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PHOTOMETRY SHOWING HD 219989 IS AN ECLIPSING BINARY

In this paper we present photoelectric photometry obtained at ten different observatories between 1974 and 1984 showing that HD 219989 is an eclipsing binary with an orbital period of $20^d.8529$, an Algol-type light curve, two eclipses approximately $0^m.55$ and $0^m.38$ deep in V, and a displaced secondary. The HD spectral type is A0 and the apparent visual magnitude is approximately $7^m.2$.

During the course of ubvy photometry of the eclipsing binary AN Andromedae Crawford (1975) discovered that his comparison star, HD 219989, was variable also. He continued photometry of HD 219989 itself, using BD +40°5046 as a comparison star. On the night of August 10-11, 1974 the light dropped to $0^m.55$ fainter than normal in y, at a rate of $0^m.09$/hour. On the night of August 21-22, 1974 the light dropped to $0^m.38$ fainter than normal in y, at a rate of $0^m.05$/hour. From this he estimated JD 2442271.00 as a time of mid primary eclipse and 2442281.86 as a time of mid secondary eclipse. The depths and rates of light loss were similar in the other three bandpasses. On 20 other nights no eclipses were seen.

No further photometry of HD 219989 was obtained until it appeared on a list of bright suspected variables (Hall 1983) needing observation.

Ingvarsson found HD 219989 coming out of eclipse on two nights: October 31-November 1, 1983 and November 21-22, 1983. The slope indicated both were the rising branch of secondary eclipse; therefore, from the interval between overlapping portions, we could estimate the orbital period to be $20^d.86 \pm 0^d.01$. The observation by Boyd on the night of January 22-23, 1984 was, judging by its depth, virtually at mid secondary eclipse; the observation by Barksdale on the night of January 1-2, 1984 appeared to be on the falling branch of secondary very near the bottom. From those Boyd-Barksdale-Ingvarsson measures, we estimated JD 2445722.585 as a time of mid secondary eclipse. An earlier observation by Boyd in 1983 was, judging by its time and depth, near the bottom of primary eclipse. Recalling the

$10^{d}.86$ interval Crawford had found between primary and secondary, we concluded Boyd's measure was on the falling branch, rather than the rising branch. Then, recalling the $0^{m}.09$/hour slope Crawford had found for primary, we extrapolated to a depth of $0^{m}.55$ (assuming the depth to be identical in y and V) and estimated JD 2445711.73 as a time of mid primary eclipse.

The interval between the 1974 and 1983/84 times of minimum for primary eclipse was 3440.73, and for secondary eclipse was 3440.725, virtually the same. This interval is very nearly an integral multiple (164.94 ± 0.08) of the $20^{d}.86 \pm 0^{d}.01$ orbital period we had estimated from Ingvarsson's data. Therefore, using an exact 165 multiple, we took advantage of the 9.4-year baseline to derive an orbital period of $20^{d}.85290 \pm 0^{d}.00001$. The ephemeris we propose for primary minimum is

$$\mathrm{JD(hel.)} = 2445711.73 + 20^{d}.85290\ n \qquad (1)$$

and note that secondary minimum is displaced, falling at phase $0^{P}.52$.

A list of the observers, their telescopes, and the number of different nights they observed is given in Table I. The data have been sent to the I.A.U. Commission 27 Archive for Unpublished Observations of Variable Stars (Breger 1982), where they are available as file no. 136 (Boyd) and file no. 53 (the other observers). All the differential magnitudes have been corrected for differential atmospheric extinction and transformed differentially to the UBV system. The light curve in Figure 1 is a plot of the ΔV magnitudes, where Δ is in the sense variable minus comparison, the comparison star being HR 8902. Each point is a mean of 2-to-6 individual differ-

Table I

Observers Providing Photometry of HD 219989

Observers	Observatory	Aperture	Nights
Barksdale	Barksdale	14-inch	12
Bisard	Brooks	14-inch	5
Boyd	Fairborn West	10-inch	15
Crawford	Ojai	24-inch	10
"	U.C.L.A.	16-inch	12
Heiser	K.P.N.O.	16-inch	3
Hoff	Hillside	16-inch	4
Ingvarsson	T.I.A.O.	14-inch	18
Persinger	E.T.S.U.	8-inch	6
Stelzer	Stelzer	14-inch	4

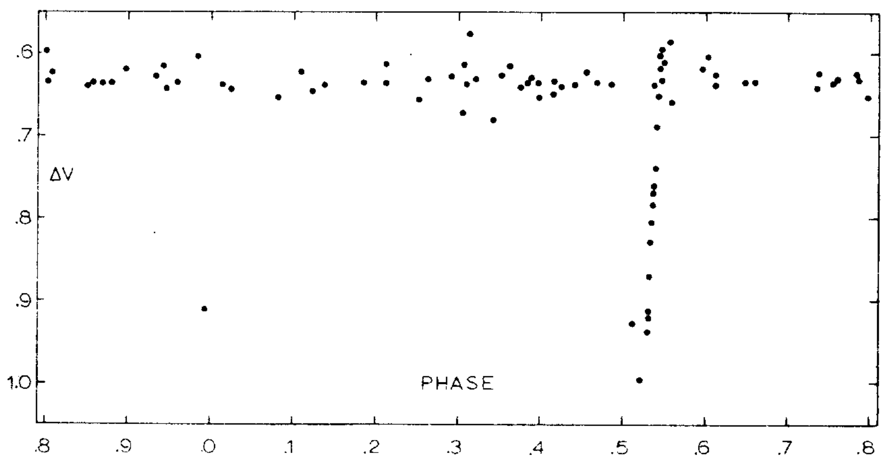

Figure 1

The light curve of HD 219989 in V based on the orbital period of 20.8529 days. Note secondary eclipse is displaced. The full depth of primary eclipse, not seen here, is 0.55 magnitude.

ential measures made on the same night, and phase has been computed with the ephemeris in equation (1). The differential magnitudes of Crawford, who used a different comparison star, are not plotted.

Of all four eclipse shoulders, fourth contact of secondary is defined best. Scrutiny of that shoulder indicates that the phase of external contact is approximately $0^{p}.015$. Thus the total duration of (either primary or secondary) eclipse, from first to fourth contact, is $D = 0^{P}.03 = 15$ hours. The displacement of secondary corresponds to $e \cos \omega = 0.03$.

It is ironic that in 1967 two other astronomers began a determination of the light curve of AN And using the same comparison star which Crawford used, namely HD 219989. It was explained by Tremko and Bakos (1978) that they made regular differential measures between HD 219989 and two check stars but found no indication that the former was variable. Indeed, their light curve of AN And showed only relatively small ($\sim 0^{m}.05$) photometric anomalies, certainly none which should have resulted from the relatively deep ($0^{m}.55$ for primary and $0^{m}.38$ for secondary) eclipses of their comparison star. A tally of the 72 nights they observed between 1967 and 1977 was published in Table 1 of Bakos and Tremko (1981). From this list we can compute phases with our ephemeris in equation (1). The results

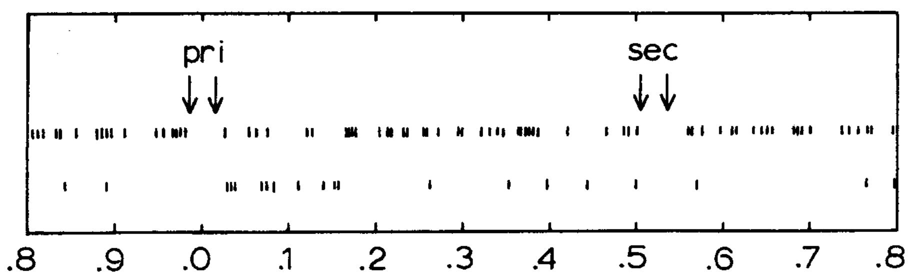

Figure 2

The 72 nights observed by Bakos and Tremko and the 20 nights observed by Crawford, when HD 219989 was NOT found in eclipse. Phases are computed with the ephemeris in our equation (1) and arrows mark the external contact points for primary and secondary eclipse.

are shown in Figure 2. It seems Bakos and Tremko were very fortunate. First, because of the Algol-type shape of the light curve of HD 219989, it maintains nearly constant brightness when it is NOT eclipsing, thereby serving as an adequate comparison star. Second, as Figure 2 shows, none of their 72 nights of observation fall within either primary or secondary eclipse. (For a binary which undergoes eclipse during 6% of its orbital cycle, anyone observing it on 72 randomly selected nights should have encountered it in eclipse on 4 or 5 nights; they were lucky not to have found it eclipsing even on one night.) The consistency implicit in Figure 2 is independent verification of the correctness of our ephemeris in equation (1).

Also plotted in Figure 2 are phases computed for the 20 nights in 1974 on which Crawford found HD 219989 not undergoing eclipse. This is additional confirmation of the correctness of our ephemeris in equation (1).

At Kitt Peak National Observatory on JD 2445593.7 Fekel obtained a spectrogram of HD 219989 and found the spectrum double-lined. The phase at that time, according to equation (1), was $0^{P}.34$, not far from quadrature. Spectroscopic observations obtained with the McDonald Observatory 2.1-meter telescope and coude spectrograph indicate a spectral type of A3 V for both components, with similar line strengths. The rotational velocities also are similar, with V sin i approximately 40 km/sec for each.

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