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THE FOUR BODY SYSTEM Y Cam?

The eclipsing binary system Y Cam (V=$10^m50-12^m24-10^m60$; P=3^d31; Sp:A9IV + (K1)) was discovered by Ceraski (1903). The photoelectric light curves were obtained in B and V filters by Broglia and Marin (1974). The authors state that the secondary minimum is at phase 0.5. Broglia and Conconi (1984) concluded that the long series of observed moments of minimum is represented satisfactorily by means of a double sine-curve that is "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 mass of the third and fourth bodies are derived (the photometric solution does settle an upper limit to the light companions much smaller than the values expected for the massive calculated third and fourth components)".

The analysis of the O−C diagram for Y Cam calculated with the elements:

$$\text{Min I} = \text{JD}_{\odot}2424434.4806 + 3^d30552340 \times \text{E}$$

suggests that third and fourth bodies moving in independent eccentric orbits are present in the system (see Figures 1 and 2). That is why we represented the O−C diagram by a sum of two independent parts:

$$O-C = \frac{a_3 \sin i_3}{c}(1-e_3\cos E)\sin(v+\omega_3) + \frac{a_4 \sin i_4}{c}(1-e_4\cos E')\sin(v'+\omega_4),$$

where v and E are true and eccentric anomalies respectively, c is the speed of light, and parameters of the binary system relative to the mass centres of the triple and the quadruple systems are in usual designations. The parameters of long period orbits were determined graphically by Woltier's method and improved by a least squares fitting of a sum of two theoretical curves to the observed epochs E (Table 1).

Table 1
The parameters of the long period orbits
in the Y Cam system

$a_3 sin i_3$=(5.22±0.12) 10^8km	$a_4 sin i_4$=(42.42±0.14) 10^8km
e_3 =0.600±0.021	e_4 =0.475±0.03
ω_3 =87°.5±3°.2	ω_4 =77°.4±0°.4
P_3=(39.4±0.3) years	P_4 =(86.03±0.08) years
T_3=JD$_{\odot}$2419177.96±0.14	T_4=JD$_{\odot}$2417134.64±0.08

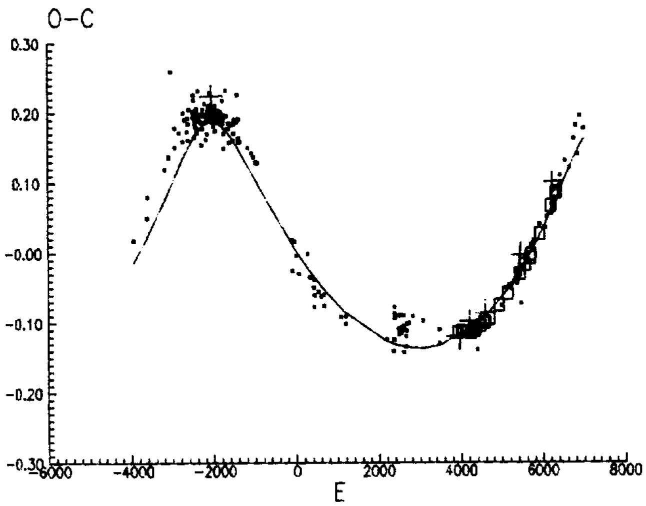

Figure 1
O−C for Y Cam (• - visual and photographic Min I, □ - photoelectric Min I, + - Min II, the solid line is the theoretical curve of the body on elliptical orbit, calculated with the fourth body's parameters from Table 1).

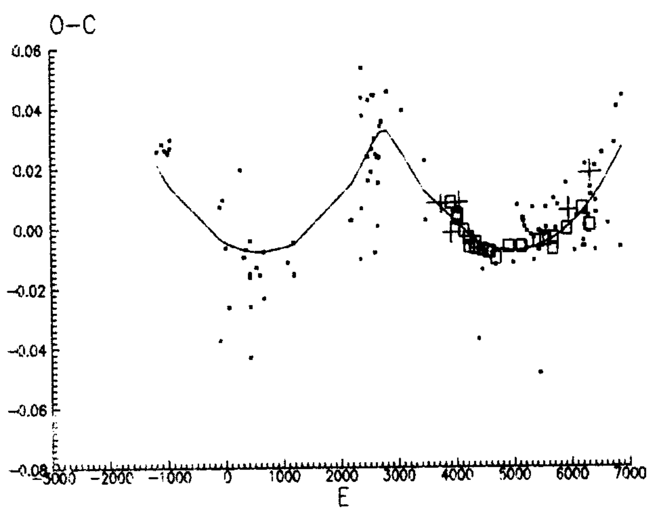

Figure 2
O−C for Y Cam, calculated with the same elements as in Figure 1, but with the values corresponding to the theoretical curve with the fourth body's parameters from Table 1 subtracted.

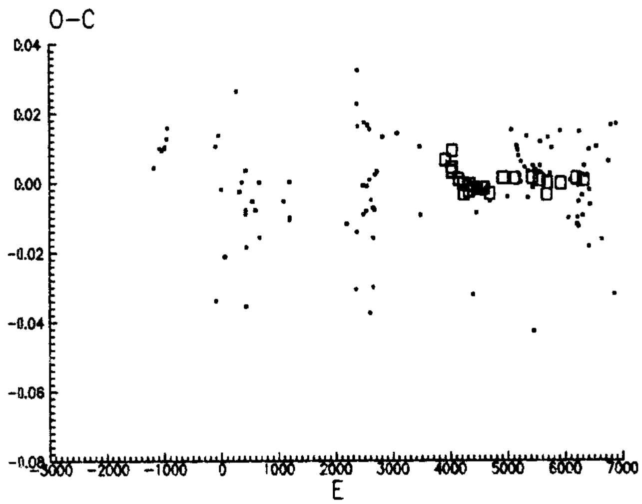

Figure 3
(O−C) for Y Cam, calculated with the same elements as in Figure 1, but with the values corresponding to the theoretical curve with the third and fourth bodies' parameters from Table 1 subtracted.

We solved the problem of the approximations by the third and fourth bodies for the 131 latest primary minima (Figure 2), because for the earlier 120 primary minima the residuals between O−C and values corresponding to the theoretical fourth body in an elliptical orbit vary very irregularly. It is probably caused by great errors in the determination of the moments of primary and secondary minima in early times. We assigned larger weight to the photoelectric observations as compared with the photographic and visual ones. The residuals in O−C after the approximations by the third and fourth bodies are nearly zero (Figure 3).

The derived parameters of the long period orbits enable us to compute a lower limit for the masses of the third and the fourth bodies. Supposing the main component mass $\mathcal{M}_1=1.53\mathcal{M}_\odot$ Svechnikov and Taidakova, 1984) and computing the secondary component mass from the mass function f(m)=0.015$\mathcal{M}_\odot$ (Struve et al., 1950) we have: $\mathcal{M}_3>0.55\mathcal{M}_\odot$, $\mathcal{M}_4>6.04\mathcal{M}_\odot$.

From the solution of the light curves in the filter V by differential correction method (Khaliullina and Khaliullin, 1984) using our observations and Broglia and Marin (1974) data, we obtained that the third light is present in the system: $L_3=0.10$ (Mossakovskaya, 1991). Assuming that only one main sequence star gives this third light, we can estimate its mass, using the mass-luminosity law: $L\sim\mathcal{M}^{3.99}\rightarrow\mathcal{M}_{max}=0.94\mathcal{M}_\odot$. That is, the photometric data do not contradict the assumption that a main sequence star with the mass $\mathcal{M}_3$>0.55$\mathcal{M}_\odot$ is present in the system, but do not agree with the presence of a star with the mass $\mathcal{M}_4$>6.04$\mathcal{M}_\odot$. We can reconcile the obtained results only if the fourth body is a relativistic object. Of course this is but a hypothesis. The system Y Cam needs continued photoelectric observations of the moments of both primary and secondary minima.

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