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SOME COMMENTS ON THE MINIMA OF THE RS CVn TYPE ECLIPSING BINARIES CQ Aur, RU Cnc, VV Mon AND SZ Psc

In recent years a considerable effort has been made to describe in the most comprehensive way the features of the photometric wave-like distortions shown by the RS CVn type binaries. However, there are some problems that, on the contrary, have received less attention; among them we should like to quote the effects produced by the migrating wave on the epochs of minimum light (changes in the slopes of ascending and descending branches) and on the levels at the bottoms of primary and secondary minima (related to size and position of the perturbed regions). In this work we report on some results obtained from the extensive V photometry carried out at the Astronomical Observatory of Torino in the interval 1975 - 1984 on the systems CQ Aur, RU Cnc, VV Mon and SZ Psc.

CQ Aurigae ($P = 10^{d}.62$)

Most of the epochs of primary minimum (Kurotschkin, 1940) seem to be quite uncertain; therefore, in order to minimize the large scatter shown by them, we assumed, as representative of the oldest epochs, the mean value as deduced by Kurotschkin (1940), i.e. JD 2429558.78. More recently, timings were determined by O'Connell (1978) (JD 2440000.281) and by us (JD 2443814.05 $\pm$0.01 and JD 2445396.850 $\pm$0.004). The weighted period as derived from these four epochs is $P = 10^{d}.62251 \pm 0.00004$. We suggest that the following ephemeris:

$$\text{Min.I(Hel.)} = 2443814.05 + 10^{d}.62251 \cdot E$$

can be used to predict future epochs of minimum light with a good reliability.

From our photometry, spread over the interval 1978 - 1985, we infer no appreciable variations in the luminosity level at the bottom of the secondary minimum; on the contrary, an increase larger than the experimental error (up to about 0.1 mag) occurs near phase 0.0 (when only the cooler active component is visible) at the epochs 1978.02 and 1980.96.

RU Cancri ($P = 10^{d}.17$)

The oldest photographic and visual estimates can be found in Hall and Kreiner (1980). We are able to add the epochs: JD 2441775.856 ±0.001 (as derived from the data kindly sent to us by Dr. D.M. Popper (see also Popper and Dumont, 1977)) and JD 2445356.713 ±0.001 from our own photometry. Both linear and parabolic fits to the (O-C)'s have been calculated; the best agreement has been found using the following light elements:

$$\mathrm{Min.I\ (Hel.)} = \underset{\pm 0.0024}{2422650.7152} + \underset{\pm 0.00000005}{10^{d}.17298843} \cdot E - \underset{\pm 0.05}{2.25} \cdot 10^{-8} \cdot E^{2}$$

No clear evidence can be drawn about the bottoms of primary and secondary minima even if a quite large spread (up to about 0.06 mag) suggests possible variations in the luminosity levels.

Assuming an inclination $i = 90^{o}$, the durations of the eclipse ($0^{d}.894 \pm 0.020$) and of the totality ($0^{d}.314 \pm 0.016$) allow to determine the fractional radii of the components, R_S=0.089+0.006 and R_L=0.186+0.010 .

VV Monocerotis ($P = 6^{d}.05$)

For this binary the ephemeris found by Scaltriti (1979) proved to be satisfactory also for the new epoch JD 2444189.440 ±0.003 . A weighted linear least squares fit led to:

$$\mathrm{Min.I\ (Hel.)} = \underset{\pm 0.010}{2442834.110} + \underset{\pm 0.000006}{6^{d}.050592} \cdot E$$

As far as the luminosity levels at the bottoms of minima are concerned, the same conclusions drawn for RU Cnc are valid in the case of VV Mon.

SZ Piscium ($P = 3^{d}.97$)

As pointed out in Catalano et al. (1978) and Hall and Kreiner (1980), this system shows one of the largest amplitudes in the O-C curve (up to about $0^{d}.6$) among the eclipsing binaries. In Table I we collected all the epochs we could find in the literature. In order to minimize the uncertainty in the older determinations of Jensch (1934) and Gaposchkin (1943, 1952), we have constructed normal minima wherever some epochs a few cycles apart were present. The $(O-C)_1$ values calculated by means of the linear ephemeris by Catalano et al. (1978) (see Table I) are plotted in Figure 1.

Quadratic fits to this trend were calculated by Hall and Kreiner (1980) and Tunca (1984); however, unacceptable deviations (up to about $0^{d}.13$) suggest different approximations to the observed (O-C)'s; we find that the curve

$$(O-C) = 0^{d}.4 \cdot \sin((360^{o}/7200)(E + 4000)) \qquad (1)$$

represent quite well the $(O-C)_1$ values; the $(O-C)_2$'s listed in Table I have

Table I. Times of minimum of SZ Psc

JD(Hel.)	E	$(O-C)_1$	$(O-C)_2$	Source
2425576.836	-4219	-0.119	-0.022	Jensch(1934)
25854.410	4149	-0.157	-0.084	Jensch(1934)
26262.943	4046	-0.107	-0.070	Jensch(1934)
27036.365	3851	-0.030	+0.042	Jensch(1934)
27409.322	3757	+0.136	+0.072	Jensch(1934)
28000.255	3608	+0.155	+0.040	Gaposchkin(1943)
29935.858	3120	+0.415	+0.154	Gaposchkin(1952)
35741.819	1656	+0.348	+0.003	Jakate et al.(1976)
36114.574	-1562	+0.311	-0.018	Jakate et al.(1976)
42308.767	0	-0.179	-0.038	Jakate et al.(1976)
43117.822	+ 204	-0.161	+0.043	From Eaton (1977)
43498.502	300	-0.204	+0.028	Catalano et al.(1978)
43815.707	380	-0.268	-0.014	From Hall and Kreiner(1980)
43823.674	382	-0.233	+0.021	Present paper
44069.544	444	-0.247	+0.024	Tunca(1984)
44073.51	445	-0.25	+0.03	From Tumer et al.(1980)
44184.529	473	-0.272	+0.006	Present paper
44573.16	571	-0.30	+0.01	Present paper
2444827.005	+ 635	-0.266	+0.049	Tunca(1984)

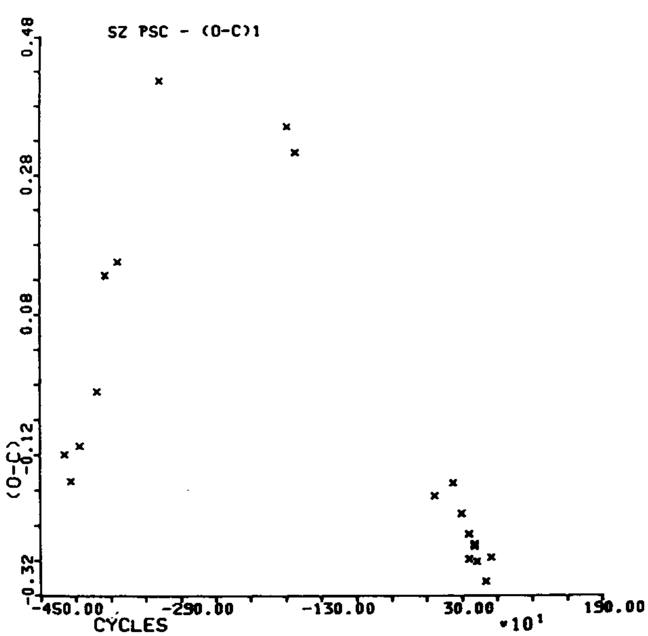

Figure 1. O-C values of SZ Psc

been calculated taking into account the contribution of formula (1); the resulting period of the cycle is about 78 years, which is longer than the estimation reported by Ahn (1982) (66 years).

It is clear that only determinations of future epochs can prove the long-term validity of the new ephemeris. In fact, we may notice that the last epoch in Table I gives $(O-C)_2 = 0.049$, a quite large value for a photoelectric timing; moreover, the periodicity of formula (1) might imply:

i) a light-time effect in a triple system, that would require a very massive third body ($M > 50\,M_\odot$); a similar phenomenon seems to be present in the RS CVn type system SV Cam (Cellino et al., 1985),

ii) an apsidal motion in an orbit with $e \cong 0.15$, far larger than found by Jakate et al. (1976) from a spectroscopic orbit solution ($e \cong 0.04$).

Perhaps we are witnessing just a long-term cyclic variation similar to those characterizing other RS CVn and W UMa type binaries.

Eventually, we notice that the epochs with $E > -1656$ can also be fitted by a linear least squares approximation, leading to the ephemeris:

$$\text{Min.I (Hel.)} = \underset{\pm 0.007}{2442308.817} + \underset{\pm 0.0000096}{3^{d}.9655847} \cdot E$$

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