EVIDENCE FOR SMALL, SHORT-TERM PERIOD CHANGES IN RZ DRACONIS

by

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Abstract

An intensive series of timings of minima reveals a quasi-periodic O-C curve. Explanations in terms of a third body or apsidal motion seem unlikely, and mass exchange may be the cause. The importance of timing the secondary minima is stressed.

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The eclipsing binary RZ Dra has a period of $0^d.55$ and a primary eclipse $0^m.9$ deep, hence it is an attractive object for visual observers who time minima. It is classified as a β Lyrae-type because of the A5 spectral class, although the period is very short for this type. In recent years an unusually large number of minima have been timed (40 minima in an interval of 700 days), and the O-C curve for this interval, Fig. 1., indicates an interesting pattern of period changes. The large number of timings makes it possible to estimate the accuracy of the observations; it is clear that the O-C changes are real and not due to scatter in the observations. In fact, Mallama (1974) indicates that the standard deviation of a single visual minimum of a star with this type of light curve is about $0^d.005$, or 1/5 of the full range of O-C's in Fig. 1 and 1/2 of the range represented by the smooth curve.

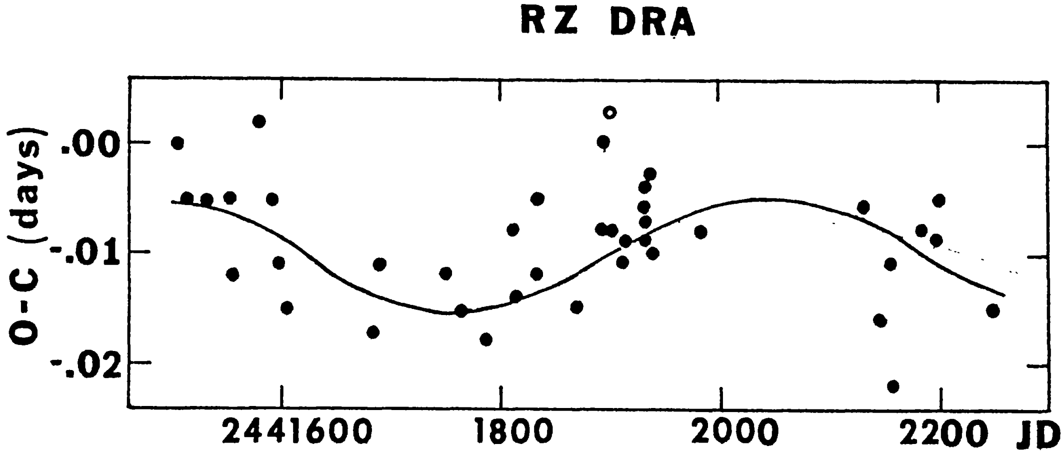

Figure 1. RZ Draconis. O-C residuals vs. Julian Date. The sine curve was fitted to the observations by hand and is believed to be a statistically significant deviation from a straight line in light of the expected uncertainty of the measurements. The open circle represents an uncertain datum.

If the O-C curve is sinusoidal or quasi-sinusoidal, and strictly periodic, the O-C changes could be due to motion of the eclipsing pair around a third body or could be due to precession of the line of apsides. The possibility of motion around a third body seems unlikely for the following reasons. Consider the mass function for three bodies:

$$f(M) = \frac{(a_{12} \sin i)^3}{P^2} = \frac{M_{12} \sin^3 i}{\alpha(1+\alpha)^2}, \qquad (1)$$

where a_{12} is the semi-major axis of the orbit of the eclipsing binary around the third body, i is the inclination of this orbit, P is the period of this orbit, M_{12} is the combined mass of the eclipsing binary, $\alpha = M_{12}/M_3$, and M_3 is the mass of the third body. Since the value of M_{12} is uncertain, the author estimated the mass as follows: Struve (1946) gives the spectral type of the hot component as A5; and his determination of a_1 = 0.79 x 10^6km is evidence that the A5 star is on or not much above the main sequence. The mass of an A5 main-sequence star is $2.2M_\odot$ according to Allen (1963) and is not strongly dependent on luminosity class. Substituting $M_1 = 2.2M_\odot$ into Struve's spectroscopic mass function for the eclipsing pair [defined like the mass function in equation (1) except that the parameters for the eclipsing pair and the third body are replaced by parameters for the primary and secondary star, respectively] which was corrected for a numerical error by Blanco and Tollinchi (1957) and found to be f(M) = 0.064 shows the mass of the secondary to be $M_2 \geq 0.8M_\odot$ depending on whether $i \leq 90°$ for the eclipsing pair. And we know that an upper limit for M_2 is about $1.2M_\odot$; otherwise the spectrum would be double-lined rather than single-lined, as seen by Struve. Hence, we can estimate that M_{12} is about 3 or 4 $M_\odot$. Let us return now to the mass function for three bodies and use a_{12} = 0.005 light-day = 0.86 A.U., P = 1.4 year (both from the sine curve in Fig. 1), a very generous range of values for M_{12}, and the most favorable value of i for finding an acceptable value for M_3, viz. i = 90°. The result, summarized in table 1, shows that M_3 would be so large that its light should be visible spectroscopically, if it obeys the usual mass-luminosity relation, although it is in fact not visible. Hence, motion around a third body can probably be ruled out.

TABLE 1

Eclipsing Pair	Third Body	
M_{12} (in $M_\odot$)	M_3 (in $M_\odot$)	Spectral Class for a Main Sequence Star of $M = M_3$
2.0	1.6	F2
3.0	2.0	A8
4.0	2.3	A5
5.0	2.5	A4

The possibility that the O-C changes are due to apsidal motion cannot be ruled out, although it is not very likely that this is the cause. In short period binaries the frequency of measurably eccentric orbits is quite small (Lucy and Sweeney 1971), therefore it would be very unusual if this extremely short period system has an eccentricity large enough to cause O-C changes that are due to apsidal motion. For apsidal motion, eccentricity is given by the approximation

$$e = \pi \frac{\Delta(O-C)_{max}}{P} \qquad (2)$$

where $\Delta(O-C)_{max}$ is the maximum displacement from a linear O-C representation. For $\Delta(O-C)_{max} = 0^d.005$ (from Fig. 1) we find e = 0.03 for RZ Dra. This is smaller than the limit of spectroscopic detection. To test the apsidal motion hypothesis, observers should time secondary minima as well as primary. The depth of secondary minimum for this star is $0^m.4$; thus many visual timings (or one good photoelectric determination) would be necessary for a good study. If the O-C changes are caused by apsidal motion, the O-C changes of the secondary minima should be equal to those of the primary minima but 180° out of phase with them; and, of course, the changes should be strictly periodic.

If the O-C curve is not strictly periodic, then it cannot be due to motion around a third body or to apsidal motion. In that case it is likely that the O-C changes are due to a real alteration of the period of revolution of the eclipsing binary. The most reasonable cause of such an alteration is the transferal of mass between the components of a binary and/or the loss of mass by either or both stars from the binary system. There may be evidence for mass transfer in RZ Dra. There seems to be an intermittent occurrence of asymmetries in the light curve which could imply that circumstellar material passes in front of the hotter star occasionally. (It is assumed in this paper that the O-C changes are not caused by these light curve asymmetries). The asymmetries in the light curve of RZ Dra have been known for more than 20 years (O'Connell 1951, Krobusek and Gliba 1974) and have also been seen by the present author. Although one should remember that the observations which show the asymmetries are visual or photographic, Krobusek and Gliba and also the author are confident that they do exist. If the O-C changes are due to mass transfer it is somewhat worrisome that these changes have never amounted to more than a few hundredths of a day at most. In fact, older period studies could not even agree that the period was variable at all; Whitney (1959) found a variable period, but Chou (1962) found a constant period. Kreiner (1971) also published an O-C diagram for RZ Dra but did not discuss the system itself. (It should be mentioned that these studies considered minima spread over decades rather than a large number of minima observed within a few years, as in the present paper). It would be surprising that a cyclical but not strictly periodic period change could produce O-C changes that do not amount to more than a few hundredths of a day. Typically, these amount to many hundredths or even a few tenths of a day (e.g., Hall 1974). However, a study by the author (Mallama 1975) shows that O-C changes in X Tri, which seem to be due to mass transfer, have not amounted to more than $0^d.04$ in over 50 years. Hence, it is possible that some binaries, like RZ Dra, undergo mass transfer which does not produce large cumulative O-C changes, but rather makes small rapidly alternating period changes which can cancel out long-term O-C changes. In the case that the O-C changes are due to mass transfer, observations of secondary minima should show O-C changes which are equal to the O-C changes of the primary eclipse and in phase with them.

In summary: an unusually large number of minimum timings of RZ Dra during a relatively short interval of time reveal O-C changes of about $0^{d}.01$ on a time scale of $\leq$ 600 days. These changes cannot reasonably be due to the presence of a third body in the system, but they could reasonably be caused by apsidal motion or mass transfer. It will be helpful to observe secondary minima of this star in order to decide which of the last two causes is responsible for the observed O-C changes.

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TABLE 2

RZ Draconis Minima

Minimum I = 2429448.787 + $0\overset{d}{.}55087668$

JD		O-C	OBSERVER	B.B.S.A.G. BULLETIN
2441	506.376	$\overset{d}{.}000$	R. Germann	1972a
	513.532	-.005	K. Locher	1972a
	534.465	-.005	K. Locher	1972b
	555.392	-.012	R. Diethelm	1972b
	555.398	-.005	R. Germann	1972b
	581.298	+.002	H. Peter	1972b
	592.308	-.005	R. Germann	1972c
	598.361	-.011	H. Peter	1972c
	604.417	-.015	H. Peter	1972c
	687.597	-.017	K. Locher	1973a
	688.705	-.011	K. Locher	1973a
	748.749	-.012	A. Mallama	1973b
	764.722	-.015	A. Mallama	1973b
	786.754	-.018	A. Mallama	1973c
	815.404	-.014	R. Germann	1973c
	815.409	-.008	H. Peter	1973c
	818.716	-.008	A. Mallama	1973c
	834.687	-.011	A. Mallama	1973c
	834.693	-.005	G. Gliba	1973d
	837.440	-.012	R. Germann	1973d
	869.388	-.015	R. Germann	1973d
	893.634	-.008	A. Mallama	1973d
	893.642	.000	G. Gliba	1973d
	901.357:	+.003:	R. Diethelm	1973e
	907.406	-.008	H. Peter	1973e
	912.357	-.015	R. Germann	1973e
	918.422	-.009	H. Peter	1973e
	932.745	-.009	G. Gliba	1973e
	934.403	-.004	H. Peter	1973e
	936.604	-.007	A. Mallama	1973e
	936.605	-.006	G. Gliba	1973e
	939.362	-.003	H. Peter	1973e
	941.558	-.010	G. Gliba	1973e
	982.325	-.008	H. Peter	1973f
2442	131.615	-.006	K. Locher	1974a
	146.478	-.016	R. Germann	1974b
	156.399	-.011	R. Germann	1974b
	157.490	-.022	R. Diethelm	1974b
	183.395	-.008	R. Diethelm	1974b
	200.475	-.005	H. Peter	1974c
	205.429	-.009	K. Locher	1974c
	254.452	-.015	H. Peter	1974c