12-1989

HR Aurigae: An Active Binary ?

Charles G. Loomis
NASAIGoddard Space Flight Center

Edward G. Schmidt
University of Nebraska at Lincoln, eschmidt1@unl.edu

THE ASTROPHYSICAL JOURNAL, 347:L77–L79, 1989 December 15

HR AURIGAE: AN ACTIVE BINARY?

CHARLES G. LOOMIS AND EDWARD G. SCHMIDT
Behlen Observatory, Department of Physics and Astronomy, University of Nebraska-Lincoln
Received 1989 July 19; accepted 1989 October 6

ABSTRACT

Photometric and spectral observations of the variable star HR Aurigae are presented. Based on these data we conclude that this star, previously regarded as a type II Cepheid, is, in fact, an active binary.

Subject headings: stars: eclipsing binaries — stars: variables

I. INTRODUCTION

The variable star HR Aur, with a period of 1.63 days, has been classed as a short-period type II Cepheid (CWB) (Kholopov 1985, hereafter GCVS; Harris 1985). However, early studies revealed a light curve which was unusual for a pulsating star (Tsesevich 1957; Kholopov 1969, 1971); rising light is appreciably slower than declining light and the light curve is quite flat-topped. A single spectrogram was obtained by Vitrichenko (1970) who gave a spectral type, G0 I, inconsistent with a W Vir star but a velocity, $+85$ km s^{-1}, appropriate for a halo star. Diethelm (1986) suggested that HR Aur is similar to V533 Cen and GR Nor based on two photometric observations. Lloyd Evans (1984) had previously classed GR Nor as a RS CVn or FK Com star due to its light curve and emission lines in its spectrum.

II. THE OBSERVATIONS

a) Photometry

Between 1986 January and 1987 March (JD 2,446,444–2,446,857), *VR* photometry was obtained with the photoelectric photometer on the Behlen Observatory 76 cm telescope. The instrument and methods used are identical to those described in Loomis, Schmidt, and Simon (1988), and the description will not be repeated. The comparison and check stars and the variable are identified with their coordinates in Table 1 since none has an SAO number. The mean magnitudes and colors, listed in Table 1, for the comparison star were derived from eight photometric nights. The differential comparisons of the check and comparison star exhibited an r.m.s. scatter of 0.0023 mag in V and 0.0038 mag in R verifying the constancy of the comparison star.

From 1988 February to October (JD 2,447,204–2,447,444), we obtained photometry of HR Aur with the CCD photometer on the Behlen Observatory 76 cm telescope. The instrument and methods will be described by Schmidt (1990) and Schmidt *et al.* (1990) and, again, will not be repeated. Unfortunately, no data for the CCD comparison star were obtained on photometric nights. Since the minimum of HR Aur had been very stable during the previous two observing seasons, we adjusted the CCD magnitudes of the variable to produce a good fit in that part of the light curve. The magnitudes and colors of the comparison star given in Table 1 were then inferred.

The light and color curves are plotted in Figure 1, while Figure 2 shows the portion of the light curves around minimum light. A table of the original data points is available from the second author by electronic mail. The intensity means of the magnitudes and color are listed in Table 1. The period from the GCVS, 1.627777 days, was used, and the epoch of minimum at was taken to be HJD 2,446,759.855.

While the light curve is very stable around minimum, other parts exhibit variations from year to year of slightly more than one-tenth of a magnitude. The scatter within a single season also exceeds the observational errors but by a lesser amount. Diethelm's (1986) two V magnitudes also fit within the scatter in our V light curve when they are rephased with the above elements.

b) Spectroscopy

To further clarify the nature of HR Aur we requested spectra from the coudé feed telescope at Kitt Peak National Observatory. The spectra were each exposed for 1 hr with a Tektronix CCD on camera 5. They covered a spectra range from 6525 Å to 6720 Å with a resolution of 0.9 Å. The times and phases are listed in Table 2. It can be seen that the series of spectra began late on the rising branch of the light curve and continued to maximum light. The comparison stars 10 Tau (F9 V), Beta Lep (G5 II), and Beta Gem (K0 IIIb) were also observed with the same spectrograph settings.

The portion of the spectra around Hα is plotted in Figure 3. Hα is strongly in emission. The peak of the emission relative to continuum, and the equivalent width above the continuum are listed in Table 2. The emission flux decreased at first but then increased toward the end of our series of spectra.

The absorption lines in HR Aur were generally stronger than in either 10 Tau or Beta Lep, and many were stronger than in Beta Gem. This indicates that the spectral type is later than G5 and possibly even later than K0 in disagreement with the type quoted by Vitrichenko (1970). Unfortunately, the signal-to-noise ratio in the HR Aur spectra, the lack of later type comparison spectra, and the spectral region observed prevent the assignment of an accurate spectral type. The lines in HR Aur were also broadened compared with the three comparison stars; the lines averaged 25 km s^{-1} wider than the average of the corresponding lines in the comparison stars.

In attempting to determine the radial velocity from six selected absorption lines, we found that the relative velocities of the three comparison stars were not consistent with their published velocities to better than 15 km s^{-1}. Nonetheless, we can safely conclude that the velocity of HR Aur increased over the interval of observation with a total range amounting to 10 km s^{-1} and a mean no larger than $+10$ km s^{-1}.

III. THE NATURE OF HR AURIGAE

Our light curve for HR Aur does not resemble those of other short-period type II Cepheids (see, for example, Kwee 1967;

TABLE 1

COMPARISON AND CHECK STARS

Star	V	s.e.	R	s.e.	$V-R$	s.e.	R.A. (2000)	Decl. (2000)
HR Aur	11.435	5	10.774	5	0.661	3	$6^h31^m13^s$	30°56′19″
Photoelectric comparison	11.073	5	10.401	5	0.672	3	6 31 18	30 53 54
Photoelectric check	8.435	6	7.791	6	0.644	4	6 30 19	30 26 50
CCD comparison	12.458	10	11.506	10	0.952	10	6 31 16	30 58 12

Diethelm 1983); rising light in HR Aur occupies about 70% of the cycle and maximum occurs at the end of the flat-topped portion of the light curve. No type II Cepheid light curve shown by Kwee or Diethelm has the very narrow minimum seen in HR Aur. The light curve of HR Aur repeats well around minimum but is unstable around maximum while the reverse

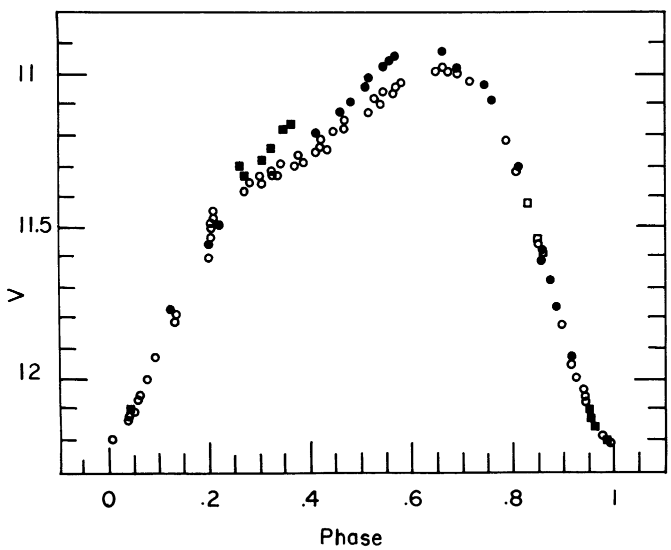

FIG. 1*a*

TABLE 2

SPECTRAL OBSERVATIONS

HJD −2,447,144	PHASE	Hα EMISSION: F(peak) / F(continuum)	Hα EMISSION: Equivalent Width (Å)
0.768..........	0.465	1.32	0.47
0.810..........	0.491	1.33	0.52
0.944..........	0.574	1.12	0.13
0.986..........	0.599	1.22	0.25
1.028..........	0.626	1.23	0.30

tends to be true of type II Cepheids (Loomis, Schmidt, and Simon 1988).

Although hydrogen emission is observed in type II Cepheids it is weak or nonexistent at periods shorter than 10 days (see, for example, Wallerstein 1958; Abt and Hardie 1960; Harris and Wallerstein 1984). Even though we have observed Hα while the cited studies refer to other Balmer lines, the strong emission over the 0.16 cycles of our spectral coverage seems inconsistent with a short-period type II Cepheid.

The velocity cited by Vitrichenko (1970) was obtained about 0.15 cycles earlier than our first spectrum. If we accept her velocity of +85 km s^{-1}, our values imply a change in velocity of 75 km s^{-1} in a quarter of the cycle. The velocity amplitudes of type II Cepheids average about 50 km s^{-1} (Harris and

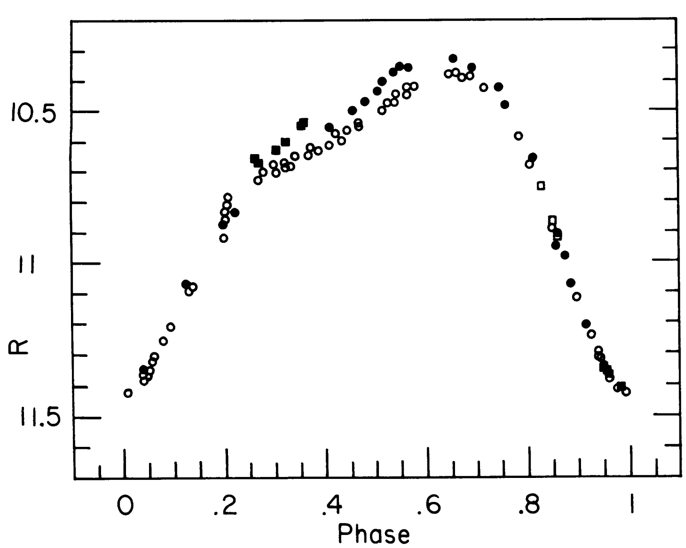

FIG. 1*b*

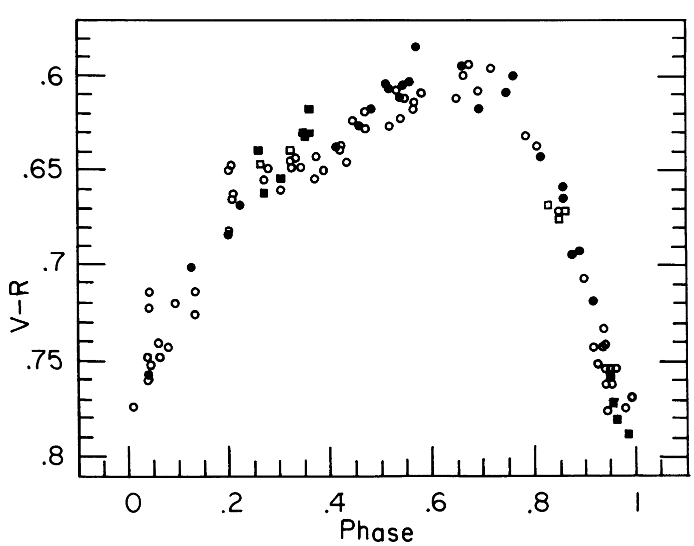

FIG. 1*c*

FIG. 1.—Light and color curves for HR Aurigae. Phases are relative to an epoch of minimum at HJD 2,446,759.855 with a period of 1.627777 days. Different seasons' observations are denoted with different symbols as follows: *solid circles*, 1986 January–April (JD 2,446,444–2,446,542); *open circles*, 1986 October–1987 March (JD 2,446,710–2,446,857); *solid squares*, 1988 February–March (JD 2,447,204–2,447,248); *open squares*, 1988 October (JD 2,447,444).

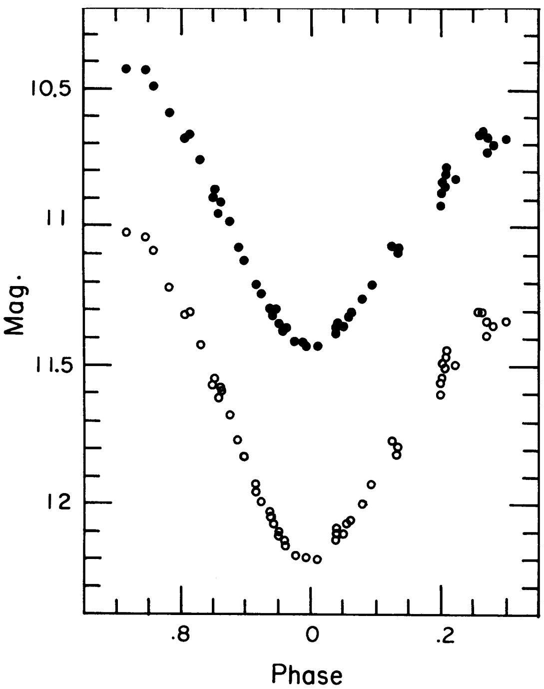

FIG. 2.—The region of the light curves around minimum light. The open circles represent the V magnitudes, and the filled circles, the R magnitudes.

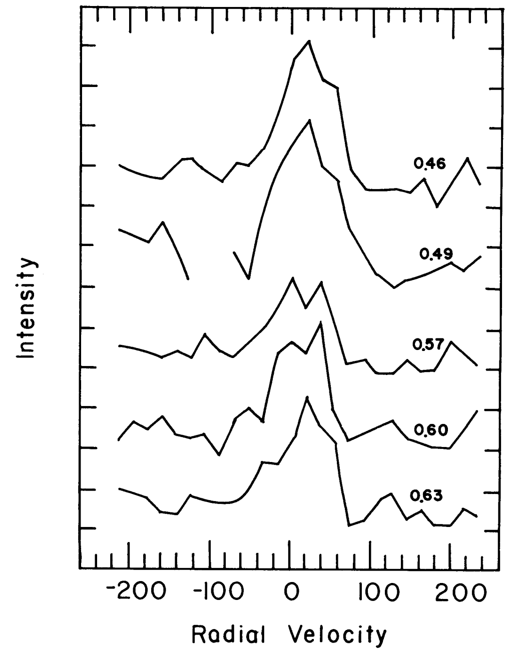

FIG. 3.—Spectra in the Hα region of HR Aurigae. The spectra are plotted with the same vertical scale, out each is displaced from the others for clarity and is labeled with the phase from Table 2. The tick marks on the left-hand axis are at intervals of 10% of continuum intensity. The gap in the spectrum at phase 0.49 is due to a cosmic-ray hit.

Wallerstein 1984), so the velocity data seem inconsistent with a type II Cepheid.

Thus, we find no observational evidence to support the classification of HR Aur as a type II Cepheid.

We suggest that HR Aur is an active binary. In that case, the relatively narrow minimum (Fig. 2) can be understood as an eclipse. A factor in favor of this is the similarity of its light curve to that shown by the RS CVn star HD 127535 at some epochs (Innis *et al.* 1985) although the amplitude of HR Aur is much larger. The presence of strong Hα emission in such stars is well known (cf. Lloyd Evans 1984), and the velocity amplitudes can be large enough to encompass both our velocity data and that of Vitrichenko. The long-term variations in the light curve are readily explained in terms of the well-known variations in the activity of such stars. The breadth of the spectral lines is explained by rapid synchronous rotation which is common in such stars.

HR Aur promises to be an interesting system in view of its large amplitude, strong emission, and broad eclipse. It deserves further detailed study.

This research was supported in part by grants AST-8504072 and AST-8815806 from the National Science Foundation. We are grateful to C. Pilachowski who carried out the spectral observations at the Kitt Peak coudé feed telescope. The reductions were carried out with the facilities of the Minnich Astronomical Computing Center which was donated by Commander C. B. Minnich. We thank Valentina Ziverts who translated several papers from Russian for us.

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CHARLES G. LOOMIS: International Ultraviolet Explorer Observatory, Code 684.9, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

EDWARD G. SCHMIDT: Behlen Observatory, Department of Physics and Astronomy, University of Nebraska, Lincoln, NE 68588-0111
[BITNET:phys055@unlcdc3]