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PHOTOMETRY OF THE ECLIPSING BINARY DHK 11 = SAO 23229

Kaiser discovered that the 6th-magnitude F5V star SAO 23229 (BD +53°507, HD 14384) is an eclipsing binary, designated DHK 11 in his discovery list (Kaiser et al. 1990). The eclipses were found to occur at intervals of 2.111 days. Marschall et al. (1990) reported that the variable is a double-lined spectroscopic binary with nearly equal line strengths, indicating that the period is probably 4.222 days and the alternate minima are primary and secondary eclipses of nearly equal depths.

Our photoelectric observations support this conclusion. We have obtained a total of 100 differential measures in the V band, mostly during the two eclipses. Williams observed with a 28-cm Schmidt-Cassegrain and Optec SSP-3 photometer; Landis used a 20-cm Newtonian and 1P21-based photometer; and Pray used a 25-cm Newtonian and Optec SSP-3 photometer. All observations have been corrected differentially for extinction and transformation to V of the UBV system.

Figure 1 shows the observations phased to the period 4.222 days. The mean differential magnitudes measured by Williams and Pray near phases 0.45, 0.55, and 0.75 are equal within $\pm 0\overset{m}{.}005$. The observations at phase 0.75 would be at phase 0.5 if the period were 2.111 days, but there is no decrease in magnitude at this point. Since the spectrum is double-lined with nearly equal strength, there must be a detectable secondary eclipse and these observations confirm the 4.222-day period.

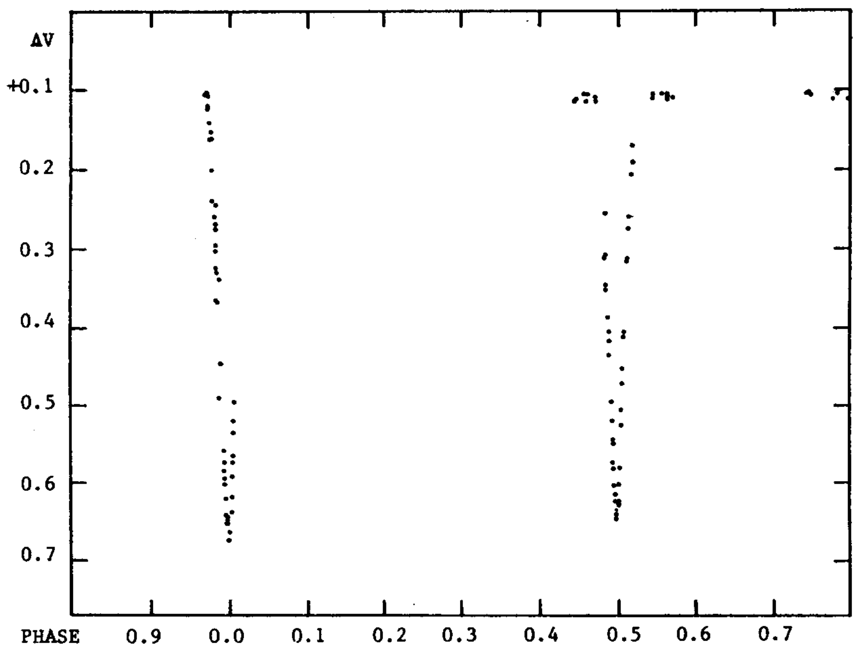

Figure 1. SAO 23229, V-band photometry phased according to Eq. 1. Differential magnitudes refer to the comparison star SAO 23407.

Times of mid-eclipse determined from our observations by the tracing paper method are listed in Table I, which also includes a photoelectric timing by F. Agerer (1990). We have adopted the initial epoch in the light elements of Kaiser et al. (1990) and subsequent alternate minima as the nominal primary eclipses.

TABLE I.

HJD	E	O–C	Obs'r
2447808.5994 ±0.0006	-13.0	$-0^{d}.0002$	Landis
810.7099 ±0.0008	-12.5	-0.0007	Williams
922.5949 ±0.0004	+14.0	+0.0008	Agerer

The cycle numbers and O–C residuals refer to Equation 1, in which the initial epoch is a normal time of minimum from the three photoelectric timings and the period is twice the value from Kaiser et al. (1990):

$$\text{Min. I} = \text{HJD } 2447863.4858 + 4\overset{d}{.}222017\ E \qquad (1)$$
$$\pm.0008 \quad \pm.000002$$

The primary and secondary eclipses are nearly equal in depth. Landis and Williams observed consecutive eclipses (Table I) but used different comparison stars: Landis SAO 23389, Williams SAO 23407. Landis did not obtain any observations outside of eclipse, so the differential magnitude of maximum relative to his comparison star, and therefore the total amplitude of the eclipse he observed, cannot be determined directly from his observations. The eclipse observed by Williams was $0\overset{m}{.}54 \pm 0\overset{m}{.}01$ deep.

Williams happened to use Landis' comparison star SAO 23389 as a check star, so the two sets of observations can be reduced to the same differential scale relative to Williams' comparison star SAO 23407. When this is done, the primary minimum observed by Landis is $0\overset{m}{.}02$ – $0\overset{m}{.}03$ deeper than the secondary minimum observed by Williams. However, SAO 23389 has a faint companion that may have affected the results of one or both observers.

Agerer (1990) has published a photoelectric light curve of a primary minimum using yet a third comparison star, SAO 23283, which we note is the variable V440 Per, a Cepheid with amplitude $0\overset{m}{.}14$ V, P = 7.57 days. These observations remain useful, however, because V440's average rate of variation would be less than $0\overset{m}{.}005$ during the 2.5 hours of the eclipsing binary's decline to minimum.

The depth of the primary minimum observed by Agerer is $0\overset{m}{.}54$ or $0\overset{m}{.}55$ V (estimated from the printed light curve), almost indistinguishable from the secondary minimum observed by Williams, so the two eclipses may be virtually equal. More observations made in a consistent photometric system are clearly needed. For now, we can say that the primary and secondary minima are nearly identical and differ by no more than $0\overset{m}{.}03$.

Based on differential measures with 11 Persei, $5^{m}.77$ V, -0.13 B-V, in the Bright Star Catalogue (Hoffleit and Jaschek 1982), the variable at maximum is $6^{m}.87$ V, B-V +0.43 (the color expected for an unreddened F5V star).

As noted, the observations outside of eclipse are constant to $\pm 0^{m}.005$, so there are no indications of ellipticity or re-radiation effects. The first observations on the descending branch of the primary minimum at phase 0.975 (Figure 1) are equal to the observations outside of eclipse and mark the first contact. The duration of primary eclipse is therefore 0.050 P = 5.1 hours. The shoulders of the secondary minimum were not observed, but the last observation at maximum preceding the secondary minimum is at phase 0.474, setting an upper limit to the duration of secondary eclipse at 0.052 P. The secondary minimum occurred at phase 0.5 within the error of the timing.

In summary, our observations indicate that the components of the binary system SAO 23229 are very similar in luminosity. The orbit appears to be circular, and no tidal or re-radiation effects are evident.

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