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A study of the period of U Ophiuchi

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Abstract. With the available photoelectric times of minima, the variations in the orbital period of U Oph can be interpreted in terms of the presence of a third body.

Key words : eclipsing binaries—period changes—light time effect

1. Introduction

U Oph is an interesting eclipsing binary for many reasons : (i) both components belong to the same spectral type, B5n + B5n (Koch *et al.* 1963); (ii) it is a detached system; (iii) no conspicuous anomalies in light and radial velocity curves have been detected; and (iv) the masses of the components have been determined accurately. The variation in the period however has not been precisely measured. So far visual and photographic times of minima have been used to estimate the period variations. One however obtains a more precise value if only the photoelectric minima are used. This we proceed to do in this paper.

At present more than 30 photoelectric times of minima observed more or less continuously over a period of about 28 yr are available. Therefore we can get a more reliable picture of the period variation in U Oph than what so far has been obtained.

2. Light-time curve

Table 1 contains all the times of photoelectric minima available in the literature. The $O - C$ curve shown in Figure 1 is based on the light elements given by Frieboes-Conde & Herczeg (1973). An inspection of the diagram reveals that the secondary minima points follow the same trend as the primary points. Hence, the possibility of apsidal motion can be safely ruled out. The observed displacement of secondary minimum from half-phase values on certain occasions may sometimes give a false impression of apsidal motion in the system. An alternative explanation for this displacement of secondary minimum would be that either the secondary or the primary eclipse light curve is subject to slight asymmetry.

Table 1. Photoelectric times of minima of U Ophiuchi

Sl No.	*JD*⊙	$(O-C)_{\mathrm{I}}^{**}$	$(O-C)_{\mathrm{II}}^{\dagger}$	Reference
1.	243 3067.468	$+0^{\mathrm{d}}.00751$	$-0^{\mathrm{d}}.00912$	Plavec *et al.* (1960)
2.	3067.471	+0.01051	−0.00612	,,
3.	3436.4871	+0.01091	−0.00640	,,
4.	3753.503	+0.00878	−0.00912	,,
5.	3753.506	+0.01178	−0.00612	,,
6.	4900.808	+0.01041	−0.00961	,,
7.	9275.313	+0.00200	−0.02610	Frieboes-Conde & Herczeg (1973)
8.	9649.359	+0.00027	−0.02853	,,
9.	8196.7862	+0.00746	−0.01865	Koch and Koegler (1977)
10.	8201.8160	+0.00522	−0.02090	,,
11.	8227.815 II	+0.00539	−0.02078	,,
12.	244 0070.372	−0.00010	−0.02968	Frieboes-Conde & Herczeg (1973)
13.	0075.404	−0.00014	−0.02972	Pohl & Kizilirmak (1970)
14.	0392.4230	+0.00083	−0.02934	Popovici (1970)
15.	0419.260	+0.00032	−0.02989	Frieboes-Conde & Herczeg (1973)
16.	0724.533	−0.00330	−0.03408	van Gent *et al.* (1978)
17.	0788.276	+0.00062	−0.03028	Frieboes-Conde & Herczeg (1973)
18.	0831.4001*II	+0.35245	+0.32146	Popovici (1971)
19.	0843.3929*	−0.23483	−0.26584	,,
20.	0845.304	−0.00108	−0.03208	Kizilirmak & Pohl (1971)
21.	1117.8769 II	+0.00340	−0.02811	Scarfe *et al.* (1973)
22.	1133.8082	−0.00006	−0.03160	,,
23.	1135.4868	+0.00119	−0.03035	Pohl & Kiziiirmak (1972)
24.	1204.258	+0.00128	−0.03030	,,
25.	1450.8271	+0.00080	−0.03132	Becker *et al.* (1975)
26.	1461.7332 II	+0.00416	−0.02798	,,
27.	1466.7653 II	+0.00423	−0.02792	,,
28.	1476.8293	+0.004172	−0.02801	,,
29.	1494.4392	+0.001960	−0.03025	Kizilirmak & Pohl (1974)
30.	1866.809	+0.00137	−0.03153	Scarfe *et al.* (1973)
31.	2217.3754	+0.00285	−0.03069	Pohl & Kizilirmak (1975)
32.	2621.6212	+0.00872	−0.02557	Koch & Koegler (1977)
33.	2942.8337 II	+0.00982	−0.02506	Scarfe & Barlow (1978)
34.	3319.3964	+0.00877	−0.02680	Tufekcioglu (1977)
35.	3334.4917	+0.00798	−0.02763	,,
36.	3335.3291 II	+0.00670	−0.02891	,,
37.	3340.3622 II	+0.00777	−0.02785	,,
38.	3345.395 II	+0.00854	−0.02709	,,
39.	3356.2978	+0.00860	−0.02704	,,
40.	3361.3304	+0.00917	−0.02648	,,
41.	3366.3629	+0.00964	−0.02602	,,

*not included in the analysis.

**based on light-elements given by Freiboes-Conde & Herczeg (1973).

†based on light-elements given by Koch *et al.* (1963).

As the $O-C$ curve resembles sine curve, we assume that it is produced by the motion of the eclipsing system about the barycentre of the triple system. From Figure 1 one can get approximately the period as 27.55 yr. How far the eclipsing period used in the computations of time residuals in the present study is reliable can be seen only after we have a complete coverage of the light-time curve which will take about 25 years henceforward.

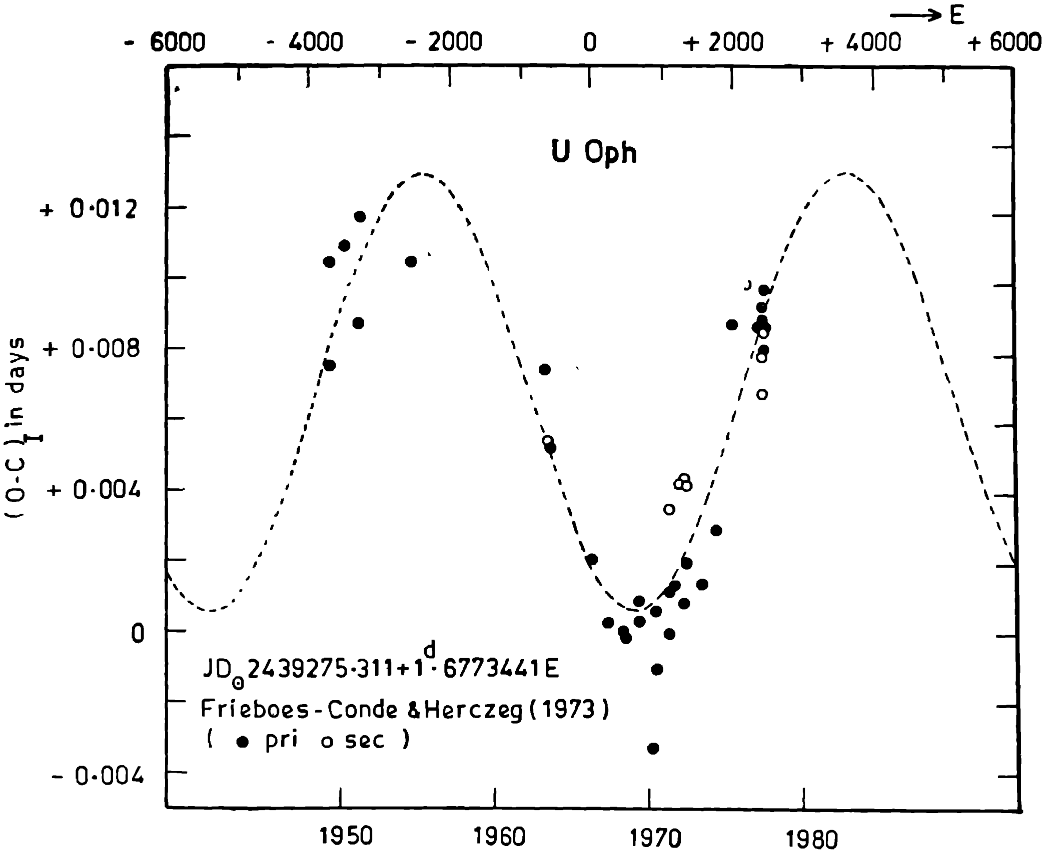

Figure 1.

It may be noted that unless through some unique technique we know the correct binary period, it is quite difficult to get the proper third-body period. For example, if the third component is bright enough to form a visual system such as 44i Boo, orbital elements of visual binary will provide us with the correct eclipsing period. In case the third body is invisible or unresolved, the eclipsing period could be obtained through astrometric studies. On the other hand if the eclipsing pair is a member of a quadruple system we can easily pin-point the appropriate eclipsing period as has been done in the case of SW Lac (Panchatsaram & Abhyankar 1981) and RT Per (Panchatsaram 1981). So, with the currently available light-time curve of U Oph it is quite difficult to judge whether it is caused by a truly triple or quadruple system. This problem of multiplicity of the system can be solved only when observations covering a complete orbital period become available.

Assuming that U Oph is truly triple and using the above third body orbital period, a least squares solution yields

$$(O-C)_{\mathrm{I}} = \underset{\pm 4}{0.0068} - \underset{\pm 2}{0.0062} \sin \frac{360}{6000}\,[E + \underset{\pm 1.2}{904.5}] \qquad \ldots(1)$$

The curve in Figure 1 represents equation (1).

3. Mass of third component

Table 2 illustrates the probable masses for various third-body orbital inclinations of the third component obtained through Fourier coefficient in equation (1). The mass of the third component turns out to be much smaller than previous estimates (Frieboes-Conde & Herczeg 1973; Koch & Koegler 1977). It is perhaps the only spectroscopic eclipsing binary for which we have a few reliable determinations of γ-velocity at different epochs. For $i = 30°$ (i represents the third-body orbital inclination with the plane of the sky) the amplitude of the radial velocity curve is 2.3 km s^{-1} for the sine curve represented by equation (1). As the predicted amplitude is rather small and comparable with the errors involved in the determination of the γ-velocity itself, it is difficult to get conclusive evidence as to the presence of third body from the considerations of available γ-velocities.

Table 2. Mass of the third component of U Ophiuchi

$a \sin i$	P	$f(m)$	i	Mass of third body (M_3)
A.U.	yr	$M_\odot$	deg	$M_\odot$
			90	0.57
1.08	27.55	0.0017	60	0.66
			30	1.18

Note : The mass of the eclipsing pair, used in the above computation is 9.8 $M_\odot$ which is due to Clements & Neff (1979).

4. Concluding remarks

With the observations available at present the $O - C$ curve of U Oph can be interpreted in terms of the presence of a third body. Whether or not the system is truly triple can be known only about 25 yr hence. In the meantime, as we have been advocating, astrometric studies, though time-consuming, can be planned on a systematic basis wherever possible for all the eclipsing binaries along with routine photoelectric minimum time observations to study in detail the cause for the observed period variations.

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