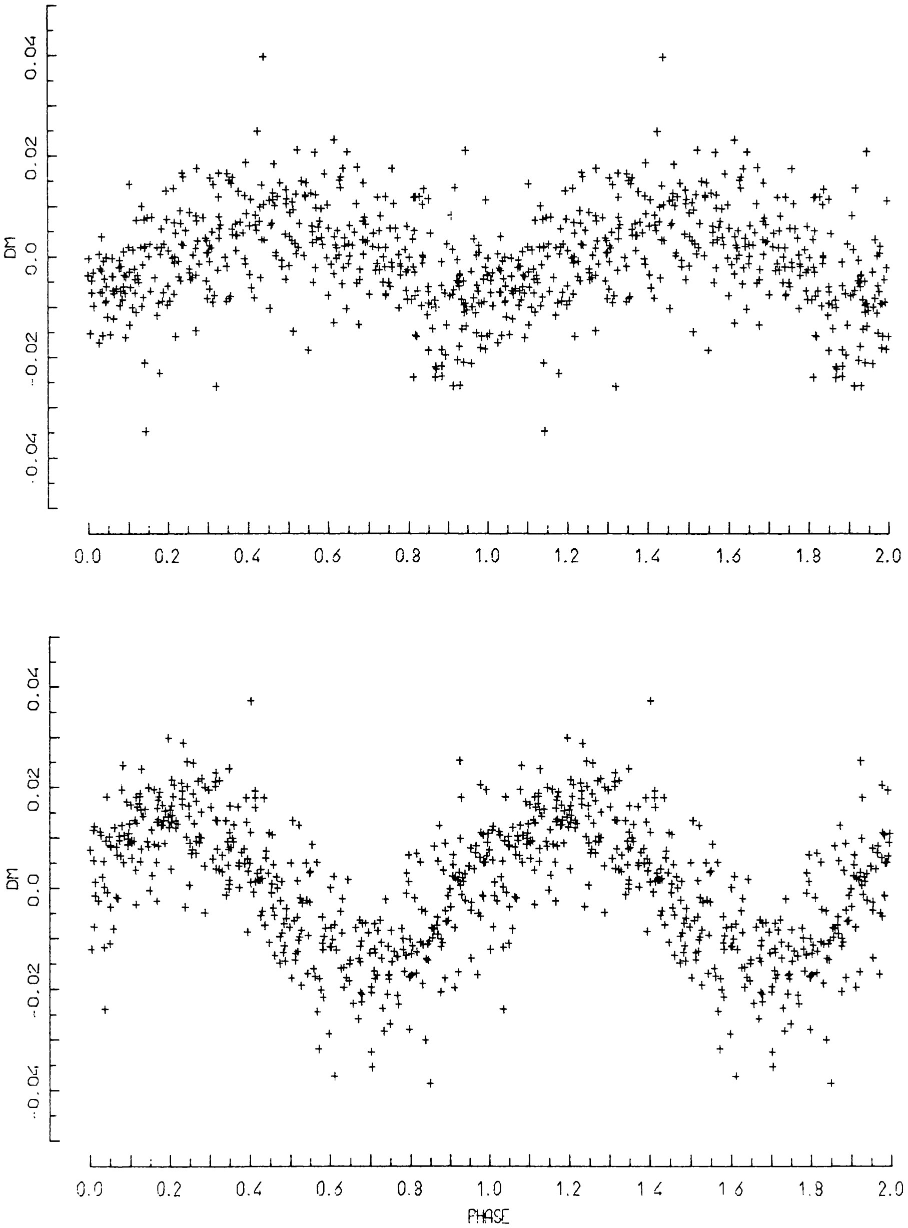

Fig. 5. Folding of single observations using the period P_1 after the sine-wave with period P_0 has been subtracted (top), and using the period P_0 after the sine-wave with period P_1 has been removed (bottom)

c) A satisfactory representation of the O–C diagram can be obtained combining an apsidal motion of the binary system moving in an orbit with small eccentricity and a light time effect caused by a third body, or assuming a quadruple system. In both cases unreasonably high values for the masses of the third and fourth bodies are derived: the photometric solution does settle an upper limit to the light of companions much smaller than the values expected for the massive calculated third and fourth components. The present much richer material carries us on this point to the same disappointing conclusions as obtained by Plavec et al. twenty-two years ago (Plavec et al., 1961). Moreover the data we now dispose of give evidence of a second period: therefore a more complicated model is required for the Y Cam system.

d) It is possible to suppose that the effects of rotational or tidal distortion on a pulsating star equilibrium configuration due to a close companion and the mutual heating of the components may influence the pulsation properties. However the interaction of pulsation and duplicity effects has met a great deal of resistence (Fitch, 1980). Because of these effects the pulsation should vary over the stellar surface in a zonal way. Moreover gas streams and mass transfer may also perturb the outer layers of a pulsating star in a more complicated manner. All these factors can be at work in a given system, with a different weight: observations however can help to evaluate their relative importance.

The B and V light curves of Y Cam appear to be stable from one season to the other (Broglia and Marin, 1974). The photometric perturbations and the mutual heating are moderate, as depicted by the terms of the usual Fourier representation of out of eclipse light changes ($A_1 = -0.004$, $B_1 = 0.004$ in B filter and $A_1 = -0.006$, $B_1 = 0.004$ in V band). It is therefore reasonable to suppose that the δ Sct pulsation is little disturbed by gas streams or mass transfer or radiative interaction.

Assuming a synchronism between rotation and orbital motion, the rotational velocity of Y Cam turns out to be: $V_{\rm rot} = 46\,{\rm km\,s^{-1}}$

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...138..443B

(Frolov et al., 1982). Referring to the correlation between light amplitudes and rotational velocities of δ Sct stars given by Breger (1982) Y Cam appears to be situated near the border of the region where large and small amplitude radial pulsator coexist. Because the few other non radial pulsators have rotational velocities comprised between 100 and 25 km s^{-1}, the position of Y Cam in the above diagram probably has no particular meaning.

Y Cam and δ Del (Fitch, 1980; Baglin et al., 1973) conform to the correlation between $V \sin i$ and period ratio proposed for non radial pulsators by Pena and Warman (1979). The following stars can be considered now: HR 1170 ($V \sin i = 100$ km s^{-1}; $P_0/P_1 = 0.92$), HR 7331 (59; 0.94), Y Cam (46; 0.97), δ Del (41; 0.97), 1 Mon (25; 0.98). The regression coefficient of linear relation between $V \sin i$ and P_0/P_1 turns out to be 0.95; when the ratio of periods tends to 1 and the two pulsations merge into one, $V \sin i$ tends to zero.

The photometric solutions show that the δ Sct component is moderately distorted by the companion (Fig. 3) and the orbit can be assumed to be circular. According to Fitch (1976) if a pulsating star moves in an eccentric orbit one should expect all non-radial modes to be damped out by the continuously changing tidal deformation. On the contrary in a circular orbit a steady situation should settle down after a sufficient time and the non-radial modes should grow to a significant level. This seems to be the case of Y Cam, where the period of the larger pulsation appears stable over at least an interval of 120,000 cycles. On the basis of the present photometry however it is likely that the pulsation with smaller amplitude has not yet attained a stable situation.

Acknowledgement. This work was supported in part by the Consiglio Nazionale delle Ricerche

References

Baglin, A., Breger, M., Chevalier, C., Hauck, B., Le Contel, J.M., Sareyan, J.P., Valtier, J.C.: 1973, *Astron. Astrophys.* **23**, 211

Bortle, J.: 1973, 1973, *IBVS* **795**

Breger, M.: 1982, Publ. Astron. Soc. Pacific **94**, 845

Broglia, P., Conconi, P.: 1973, *Publ. Oss. Astron. Milano-Merate* No. 27

Broglia, P., Marin, F.: 1974, *Astron. Astrophys.* **34**, 89

Dugan, R.S.: 1924, *Princeton Contr.* No. 6

Fitch, W.S.: 1976, Multiple periodic variable stars, Reidel, Dordrecht, p. 167

Fitch, W.S.: 1980, in *Nonradial and Nonlinear Stellar Pulsation*, ed. H.A. Hill, W.A. Dziembowski, Springer, Berlin, Heidelberg, New York, p. 7

Frolov, M.S., Pastukhova, E.N., Mironov, A.V.: 1982, *IBVS* 2179

Frolov, M.S., Pastukhova, E.N., Mironov, A.V., Mashkalev, V.G.: 1980, *IBVS* 1894

Germann, R.: *BBSAG Bull.* 1978, 36; 1982, 58, 59, 60; 1983, 64

Giannone, P., Giannuzzi, M.A.: 1974, *Astrophys. Space Sci.* **26**, 289

Leung, K.C., Wilson, R.E.: 1977, *Astrophys. J.* **211**, 853

Kreiner, J.M., Mistecka, A.: 1980, *Astron. Nachr.* **301**, 327

Locher, K.: *BBSAG Bull.* 1973, 8, 12; 1974, 15; 1975, 20, 21, 24; 1976, 27; 1977, 33, 35; 1979, 43; 1980, 49; 1981, 52, 56, 57; 1982, 58, 59, 60; 1983, 65

Martynov, D.Ya.: 1973, in *Eclipsing Variable Stars*, ed. V.P. Tsesevich, *IPST Astrophys. Lib.*, Jerusalem

Pena, J.H., Warman, J.: 1979, *Astron. J.* **84**, 1046

Peter, H.: *BBSAG Bull.* 1972, 4, 5, 6; 1975, 23

Plavec, M., Smetanova, M., Peknyz, Z.: 1961, *Bull. Astron. Czech.* **12**, 177

Wilson, R.E., Biermann, P.: 1976, *Astron. Astrophys.* **48**, 349

Wilson, R.E., Devinney, E.J.: 1971, *Astrophys. J.* **166**, 605

© European Southern Observatory • Provided by the NASA Astrophysics Data System