COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS

Number 2769

Konkoly Observatory
Budapest
5 August 1985

HU ISSN 0374 - 0676

A SMALL ELLIPTICITY EFFECT IN THE RS CVn BINARY 33 PISCIUM

33 Psc = HR 3 = HD 28 first came to our attention when Young and Koniges (1977) and Lloyd Evans (1977) noted this SB1 showed Ca II H and K emission, indicating it is an RS CVn binary. Therefore we suspected photometry might show the characteristic "wave". Because of the large orbital eccentricity, e = 0.272 ± 0.017, found by Harper (1926) it was additionally interesting in connection with the question of synchronous rotation in eccentric orbits (Eaton et al. 1983). The spectral type appears in the literature most often as K1 III. The orbital period is $72^{d}.93$ (Harper 1926, 1935). The H and K emission is not very strong, only 2 on Wilson's 0-to-5 scale (Glebocki and Stawikowski 1979).

According to Eggen (1978) "numerous UBV observations indicate a range of about $0^{m}.05$ in V." Percy and Welch (1982), however, made differential photoelectric measures on 9 nights over a 118-day interval and found no indication of variability. The rms deviation of their 9 measures was only $\pm 0^{m}.004$.

Between July 1979 and January 1985 (JD 2444069.6 through 2446077.6) 11 different observers observed 33 Psc differentially with respect to the comparison star HR 29 = HD 587. Altogether they obtained 201 values of ΔV, each a mean of generally three intercomparisons between variable and comparison. A few observed in B and U also, but in this note we analyze only the more numerous ΔV values. This is summarized in Table I. All photometry was, of course, corrected for differential atmospheric extinction and transformed differentially to V of the UBV system with known transformation coefficients. Because 33 Psc and HR 29 differ in B-V color index by only $0^{m}.06$, the 5.5 years of photometry from 11 different observatories resulted in an unusually homogeneous set. Some earlier photometry of 33 Psc was obtained in 1978 by Robert E. Montle at the James C. Veen Observatory, but unfortunately his comparison star was 30 Psc, the known variable YY Psc.

To search for possible variability, we generated a periodogram by fitting a sinusoid to the ΔV values, with periods ranging between 1^{d} and 150^{d}. Nowhere in that range did the resulting full amplitude exceed $0^{m}.010$. We considered it significant, however, that a $0^{m}.008$ amplitude (and corre-

Table I

Tally of Observations

Observer	Observatory	Location	Telescope	Means
Barksdale	Barksdale	Florida	14-inch	8
Boyd	Fairborn	Arizona	10-inch	124
Eaton	Kitt Peak	Arizona	16-inch	10
Fried	Braeside	Arizona	16-inch	3
Henry	Dyer	Tennessee	24-inch	11
Henry	Kitt Peak	Arizona	16-inch	12
Hopkins	Hopkins-Phoenix	Arizona	8-inch	10
Pazzi	Nigel	South Africa	12-inch	6
Poe	Dyer	Tennessee	24-inch	5
Renner	Scuppernong	Wisconsin	10-inch	7
Rogers	Southwestern Oklahoma	Oklahoma	14-inch	4
Sabia	Keystone	Pennsylvania	9-inch	1

sponding diminution in the sum of the squares of the residuals) occurred at $36^{d}.51 \pm 0^{d}.12$, which is (within the uncertainty) exactly half the $72^{d}.93$ orbital period. This can be explained most simply as a detection of the cos 2Θ variation produced by the ellipticity effect. The amplitude at $72^{d}.93$ was only $0^{m}.001$, indicating that the cos Θ reflection effect was undetectable. A portion of the periodogram, between 31^{d} and 41^{d}, is shown in Figure 1.

Noting that 365 days is almost exactly 10 times $36^{d}.51$, we anticipate that the unavoidable 365-day observing window would produce aliases at $P = 365^{d}/9 = 40^{d}.6$ and $P = 365^{d}/11 = 33^{d}.2$. Indeed, as Figure 1 shows, prominent peaks do appear at $40^{d}.5 \pm 0^{d}.3$ and $33^{d}.2 \pm 0^{d}.1$.

Analysis of our residuals identified 5 values of ΔV which were larger than would be expected in a Gaussian distribution, i.e., greater than 3σ. To check whether these were influencing our results, we redid the analysis with these 5 values excluded. The results, however, were not significantly altered. Table II is a summary of parameters deduced from the two sets of data. Both estimates of the period, $36^{d}.51 \pm 0^{d}.12$ and $36^{d}.38 \pm 0^{d}.10$, are consistent with $36^{d}.465$, which is half the orbital period. The full amplitude of the light variation, an average for the two estimates, is $0^{m}.007$. Note that the rms derivation from the Fourier fit was reduced to $\pm\ 0^{m}.009$ when we used the abbreviated data set. The time of minimum light, given for the middle of the 5.5-year interval, should be useful as a recent time of conjunction.

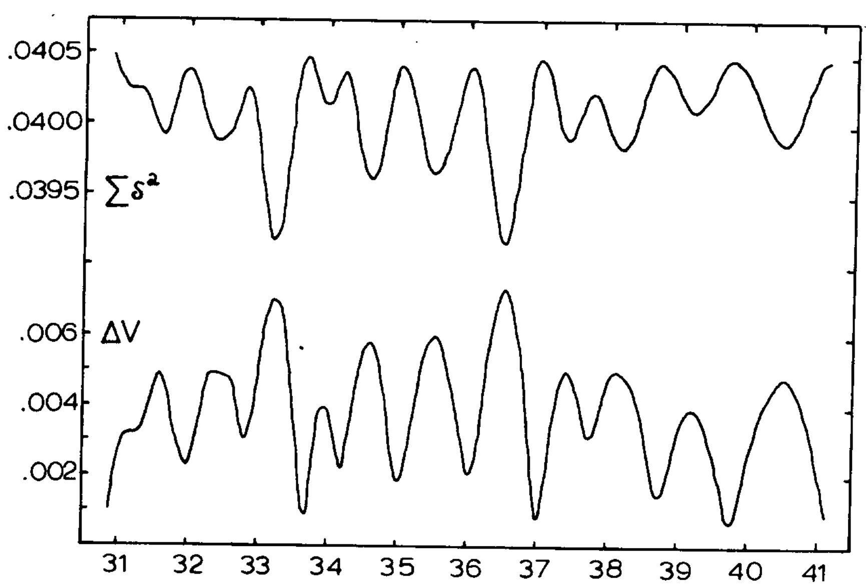

Figure 1

Periodogram for 5.5 years of V-band photometry of 33 Piscium. The abscissa is assumed period, in days. The lower part is the full amplitude of a sinusoidal fit. The upper part is the sum of the squares of the residuals from that fit. Note the 0.007 amplitude at 36.5 days, which is half the known orbital period; it probably arises from the ellipticity effect. Two other peaks, at 33.2 and 40.5 days, are aliases produced by the 365-day observing window.

Table II

Parameters from Fourier analysis

number of points	201	196
best period	$36^{d}.51 \pm 0^{d}.12$	$36^{d}.38 \pm 0^{d}.10$
mean ΔV	$-1^{m}.218 \pm 0^{m}.001$	$-1^{m}.219 \pm 0^{m}.001$
full amplitude in V	$0^{m}.008 \pm 0^{m}.003$	$0^{m}.006 \pm 0^{m}.002$
JD (minimum light)	2445072 ± 2	2445069 ± 2
rms deviation	$\pm 0^{m}.014$	$\pm 0^{m}.009$

Other possible periods seen in the complete periodogram may be significant but, because the amplitudes are so small and because the periods are neither close to nor commensurate with the orbital period, we are reluctant to make additional conclusions.

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