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THREE MODES OF VARIABILITY IN THE BRIGHT STAR HR 7428

We began photometry of HR 7428 = HD 184398/9 after it appeared on listings of bright suspected variable stars (Hall 1983ab). The literature contains rather many references to this bright spectroscopic binary, of which we mention about half. Radial velocity measures by Sanford (1925) showed the orbital period to be $108^{d}.5707 \pm 0^{d}.05$. Lucy and Sweeney (1971) later recomputed a circular orbit after concluding it was not significantly eccentric. The spectral type of the primary component has appeared in the literature as K2, cG6, K2 III, K2 (II-III), K2 II-III, and K2 II-III e; the secondary component has been designated variously as A3, A, A?, A0, and A0 V. Ca II H and K emission was first noted by Bidelman (Gratton 1950), the strength being 3 on Wilson's 0-to-5 scale (Glebocki and Stawikowski 1979), whereas H alpha appears in absorption (Bopp and Talcott 1978). Soft x-ray emission has been detected by Walter and Bowyer (1981). Argue (1966) gives the magnitudes as $V = 6^{m}.36$, $B-V = 1^{m}.16$, $U-B = 0^{m}.91$.

As shown in Table I, we obtained differential photometry at eight different observatories in one or all three bandpasses of the UBV system. From the middle of 1982 through the end of 1984, we obtained 179 means of 2-to-5 individual differential measures between HR 7428 and the comparison star HD 184170.

Inspection of our 2.5 years of photometry showed that HR 7428 was varying by about $0^{m}.05$ with a period around 55 days. Since this was so nearly half the known orbital period, we did Fourier analysis with the familiar truncated series which allows for terms in $A_1 \cos \theta$ and $A_2 \cos 2\theta$. Repeated fits with different values assumed for the period, along with chi-squared analysis, indicated $P = 108^{d}.85 \pm 1^{d}.15$. Application of the period-finding technique of Lafler and Kinman (1965) found values which were consistent. Thus both estimates (Fourier and Lafler-Kinman) are in agreement with Sanford's spectroscopically determined orbital period.

Table I

Tally of Observations

Observer	Location	Telescope	Means	λ
Barksdale	Florida	14-inch	2	V
Boyd	Arizona	10-inch	117	VBU
Fried	Arizona	16-inch	11	VBU
Hoff	Iowa	16-inch	3	V
Ingvarsson	Sweden	14-inch	21	V
Nielsen	Delaware	4-inch	5	V
Stelzer	Illinois	14-inch	14	V
Wasson	California	8-inch	6	V

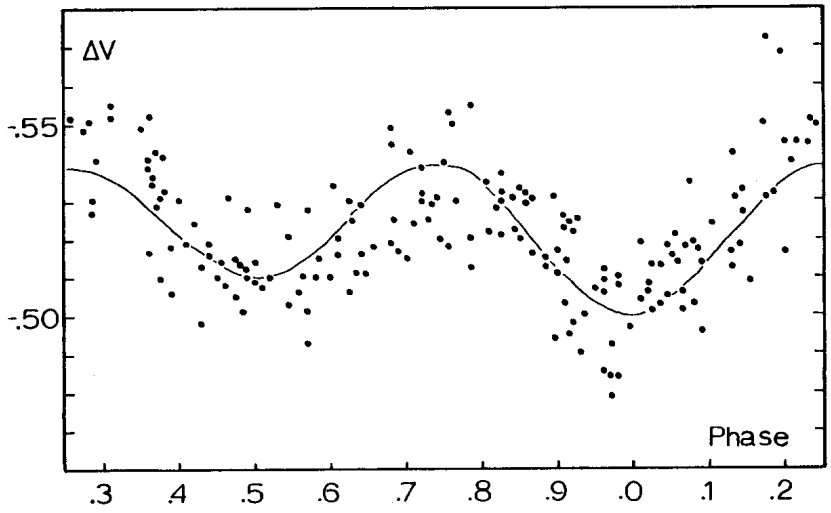

Figure 1

Light curve of the K2 II-III + A spectroscopic binary HR 7428, where ΔV is in the sense variable minus comparison and phase is based on the $108^{d}.6$ orbital period of Sanford. Each point is a mean of 2-to-5 individual intercomparisons. The solid curve is a Fourier fit allowing for terms in cos θ and cos 2θ. Two points ($0^{p}.38$,$-0^{m}.43$ and $0^{p}.98$,$-0^{m}.45$) were off scale and are not plotted but were included in the Fourier analysis. We see evidence of an ellipticity effect and a smaller reflection effect. The $0^{m}.015$ difference between the two maxima, at $0^{p}.25$ and $0^{p}.75$, indicates a possible RS CVn-type wave. The total range from minimum at $0^{p}.00$ to the higher maximum at $0^{p}.25$ is $0^{m}.045$ in V.

Redoing the Fourier analysis with the $108^{d}.5707$ period exactly, we found $A_2 = -0^{m}.017$, $A_1 = -0^{m}.005$, a mean light level of $\Delta V = -0^{m}.522$, and JD 2445062.88 ± $0^{d}.05$ for a time of the deeper minimum. The 179 mean values of ΔV are plotted in Figure 1, where the curve represents the above Fourier coefficients and zero phase is at the deeper minimum.

A reasonable interpretation of the light curve would be that the A_2 coefficient indicates the ellipticity effect, not surprising in a binary with one very luminous (hence, large) star, and that the A_2 coefficient indicates the differential reflection effect, not surprising in a binary composed of a large cool star and a smaller hot star. A residual asymmetry, not allowed for in our Fourier analysis which contained no sin θ terms, appears in Figure 1 as a $0^{m}.015$ difference in height between the maxima at $0^{P}.25$ and $0^{P}.75$. This might be a manifestation of the "wave" seen in other chromospherically active stars, even ones with quite long rotational periods, the longest known being HR 1362 with P = 154 days (Boyd et al. 1985). We see that HR 7428 reaches maximum brightness around $0^{P}.25$ (because of this asymmetry) and minimum brightness around $0^{P}.00$ (because of the reflection effect), the full range being approximately $0^{m}.045$ in V.

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