ACTA ASTRONOMICA
Vol. 39 (1989) pp. 333–339

Photoelectric Photometry of the Am Star HR 976 = V423 Per*

by

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Received May 22, 1989

ABSTRACT

This spectroscopic binary is the largest amplitude variable among Am stars. *UBV* observations of the star are presented. They show that in 1964 and 1965 it was constant in *B* and was only marginally variable in *U*. The hypothesis of the ellipsoidal variability of HR 976 is then discussed and found untenable. It is pointed out that this result may reopen the issue of light variability of Am stars.

1. Introduction

In an unpublished dissertation, Winzer (1974) reported finding small-amplitude light variations in at least six metallic-line (Am) stars out of twelve he observed. The periods ranged from 1.8 to 5.5 days. The largest light-ranges, amounting to $0^m.01$ in *V* and *B*, and $0^m.03$ in *U*, he found for HR 976 = V423 Per.

As most Am stars, HR 976 is a spectroscopic binary (Harper 1932, 1935). Using Harper's and their own radial-velocity data, Abt and Levy (1976) derived improved elements of the system, including the epoch of maximum velocity, JD 2426482.66 ± 0.010, and the orbital period, $P_{orb} = 5.543491 \pm 0.000008$ days. This allowed them to calculate accurate orbital phases of Winzer's (1974) observations. From a comparison of the *U* magnitudes with the radial-velocity data, Abt and Levy (1976) were then able to conclude that HR 976 shows a relationship between the light and velocity curves which is typical of ellipsoidal variables, and that the light range is reasonable for the observed period.

This interpretation of HR 976 as an ellipsoidal variable has been recently challenged by Morris (1985) on the grounds that the light curve on which Abt

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* Based on data obtained at Lowell Observatory.

and Levy (1976) based their conclusion does not appear ellipsoidal in nature. Morris (1985) points out that more photometry is needed to settle the issue.

HR 976 was observed by the writer in 1964 and 1965 at Lowell Observatory. In the present not these observations are reported and used to discuss the question of the star's light variability.

2. Observations

The star was observed with the Lowell Observatory's 21-inch reflecting telescope and the old Solar Variation equipment (see Jerzykiewicz and Serkowski 1966). The equipment consisted of a one-channel photometer, a General Radio DC amplifier and a Brown recording potentiometer. The photometer contained a set of standard *UBV* filters. An EMI 6256 S multiplier phototube, operated at ambient temperature, served as the detector.

The differential observations of HR 976 were made on 13 nights between early November 1964 and the middle of February 1965, and on four nights in September 1965. On eight nights the star was observed with the *B* filter only. In each filter, an observation consisted of 2 to 6 sequences of 30-second deflections, taken according to the following scheme:

$$\ldots\text{sky} \quad C_1 \quad P \quad \text{sky} \quad P \quad C_2 \quad \text{sky} \quad C_2 \quad C_1 \quad \text{sky}\ldots, \qquad (1)$$

where P represents the program star, HR 976, while C_1 and C_2, the comparison stars, HR 1019 and HR 975, respectively.

In addition to the differential observations, HR 975, HR 976, and HR 1019 were directly compared with primary standards of the *UBV* system on three nights in October 1965. These observations, reduced in the usual way, yielded the magnitudes and colour indices given in Table 1. The MK spectral types of

Table 1

The magnitudes and colour indices of the program and comparison stars on the *UBV* system

HR	V	$B-V$	$U-B$	*Spectral type*
975	6.301	0.370	−0.031	F4 V
976	6.252	0.266	0.102	Am(K/H/M = A2/A9/F2)
1019	5.782	−0.016	−0.166	A0 V

the comparison stars in the last column of the table are from Hoffleit (198 and that of the program star, from Abt and Levy (1976).

As in the case of other Am stars, the hydrogen line spectral type of HR 9 is approximately consistent with its $B-V$ colour index. However, the spect type also indicates very pronounced metallicity. It is therefore somew surprising that on the two-colour diagram (FitzGerald 1970), Table 1 colour indices place HR 976 only $0^m.01$ below the main-sequence line.

Photometric reductions of the differential observations consisted in deriving differential magnitudes, ΔP = "P *minus* a mean of C_1 and C_2" and ΔC = "C_1 *minus* C_2", corrected for the effect of atmospheric extinction and transformed to the *UBV* system. The extinction and transformation corrections were very small. Mean *UBV* magnitudes of the program and first comparison star were then computed from the mean differential magnitudes and the suitable magnitudes and colour indices of Table 1. The results are listed in Table 2. The number of sequences (1), used to form the means, is given in the last column.

Table 2

The *UBV* magnitudes of P = HR 976 and C_1 = HR 1019 derived from the differential observations

JD 2430000+	*U*		*B*		*V*		*N*
	P	C_1	*P*	C_1	*P*	C_1	
$8701^d.798$					$6^m.250$	$5^m.784$	6
.819			$6^m.520$	$5^m.773$			5
.834	$6^m.621$	$5^m.606$					3
8704.828			6.518	5.768			6
8705.826			6.520	5.772			6
8736.714					6.252	5.778	4
.730			6.517	5.770			4
.749	6.614	5.608					5
8737.744			6.519	5.769			6
8740.714			6.521	5.766			6
.738	6.621	5.602					5
8762.659			6.521	5.766			6
8769.650			6.516	5.767			6
.679	6.614	5.606					6
8784.596			6.518	5.769			5
.623	6.618	5.604					5
8786.622			6.516	5.767			4
8789.603			6.518	5.768			4
8794.598			6.520	5.767			5
8803.597			6.518	5.768			5
9017.983					6.253	5.784	2
.997			6.514	5.775			3
9018.994					6.244	5.792	2
9019.007			6.517	5.768			2
9027.971					6.246	5.787	3
.987			6.515	5.773			2
9028.000	6.615	5.605					2
9034.958	6.614	5.606					3

The mean standard deviations of ΔP and ΔC, computed from the scatter around the nightly means, amount to $0^m.0018$ and $0^m.0021$, respectively. These numbers can be used to estimate the internal mean errors of the *UBV* magnitudes listed in Table 2.

3. Ellipsoidal light variation of HR 976

3.1. Observed upper limits of the amplitude of the ellipsoidal variation

The *B* magnitudes of HR 976 and HR 1019, derived from the differential observations, are plotted in Fig. 1 as a function of orbital phase, counted from the epoch of maximum velocity. As can be seen from the figure, both stars

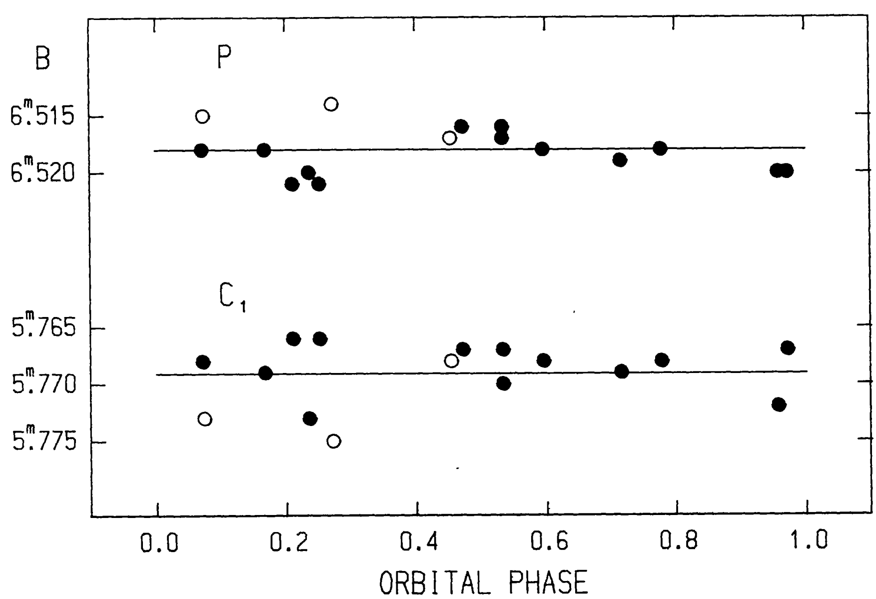

Fig. 1. The *B* magnitudes of P = HR 976 (top) and C_1 = HR 1019 (bottom), derived from the differential observations, shown as a function of phase of the orbital period. Phase zero corresponds to the epoch of maximum velocity, JD 2426482.66. Open circles denote September 1965 data. The mean level lines are also shown.

appear to be constant. The mean level lines fit the *B* magnitudes of the program and comparison star with standard deviations equal to $0^m.0021$ and $0^m.0027$, respectively. Although these numbers are somewhat greater than what one would expect from the internal mean errors mentioned in the preceding chapter, they are nonetheless typical of night-to-night scatter of good quality photoelectric photometry.

The *U* magnitudes of HR 976 and HR 1019 are plotted in Fig. 2. In this case, the mean level lines fit the program and comparison star magnitudes with

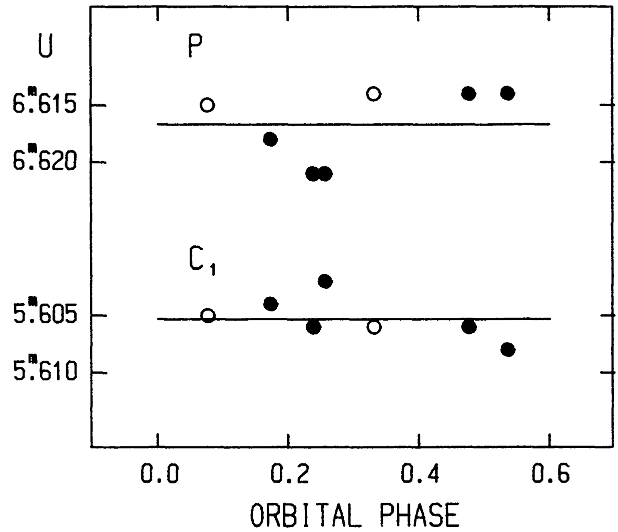

Fig. 2. The U magnitudes of P = HR 976 (top) and C_1 = HR 1019 (bottom), derived from the differential observations, shown as a function of phase of the orbital period. Phase zero and symbols are the same as in Fig. 1. Note the limited phase coverage.

standard deviations equal to $0^m.0033$ and $0^m.0019$, respectively. Thus, the U data indicate a marginal variation of HR 976.

According to Abt and Levy (1976), the orbit of HR 976 is very nearly circular. An ellipsoidal light curve would therefore have the form of a $P_{orb}/2$ wave with maxima at the epochs of maximum and minimum velocity.

Fitting a $P_{orb}/2$ sinusoid with a maximum at the phase of maximum velocity to all B magnitudes of HR 976 results in a standard deviation of $0^m.0021$ and an amplitude (half range) of $0^m.0007 \pm 0^m.0006$. These numbers, however, are strongly affected by one point at phase 0.27 (see Fig. 1, top). If this point were omitted, the standard deviation would be reduced to $0^m.0016$, and the amplitude would increase to $0^m.0012 \pm 0^m.0005$. Unfortunately, there is not much justification for rejecting this particular point, except that the corresponding B magnitude of HR 1019 (Fig. 1, bottom) shows the largest deviation from the mean level line. However, this deviation is not very large. Thus, $0^m.0012 \pm 0^m.0005$ cannot be regarded as an estimate of the amplitude of the ellipsoidal variation of HR 976 in the B band, but rather as an estimate of the upper limit of this amplitude.

In the case of the U magnitudes, a $P_{orb}/2$ sinusoid with maximum at the phase of maximum velocity fits the data with a standard deviation of $0^m.0021$, and has an amplitude equal to $0^m.0030 \pm 0^m.0010$. The latter value provides an estimate of the upper limit of the amplitude of the ellipsoidal variation of HR 976 in the U band. However, in view of the small number of data points and inadequate phase coverage, it is probably less secure than its formal mean error would indicate.

3.2. Expected ellipsoidal light variation of HR 976

The upper limits, derived in the preceding paragraph from the 1964 and 1965 observations, are much smaller than the B and U amplitudes, reported by Winzer (1974) and attributed to ellipsoidal variability by Abt and Levy (1976). We shall now show that the amplitude of a light variation resulting from the tidal distortion of HR 976 must be even smaller.

In the lowest order approximation, certainly adequate in the present case, amplitude of the light variation due to aspect changes of the tidally distorted primary can be expressed by means of the following formula:

$$\delta m = 1.6 A_\lambda q (R/a)^3 \sin^2 i, \tag{2}$$

where A_λ is the photometric distortion parameter of Russell and Merrill (1952), q is the mass ratio of the components, R is the polar radius of the primary, a is the separation of the components, and i is the inclination of the orbit to the tangent plane of the sky.

As has been found by Abt and Levy (1976), the secondary component is much fainter than the primary. Consequently, its contribution to the ellipsoidal variation can be neglected.

In agreement with the hydrogen line spectral type, quoted in Table 1, we shall now assume that the primary component's mass and radius are those of a late A type star. Assuming further that $A_\lambda < 1.3$ (see, for example, Ruciński 1969), and making use of the orbital elements of Abt and Levy (1976), we find from Eq. (2) that $\delta m < 0^m.0006$.

4. Conclusions

Our 1964 and 1965 photoelectric observations of HR 976 do not show variations seen later by Winzer (1974). In fact, we find the star to be constant in B and only marginally variable in U. The observations set upper limits for the amplitude of a $P_{orb}/2$ variation, namely, $0^m.0012 \pm 0^m.0005$ in B, and $0^m.0030 \pm 0^m.0010$ in U. These values are much smaller than the amplitudes reported by Winzer (1974). Furthermore, it is shown that the amplitude of a light variation caused by the tidal distortion of HR 976 must be even smaller. Thus, Abt and Levy's (1976) hypothesis that HR 976 is an ellipsoidal variable is not confirmed.

Abt and Levy (1976) have conjectured that the other Am stars, discovered to be variable by Winzer (1974), are also ellipsoidal variables. In view of the above result this conjecture becomes unfounded, and therefore a different explanation of Winzer's (1974) observations will have to be found. The outcome of the present investigation is thus somewhat paradoxical: by failing to discover light variations of HR 976 we may have reopened the issue of variability of Am stars.

Acknowledgement. This work was partly supported by a grant from the Polish Academy of Sciences Project CPBP-01.11.

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