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DISCOVERY OF ECLIPSES AND LONG-PERIOD VARIABILITY IN THE TRIPLE SYSTEM HR 6469

HR 6469 was recognized as a triple system when McAlister et al. (1983) resolved it with speckle interferometry. The spectrum was already noted as composite by Wilson (1966) and as SB2 by Cowley and Bidelman (1979). Later speckle interferometry by McAlister et al. (1984) showed rapid orbital motion consistent with a 5.53-year period determined spectroscopically by F. C. Fekel. C. T. Bolton, in a private communication to Bopp (1984), suspected the short period to be "a few days". Fekel (1984) obtained spectrograms with the Kitt Peak coude feed telescope and CCD detector at red wavelengths. From those observations he estimated that the single star in the long-period orbit has a G5 IV spectral type, the primary in the short-period orbit is an F7 V star, and no lines of the secondary in the short-period orbit could be seen. Previous classifications, of the composite spectrum of this triple system, have been inconsistent: G0III, F8V, F9V, G0Vn:, F9Vn:, and dF8.

HR 6469 was placed on a list of bright suspected variable stars by Hall (1983) because reports of its Ca II H and K emission suggested it might be an RS CVn-type variable. Weak H and K emission was first noted by Wilson (1966) and its flux later measured by Middelkoop (1982) and by Bopp (1984). The profile in figure 8 of Bopp (1984) shows the emission indeed is weak.

In this note we present 427 differential magnitudes obtained photoelectrically by 7 different observers on 123 nights between JD 2445151.6 and 2445874.8 in V of the UBV system using HR 6444 as the comparison star. Table I is a tally of those observations. Each individual observation was bracketed between two observations of the comparison star. The resulting differential magnitudes, corrected for differential atmospheric extinction and transformed differentially to the UBV system, have been sent to the I.A.U. Commission 27 Archive of Unpublished Observations of Variable Stars

TABLE I

Tally of Observations

Observer	Observatory	Aperture	Nights	Observations
Boyd	Fairborn	10-inch	43	121
Brooks	Brooks	12.5-inch	3	8
Fried	Braeside	16-inch	45	124
Hoff	Northern Iowa	16-inch	2	5
Lines	Lines	20-inch	5	63
Stelzer	Stelzer	14-inch	10	35
Wasson	Sunset Hills	8-inch	15	71

(Breger 1982), where they are available as File No. 150. Most entries represent individual differential measures whereas some represent means of 3 differential measures, so all are not of equal weight. Brooks and Hoff had not determined their transformation coefficients so we made their ΔV values brighter by $0\overset{m}{.}02$ and fainter by $0\overset{m}{.}05$, respectively, to fit the light curve defined by the other five observers. This procedure, we presume, provided an effective transformation.

Unexpectedly our photometry showed that HR 6469 is an eclipsing binary. We determined a preliminary ephemeris of

$$\mathrm{JD(hel.)} = 2445839.83 + 2\overset{d}{.}230\ n \qquad (1)$$

for the primary minima. After discovery of the eclipses, Boyd and Wasson covered primary eclipse by continuous observation on three nights, and Lines did the same for secondary on two nights. These Boyd and Wasson light curves, shown in Figure 1, were used to derive an improved value for the midpoint of primary eclipse. To take advantage of our 2-year baseline, we analyzed all other points occurring very near primary or secondary minima, thereby improving our estimate of the period. The resulting ephemeris

$$\begin{aligned}\mathrm{JD(hel.)} &= 2445839.813 + 2\overset{d}{.}2299\ n \\ &\qquad\ \pm.001 \quad \pm\overset{d}{.}0001\end{aligned} \qquad (2)$$

should be used for predicting times of future primary minima.

When we plotted our 2 years of photometry versus Julian date, with points within $\pm\ 0\overset{P}{.}04$ of the minima excluded, we found another unexpected result: a long-period variability with a total amplitude of $\Delta V = 0\overset{m}{.}04$.

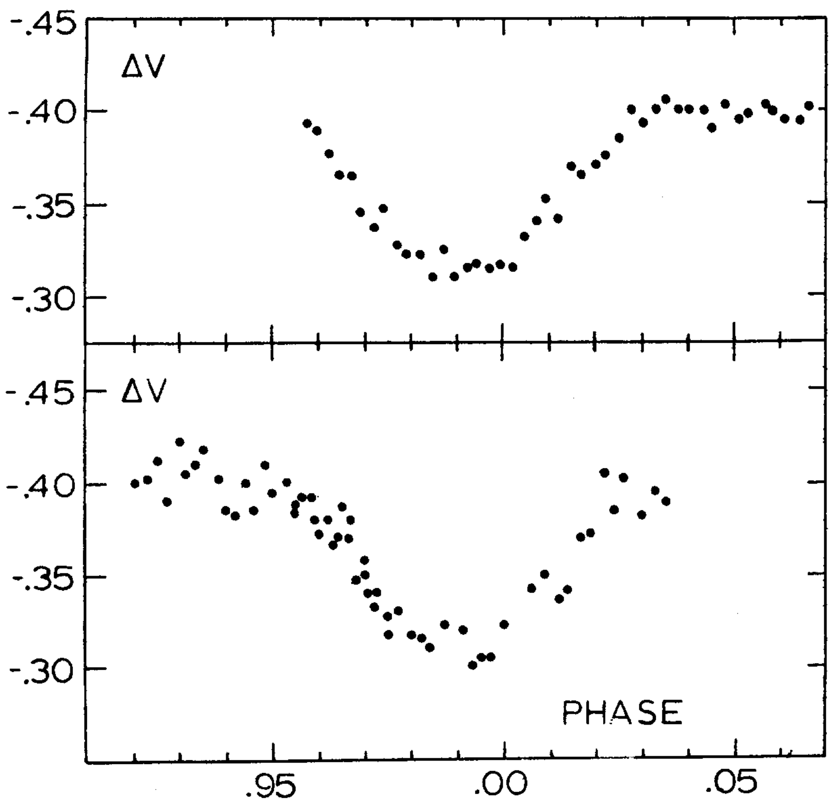

Figure 1

Primary eclipse of HR 6469 observed on one night by Boyd (upper) and on two nights by Wasson (lower). Phase is computed with the preliminary ephemeris in equation (1). The true midpoint, around 0.991 phase, was used for the initial epoch of the revised ephemeris in equation (2). Eclipse depth is around ΔV = 0.085 magnitude and the eclipse duration is D = 0.08 phase = 4.3 hours. It cannot be decided whether the eclipses are partial or complete.

Times of minimum brightness, determined graphically from the light curve, were fit by linear least squares to yield an ephemeris of

$$\begin{aligned} JD(hel.) = 2445164 &+ 83\overset{d}{.}2\ n \\ \pm 4 \quad &\pm\overset{d}{.}7 \end{aligned} \qquad (3)$$

for times of minimum light. This long-period variation is shown in Figure 2. Boyd observed the comparison star HR 6444 differentially 183 times with respect to the check star 69 Her on 88 nights in all bandpasses of the UBV

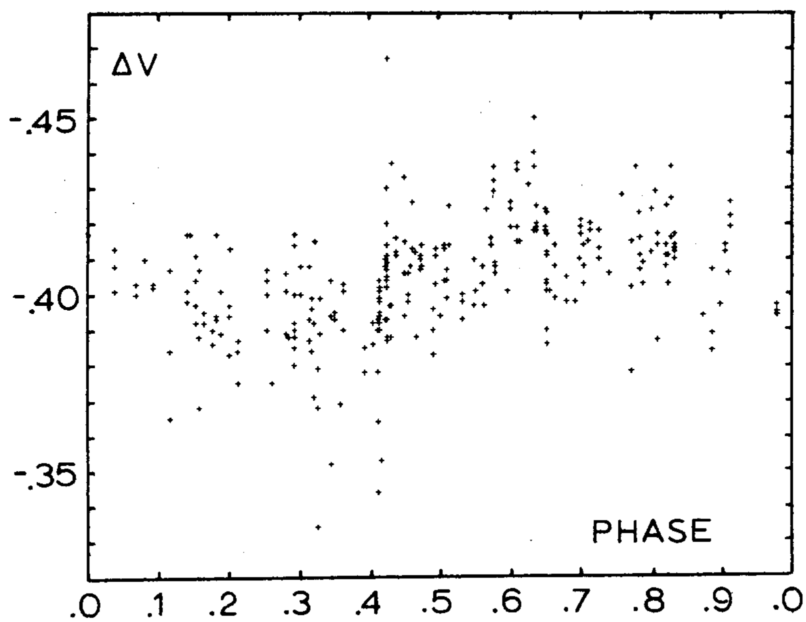

Figure 2

The light curve of HR 6469 outside eclipse, i.e., points within 0.04 phase of either mideclipse excluded. Phase is computed with the 83.2-day period in equation (3), but the origin is such that minimum light falls at approximately 0.3 phase. The variation, of total amplitude ΔV = 0.04 magnitude, probably arises from the G5 IV component of the triple system.

system. Analysis showed these differential magnitudes were not correlated with the ephemeris in equation (3); this convinced us that the $83^{d}.2$ variability is intrinsic to HR 6469. Although 69 Her is a suspected variable (CSV 101643 = NSV 8489) with a range of $4^{m}.60 < V < 4^{m}.66$, our check-minus-comparison differential magnitudes showed an rms deviation of only $\pm 0^{m}.010$ from the mean.

Before plotting the eclipse light curve, we removed the $0^{m}.04$ long-period variation by adding to each differential magnitude the quantity

$$d = 0^{m}.02 \sin \{ 360^{\circ}(JD-2445185) \ / \ 83^{d}.2 \} , \qquad (4)$$

assuming the variation can be approximated by a sinusoid. The resulting eclipse light curve is shown in Figure 3.

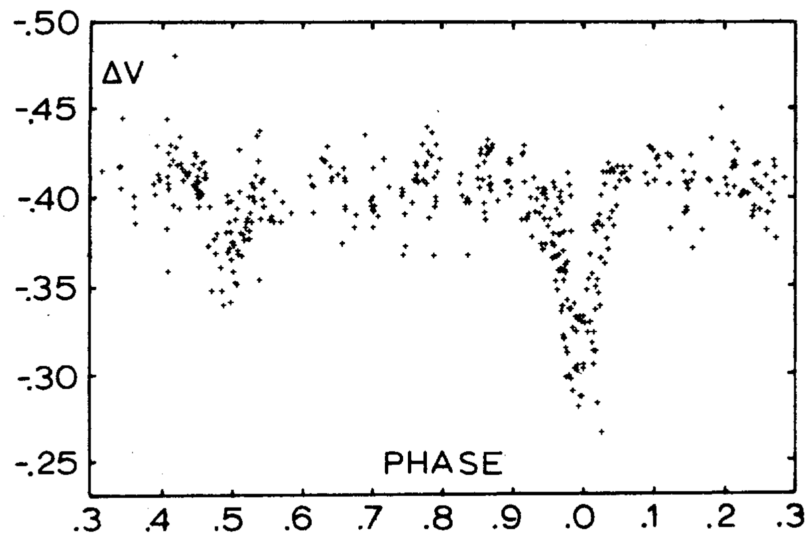

Figure 3

The light curve of HR 6469 showing primary and secondary eclipse of the F7V + ? close pair in the triple system. Phase is computed with the 2.23-day orbital period. The long-period variation seen in Figure 2 has been removed with equation (4).

Our eclipse light curve is not suitable for solution because of the somewhat large scatter relative to the shallow eclipse depths. Nevertheless, we can conclude the following. From Figure 1 we see the eclipse duration from first to fourth contact is $D = 0^{p}.08$ and it cannot be decided whether or not there is a constant phase at the bottom. From Figure 3 we see a primary minimum $0^{m}.085$ deep, a secondary minimum $0^{m}.05$ deep and not noticeably displaced, and some indication of an ellipticity effect. Although not included in Archive File No. 150, some B and U photometry was obtained at Braeside, Fairborn, and Lines Observatory. Linear regression analysis of this multibandpass photometry indicated that primary eclipse depths are in the ratio

$$\Delta V \;/\; \Delta B \;/\; \Delta U = 1.00 \;/\; \underset{\pm.05}{1.29} \;/\; \underset{\pm.07}{1.66}$$

and that secondary eclipse depths are in the ratio

$$\Delta V \;/\; \Delta B \;/\; \Delta U = 1.00 \;/\; \underset{\pm.06}{1.16} \;/\; \underset{\pm.10}{1.24} \;.$$

It may seem surprising that the depth increases at shorter wavelengths during both primary AND secondary eclipse. But this can be understood by realizing that the F7 V star and (probably) the unseen secondary in the eclipsing system are BOTH hotter than the G5 IV component of the triple system. It is consistent, we note, that the color becomes LESS blue during primary eclipse.

The results of our photometry in combination with all previously known information can best be understood in the following picture of the triple system HR 6469. The close pair consists of an F7 V primary and a not yet seen secondary which eclipse each other with an orbital period of $2^{d}.23$. The relative eclipse depths can provide an indication of the relative temperatures of those two stars. The G5 IV star orbits the close pair with an orbital period of 5.53 years and probably is responsible for the $83^{d}.2$ variability. This $83^{d}.2$ period probably is the rotation period of the G5 IV star, with the photometric variability and the weak H and K emission understandable within the context of starspot activity in chromospherically active stars.

Several of the above points need to be verified and a number of important questions need to be answered. The G5 IV star contributes how much light to the system? Is the F7 V star eclipsed at primary minimum? What will the light curve solution reveal about the unseen secondary star? Is the G5 IV star indeed responsible for the H and K emission? Is the variable G5 IV star a normal subgiant, is it an FK Comae-type variable, or might it be an SB1 with an orbital period of $83^{d}.2$?

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