The Period Change Rate in the RS CVn Binary HD 5303

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Abstract: From the observed timings of primary eclipse of HD 5303 we find that its 2.7 day period is increasing at a rate of about one second per year. In this paper we consider the implications of this in terms of mass transfer or mass loss from the system.

1. Introduction

The RS CVn eclipsing binary star HD 5303 has been observed frequently since 1978 and several light curves exist (Lloyd-Evans and Koen 1987; Collier *et al.* 1981; Coates *et al.* 1983a,b, 1984; Rucinski 1983; Budding 1984, 1985, 1987; Rounthwaite 1988; plus some unpublished Monash data). The system is G0 V + K4 IV with the cooler subgiant just inside its Roche lobe (Coates *et al.* 1983a). Superimposed on the eclipse light curve is the photometric 'spot wave' attributed to a large cool spot or spots on the cooler component.

2. Period Change

Over the last few years it has become apparent that only a changing period will fit the data on HD 5303. Table 1 lists the times of minimum light from the literature and our own observations. In each case we have replotted the data and found the minimum using the overlay method.

Table 1. Historical observations of the times of minimum light of HD 5303.

HJD – 2440000	Source
3869.524	Lloyd Evans and Koen (1987)
4219.270	"
4541.013	"
4510.227	Collier *et al.* (1981)
4513.0239	Monash data
5606.9143	Budding (1984)
5609.7113	Monash data
6390.2675	Rounthwaite (1988)
6695.221	Monash data
6801.5336	Rounthwaite (1988)
7000.175	Monash data
7929.03	Monash data

From the size of the photometric wave (Coates *et al.* 1983a) and the steepness of the light curve in the eclipse we find the measured time of minimum light to be spuriously affected by at most 0.002 days which we have ignored (Hall 1975).

Based on an epoch HJD 2444087.78 and a period of 2.79775 days we show in Figure 1 the (O – C) values from these data. The curve is a best-fit parabola ignoring the Lloyd-Evans data since those data were scattered in time and it was difficult to obtain a well defined minimum. Inspection of the Lloyd-Evans light curve and Collier's light curve also shows strong distortion at that time.

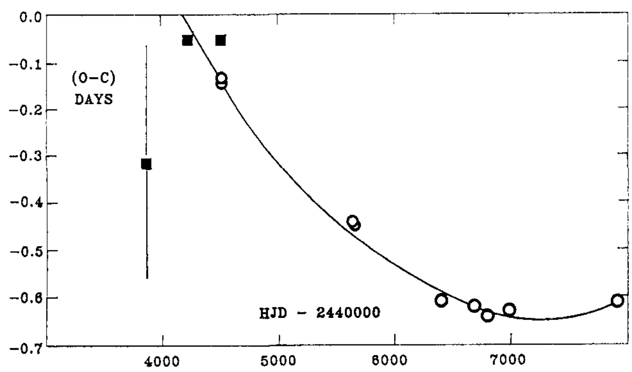

Figure 1 – (O – C) values (days) for the observed minima of HD 5303 compared with times calculated based on an epoch of 2444087.78 HJD and period 2.79775 days. The square filled-in points are from T. Lloyd-Evans' data and are not used in the calculations of the best-fit parabola.

From the nine observed times of minimum light we find an ephemeris:

$$2444087.7835 + 2.7976311E + 5.23 \times 10^{-8}E^2$$

which yields

$$\frac{d(\ln P)}{dt} = 4.89 \times 10^{-6}\,\text{year}^{-1}.$$

This is a high rate of period increase. The periods of most RS CVn variables are decreasing and at a lower rate than observed here (Hall and Kreiner 1980).

3. Discussion

We consider three separate mechanisms for period change:

(a) Direct mass transfer

The masses of RS CVn components are generally each about one solar mass and so direct mass transfer would have to be large to cause any significant period change. In this case from the known masses (Coates *et al.* 1983a), transfer from the K4 IV to the G0 V should lead to a period decrease, contrary to observation. To explain the increasing period we would need to transfer mass at the rapid rate of $1.4 \times 10^{-5}\,M_\odot$ per year from the hotter primary which is well within its Roche lobe. We reject this hypothesis. Uniform mass loss from the cooler secondary in the Jeans mode would need to be at the rate of $1 \times 10^{-5}\,M_\odot$ per year.

(b) Mass transfer to an accretion disc

Biermann and Hall (1973) developed a model to describe period change in Algols in which mass overflowing from the subgiant transfers to an accretion disc around the smaller star, causing an abrupt period decrease. However, subsequent gradual transfer of mass and angular momentum from the disc to the hotter star then causes a steadily increasing period. Since HD 5303 is not an Algol we suggest some other mechanism such as an active region may eject matter. If HD 5303 has a disc of material around the G0 V star of two stellar radii (Coates *et al.* 1983), then to explain the present period change we calculate a transfer rate of $2.4 \times 10^{-6}\,M_\odot$ per year from the disc to the G0 V star is needed. Since this has been going on for at least ten years we have a lower limit of $2.4 \times 10^{-5}\,M_\odot$ ejected from the K4 IV star, which would have caused an original abrupt period decrease of at least 1.6×10^{-4} days. In the short time that HD

5303 has been observed we have no evidence of such an abrupt period decrease. The present ephemeris is consistent with Collier's spectroscopic minimum at HJD 2443505.944 (Collier *et al.* 1981).

(c) Mass loss from coronal holes

Hall and Kreiner (1980) propose mass loss from the active component through coronal holes on the side opposite the active spot region. The published light curves for HD 5303 have all to varying amounts been non-symmetric, being darker at the 0.75 quadrature point than at phase 0.25. This would mean the active region is on the orbitally leading side of the secondary component and mass loss from the opposite hemisphere of high energy particles would increase the system angular momentum and give a period increase as observed. Using Hall's simplest model with presumed ejection velocity of 500 km s^{-1} we find a mass loss rate of $2.3 \times 10^{-6}\ M_{\odot}$ per year.

4. Conclusions

HD 5303 appears to have the highest rate of period increase among the RS CVn systems for which data are available, most of which show a period decrease. The best explanation may be a combination of uniform mass loss from the subgiant (Jeans mode) and additional loss via coronal holes. Careful spectroscopic observation of HD 5303 may identify the location of the ejected material.

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