HR 7308: A UNIQUE CEPHEID[+]

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ABSTRACT

We have obtained photometric observations and radial velocities of the F6I-IIb star HR 7308. The spectral type, the period ($1^d.49$), the relative range and phase of light, colour and velocity variations all suggest that the star is a small-amplitude Cepheid. The metal abundance appears to be normal. However, the light amplitude decreased slowly during 1978 from $0^m.3$ to $0^m.1$, and increased during 1979 and 1980 from $0^m.05$ to $0^m.15$. Such behaviour is unprecedented in a population I Cepheid.

INTRODUCTION

The variability of HR 7308 (HD 180583, F6 I-IIb, $m_V = 5.93$) was discovered by Breger (1969) in the course of a survey of δ Scuti variable stars. He commented that the variability was semi-regular, and he did not derive a period. Percy et al. (1979), unaware at the time that HR 7308 appeared in Breger's survey, rediscovered the variability. They derived a period of $3^d.040$ and a range of $0^m.33$ and $0^m.24$ in B and V respectively. [As will be shown, the resonance period $1^d.49$ fits these data equally well.] In any case, it appeared that HR 7308 was a typical, small-amplitude Cepheid.

Percy et al. (1979) noted one small discrepancy: a single observation, obtained in October 1978 at Kitt Peak National Observatory, did not fit the light curve. This discrepancy was attributed to light cloud. In fact it was due to the remarkable behaviour of the star itself, as described in the following sections. This behaviour has been independently discovered by Burki and Mayor (1980a, 1980b), in a study which demonstrates the power of the CORAVEL radial velocity spectrophotometer. These authors show convincingly that the period is $1^d.49107$, and that the 3^d period is a spurious one.

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NEW PHOTOMETRIC OBSERVATIONS

New photometric observations were made in the summer of 1979 by Douglas L. Welch using the University of Toronto 0.4 m telescope as described by Percy *et al.* (1979). These observations were made through a Johnson *V* filter only, their initial purpose being to refine the period. Although these observations could be fitted with a period near $3^d_.040$ (or $1^d_.49$), the range was only $0^m_.06$!

Further observations were therefore made in the autumn of 1979 by Percy, using the #4 0.4 m telescope at Kitt Peak National Observatory. These observations were made through a Strömgren *y* filter, which closely approximates a Johnson *V* filter for the purpose of this analysis. The comparison stars were HR 7280 and HR 7305. The phase coverage was poor because of the value of the period, but the range was apparently still rather small. Observations were also made in the summer of 1980 by Welch, using the University of Toronto 0.4 m telescope as described above.

SPECTROSCOPIC OBSERVATIONS

Nine spectrograms of HR 7308 with a reciprocal dispersion of 12 Å mm^{-1} were obtained with the Cassegrain spectrograph on the 1.88 m telescope at the David Dunlap Observatory. The plates were vacuum sensitized IIa-0 plates covering the wavelength range 3700 to 4930 Å. The projected slit width on all plates was either 22 or 28 μm (except that it was 36 μm for plate 43781) and the spectra were widened to 0.3 or 0.5 mm. The plates were measured for radial velocity on the PDS microdensitometer at the observatory and reduced in the manner described by Lane and Percy (1979). The reduction program fits a parabola by least squares to a region around the minimum density in the line core, up to half the line depth. Approximately 22 lines were measured on all plates from the observatory list of the best lines for G stars (Evans, 1974). For another Cepheid, seven plates were measured both on the microdensitometer and a Zeiss-Abbe comparator using the same wavelength list. The mean difference in radial velocities was only 0.1 km sec^{-1}, confirming the accuracy of the computer technique. Because of modifications made to the spectrograph, the small corrections derived from measures of I.A.U. standard velocity stars vary slightly during the season. These corrections (approximately +1 km sec^{-1}) compiled by Dr. Karl Kamper (private communication) have been added to the radial velocities.

RESULTS

The decrease in the range of the light variability during 1978 was quite pronounced, from $0^m_.3$ to $0^m_.1$. The range appeared to increase slightly during 1979, from $0^m_.05$ to $0^m_.07$, and by mid-1980 was about $0^m_.15$. However, there is no evidence that, during this time, the mean magnitude of the star changed significantly

The 1979 observations were analyzed for periodicity using Deeming's (1975) method of Fourier transform analysis for unequally spaced data. Two possible periods were found: $3^{d}.0294$ and the resonance period $1^{d}.491$. According to Burki and Mayor (1980a, 1980b), the latter period is the correct one, and this has been confirmed by the 1980 observations which are better distributed in hour angle.

The photometric observations were divided into seven groups and were phased using the period $1^{d}.49107$. The resulting phase diagram (phase _vs_ time) showed strong evidence for a period increase with $\beta \cong 10^{-6}$.

The radial velocities and the 1979 photometric observations were phased together with a period of $1^{d}.49107$. The velocity and light curves were in anti-phase and the ratio of velocity to light range $2K/\Delta V$ was about 75 km s^{-1} mag^{-1}, as is the case with other Cepheid variables.

Burki and Mayor (1980a, 1980b) have published a description of 132 radial velocity observations of HR 7308, but have not listed the individual observations. Their paper gives the velocity range during 1978 and 1979. This velocity range has been converted to a light range using $2K/\Delta V = 75$ and the resulting values have been compared with the actual light range. The close agreement confirms the value of $2K/\Delta V$ given above and also demonstrates the constancy of $2K/\Delta V$ during the interval when 2K and ΔV were changing.

DISCUSSION

The question of the period of HR 7308 has apparently been resolved by Burki and Mayor (1980a, 1980b) and by our 1980 photometric observations. Burki and Mayor derived a period of $1^{d}.49107$ and we will adopt this value.

Despite the rather short period (the shortest of any known classical Cepheid) the star is probably a _bona fide_ small-amplitude Cepheid. Its spectral type, period, relative range and phase of light, colour and velocity all fit this classification. Furthermore there is no reason to believe that the star is not a _population I_ Cepheid. One of us (NRE) has examined metallicity-sensitive line ratios in a tracing of the spectrum of HR 7308; these indicate that the metallicity is normal.

If this is the case, then the slow change of amplitude in HR 7308 is unique. Some other Cepheids show a beat effect, on a time scale of 10-20 days, but no other population I Cepheid has changed its amplitude on a time scale of months or years. At least one population II Cepheid [RU Cam, Demers and Fernie (1966)] has shown such behaviour, but this is less surprising in population II Cepheids, which are believed to be in a more rapid phase of evolution. The cause of the amplitude decrease in HR 7308 is not certain.

The M_V of HR 7308 is fainter than -2.3 according to Burki and Mayor (1980b). This and the intrinsic colour ((B-V) = 0.66, E(B-V) = 0.16, $(B-V)_0 = 0.50 \pm 0.05$; Fernie (1972)) and period ($1^d.49$) place it at the extreme right edge of the Cepheid instability strip (Stobie, 1969a,b, for instance). The time scale of the decrease in amplitude is not inconsistent with the theoretical decay time for non-linear pulsations of Cepheid models. However, the comparisons between observation and theory is complicated by the fact that convection is important in stars near the red edge of the Cepheid instability strip, and extensive pulsation calculations including convection have yet to be made. Nevertheless, it is quite possible that the unique behaviour of HR 7308 is connected with its position at the extreme red edge of the instability strip. On the other hand, there is mounting evidence (M. Breger, private communication; G. Henriksson, private communication via R. S. Stobie) that the long-term behaviour of HR 7308 may be periodic with a period of about three years. The cause of such behaviour is not at all clear.

Note that it is possible that a small change in period in HR 7308 may occur due to the non-linear effect of a change in amplitude. Effects of this type are predicted to occur (Cox et al., 1978), but the magnitude of the effects is uncertain. A more detailed study of the star would be worthwhile in order to search for such an effect.

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