THE UNUSUAL CLASSICAL CEPHEID HR 7308: 1966-1969

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ABSTRACT

The small-amplitude classical cepheid HR 7308 has the shortest period known in our Galaxy for a classical cepheid. 1966-1969 photoelectric observations together with more recent data show a period of $1\overset{d}{.}49078$ with sinusoidal light variations. Except for the presence of the beat period, no secondary period can be found in the extensive 1966 data. The lack of a secondary period near $P_1/P_0 = 0.7$ sets HR 7308 apart from many other short-period classical cepheids.

The amplitude of HR 7308 varies an a timescale near 970 days. The variations may be periodic. The available data do not at present allow us to distinguish between the Blazhko Effect (modulation of a regular variation) and a model with two very close interfering periods in HR 7308.

The variability of the star HR 7308 was discovered by Breger (1969) as part of a general survey of the lower instability strip. The details of the variability of HR 7308 were not published due to the variable amplitude from 1966 to 1967, which suggested further study. Percy, Baskerville and Trevorrow (1979) rediscovered the variability and reported a period near 3 days with a reasonable fit. The more detailed radial velocity observations of Burki and Mayor (1980) established a period near $1\overset{d}{.}49107$, which fits Percy's data as well (see previous papers on HR 7308 in this volume). This period makes HR 7308 the shortest period classical cepheid found in our Galaxy so far. Furthermore, the variable amplitude is unusual, suggesting a Blazhko Effect (also observed in RR Lyrae variables but not cepheids) or the witnessing of a unique evolutionary event.

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Our older unpublished Lick observations may shed some light on the properties of HR 7308. This photoelectric data is of very high accuracy, ± $0\overset{m}{.}003$ per point, as judged from the comparison stars. The primary comparison star used was HR 7280, while HR 7364 was utilized to verify the constancy of the primary comparison star periodically.

The 1966 data is extensive enough to attempt to search for multiple periods. We have applied the MULTIPER program (Breger 1980), which searches for several periods simultaneously without prewhitening. Only a single period could be found for the time period June-August, 1966. In particular, no secondary periods with a period ratio near 0.7 could be found. This period ratio has been detected in other short-period classical cepheids such as TU Cas and V439 Oph. Furthermore, the analysis showed that during June-August, 1966 the amplitude of HR 7308 was constant, viz. $0\overset{m}{.}06$ in V. We speculate that the star was in a long and shallow minimum amplitude during this time period.

One year later, in 1967, the amplitude of HR 7308 had increased from $0\overset{m}{.}06$ to $0\overset{m}{.}17$. While the 1967 photoelectric observations are not sufficient in number to check on any small changes in period, they do indicate a period near $1\overset{d}{.}49$, in agreement with the previous observations. The observations are shown in Figure 1 with a period of

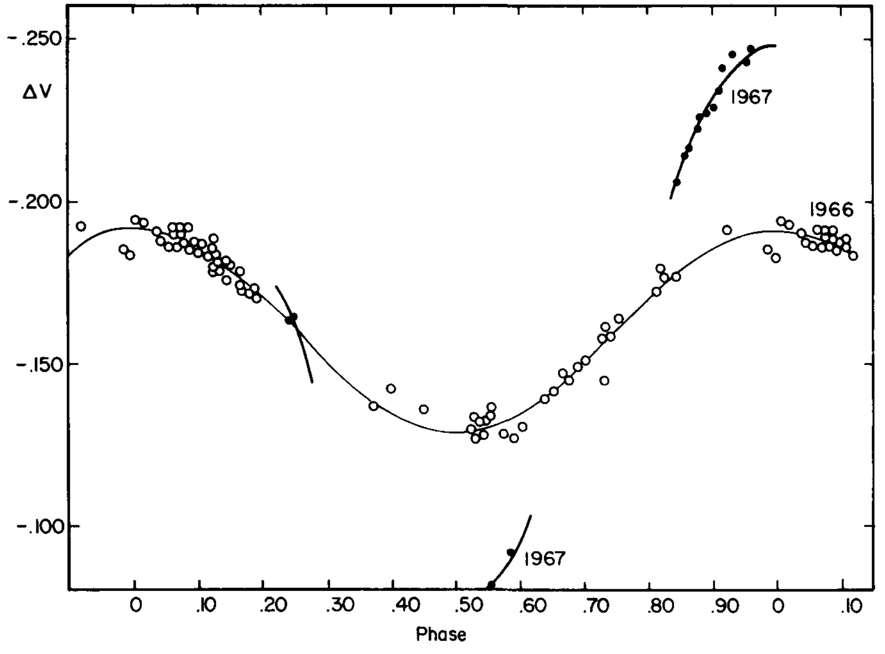

Figure 1 - Observed Variations of HR 7308 in 1966 and 1967. The curves represent sinusoidal variations derived from the ephemeris given in the text.

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$1\overset{d}{.}49078$, which we derive from all the available photometric data. During 1969, observations also obtained at Lick Observatory show that the amplitude had again decreased during the five nights of observation. The relatively long period of 1.5 days makes it impossible to cover a complete cycle from one observing sight alone. Consequently, nightly amplitudes must be derived from a portion of the cycle only. Fortunately, the overall solution for all the 1966 observations shows that a sine curve with a constant amplitude fits the observations well to $\pm\ 0\overset{m}{.}003$ per observation. We have derived nightly amplitudes (Table 1) from the following ephemeris:

$$\text{HJD of maximum light} = 243\ 9320\overset{d}{.}6859 + 1\overset{d}{.}49078.E$$

The derived amplitudes are relatively insensitive to phasing.

The constancy of the amplitude during three months in 1966 indicates that the amplitude variation of HR 7308 is relatively slow. About ten years later, the slow change is also seen in the extensive radial velocity data by Burki and Mayor. When we extend Table 1 to include similarly derived amplitudes from data by Percy and Evans (1980) and our unpublished 1980 observations, a timescale of 970 ± 40 days is found. At this time we do not know whether or not the amplitude variation is strictly periodic.

The repetitive decrease and increase of the pulsation amplitude rules out an explanation in terms of "permanent" evolutionary changes in HR 7308. The extreme amplitude variations must be considered normal behavior for this star, though extremely unusual for classical cepheids. A group of short-period variable stars, where amplitude variations occur on a similar timescale of P(pulsation)/P(beat) $\sim$ 600 are the RR Lyrae stars, where these variations are known as the Blazhko Effect. (We prefer not to use the term Blazhko Effect for the variations in stars like the large-amplitude Delta Scuti stars, where the simultaneous excitation of two pulsation modes with a period ratio near 0.76 leads to perfectly predictable and easily understood variations in the observed light curve.)

An alternative explanation for sinusoidal variations with a variable amplitude involves the simultaneous excitation of two pulsation modes with very close periods of $P_1/P_0 = 0.999$. This would also be unusual behavior for a classical cepheid. The superposition of these two sinusoidal pulsation modes would lead to an observed cycle-count period near P_0 and P_1 (i.e. $1\overset{d}{.}49$) and a longer beat period of 1000 days. Furthermore, slight phase jitter in the shorter period might be observed. To distinguish observationally between the variable-amplitude and the two-close-periods model requires extensive amounts of accurate data and lengthy analyses. Our analysis of this interesting star is proceeding and the results will be published in more detail at a later time.

TABLE 1

V AMPLITUDES OF HR 7308 FROM 1966-1969
(P = $1^{d}_{\cdot}49078$)

Year	Julian Date (days)	Peak-to-Peak Amplitude (magnitudes)
	243 0000+	
1966	9289	0.063 ± 0.003
	9303	0.063 ± 0.002
	9306	(0.057)± 0.007
	9308	(0.045)± 0.007
	9317	(0.051)± 0.006
	9319	0.073 ± 0.007
	9321	0.060 ± 0.003
	9323	(0.069)± 0.008
	9324	0.063 ± 0.005
	9359	0.064 ± 0.003
	9370	(0.073)± 0.007
1967	9680	0.171 ± 0.002
	9681	(0.172)± 0.006
	9684	(0.165)± 0.007
1969	10362	0.040 ± 0.004
	10363	0.041 ± 0.007
	10365	0.035 ± 0.005
	10367	(0.038)± 0.007

Notes to Table 1:

Uncertainties of amplitudes were determined from the scatter of the predicted amplitudes from all observations during each particular night. Where only single observations are available (bracketed values), an observational error of $\pm 0^{m}_{\cdot}003$ was assumed.

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DISCUSSION

FITCH: When we were doing RR Lyrae survey work, according to the GCVS there were some stars that were called RR Lyrae stars with a period of 1.2 days. If you called this star an RR Lyrae variable, its behavior would not be terribly peculiar.

PERCY: I guess you might call it a BL Herculis star, but then it seems to be a population I object.

A. COX: Yes, but so does BL Her.

PERCY: I wasn't aware that the BL Herculis stars did this sort of thing.

COGAN: Could you say a little more specifically how the reddening was determined and how accurately?

PERCY: I think I should ask Don Fernie to answer that question since it came from one of his papers.

FERNIE: I don't recall actually determining the reddening, but if I did I would have used the B-V, R-I diagram. I would think it is good to $0\overset{m}{.}05$.

BREGER: That reddening is quite consistent with its spectral type and the B-V color of the star.

COGAN: My reason for asking is that, as you point out, the region of instability gets quite narrow down there and, therefore, to be able to talk about being on the red edge or the blue edge you need to know the reddening to quite good precision.

PERCY: That is true. If you project the red edge downward, then it seems to lie fairly close to that.

A. COX: What do you get for the theoretical blue edge? Is it nearby?

PERCY: I am just remembering Dr. Stobie's diagram from this morning and this seems to indicate that with a lot more stars the red and blue edges are quite close together at that point. This is why I am uncertain as to whether it is on the red edge or the blue edge.

SIMON: Could there be another period?

STELLINGWERF: Maybe it is a double mode Cepheid and they just haven't picked up two modes and the power is switching back and forth.

PERCY: Over a few cycles it fits very nicely to a single period.

STELLINGWERF: The question is has that period changed by a factor of 0.7 or something over the course of a year?

PERCY: No. Over the whole summer of 1979 we could put all of our points together with the amplitude of 0.06 and the scatter was purely observational.

A. COX: Sometime ago Sweigart and Renzini proposed that RR Lyrae stars could change their periods by an adjustment of the semiconvection zone. Do you believe that could be possible in this case?

PERCY: I really would like to get all of the observations together from the past fifteen years. What we have now is suggestive of a period change, but it is not definitive.

SIMON: An old idea that I thought about and struggled with, as did John Cox to some extent, involved an interaction between the pulsation and the structure such that the pulsation slowly changes the structure. Maybe some stars, including RR Lyrae stars, are doing this. The time scale might be of the order of what is being observed here.

COGAN: Does anyone have any theoretical ideas of how one can have a beat period a thousand times as long as the fundamental period?

FITCH: That is a little long, but it is the same order of magnitude as the Blazhko effect in RR Lyrae stars. Nobody has a good explanation of it.

SIMON: Could the period be going up and down, or is that excluded?

BREGER: The period may change over the beat period as Percy indicates, but I don't think it changes over fifteen years.

SAREYAN: Do you think that the beat could be related to the one observed in 16 Lac?

BREGER: I don't know. The assumption is the same. We do have a decreasing amplitude. Maybe we have a phenomenon which occurs with the RR Lyrae stars, some β-Cephei stars, and at least one or more Cepheids.

STELLINGWERF: RR Lyrae does a very similar thing on a two year period. The 41 day cycle oscillates with an overall amplitude variation. There may be some relation there.

ROBINSON: The specific difference between amplitude change and the beat between two periods is that an amplitude change won't give you the phase residual.

BREGER: Exactly, and we have the phase residual. This is why I like the two frequency hypothesis. The only thing that prevents me from saying that the two close periods give me the answer is that I still do not have the residuals using Percy's data and my data down to the precision that I want. It may come out, given time. I am off by 0.4 per cycle in the 1969 data using the best period from everything. That change in phase is exactly what you expect with the two frequencies that the computer gave me.

PERCY: But to push it one step further, if you want a nonsymmetric modulation you need more than two frequencies.

BREGER: If it is a nonsymmetric modulation.

PERCY: I think that is clear both from the radial velocities and the light amplitude.