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PHOTOMETRIC AND SPECTROSCOPIC OBSERVATIONS OF AG AND HR CARINAE*

HOWARD E. BOND

Louisiana State University Observatory

AND

ARLO U. LANDOLT

Louisiana State University Observatory
Cerro Tololo Inter-American Observatory†
La Serena, Chile

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Photometric and spectroscopic observations are presented for the two P Cygni-like slow variable stars AG and HR Carinae.

In an attempt to add to the information known about P Cygni-like stars, photometric and spectroscopic observations have been made of two little-known southern-hemisphere variable stars.

The variability of the star AG Carinae (CoD $-59^{\circ} 3430 =$ CPD $-59^{\circ} 2860 =$ HD 94910 = GC 15044; $\alpha = 10^{\text{h}}52^{\text{m}}2$, $\delta = -59^{\circ} 55'$; 1900) was discovered by Wood (1914). Mrs. Greenstein (1938) published a photographic light curve which showed that AG Car varied slowly and irregularly over a range of nearly two magnitudes. The star presents a remarkable system of a P Cygni star surrounded by a low-excitation, ring-shaped shell, first discovered by Thackeray (1950). Direct photographs of this nebula have been published by Thackeray (1956) and also by Westerlund and Henize (1967). The light curve has been updated recently by Mrs. Mayall (1969).

Hertzsprung (Hoffleit 1940) discovered the variability of HR Carinae (CoD $-59^{\circ} 3044 =$ CPD $-58^{\circ} 2145 =$ HD 90177 = GC 14276; $\alpha = 10^{\text{h}}19^{\text{m}}4$, $\delta = -59^{\circ} 07'$; 1900). The photographic light curve compiled by Miss Hoffleit (1940) showed HR Car to vary slowly by perhaps $1^{\text{m}}5$ in an irregular fashion.

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The photoelectric data reported here for AG and HR Car were obtained at the No. 2 16-inch telescope of the Cerro Tololo Inter-American Observatory in 1967. A standard set of *UBV* filters, a refrigerated 1P21 photomultiplier, and observations of numerous *UBV* standard stars (Johnson and Harris 1954) each night permitted the transfer of all data onto the *UBV* photometric system. Mean extinction coefficients were used in the data reduction process outlined by Schulte and Crawford (1961). The external probable errors of the magnitudes and color indices are less than $\pm 0^m02$ in each instance.

The *UBV* photoelectric observations are tabulated in Tables I and II, respectively, for AG and HR Car. These data are plotted in Figures 1 and 2. The average magnitudes and color indices over the 32-day interval during which the data were gathered were: AG Car, $V = 6.70$, $(B - V) = +0.58$, $(U - B) = -0.54$; HR Car, $V = 8.51$, $(B - V) = +0.87$, $(U - B) = -0.25$. The figures indicate that whereas both objects remained constant in $(B - V)$ throughout the period of study, AG Car slowly reddened in $(U - B)$ while HR Car tended to become a bit more blue. HR Car stayed constant in the V magnitude within the limits of the observational errors. On the other hand, AG Car slowly varied in V over a range of 0^m16 , and, as is evident in Figure 1, in the sense that as AG Car became fainter, it tended to become redder in $(U - B)$. The relative constancy of brightness of these two objects confirms the previous photographic investigations, which show slow change over time intervals of hundreds of days, but with some day-to-day "flickering."

Reasonably smooth, but probably meaningless, periodic light curves can be derived from the observations of AG Car by assuming any of several possible fractional-day periods. Of course, this will almost always be the case when a slowly varying star is observed only once a night. In the apparent absence of published observations, one wonders whether similar comments might apply to the half-day period for P Cygni itself found by Kharadze and Magalashvili (1967). Alexander and Wallerstein (1967) and Fernie (1969) were unable to confirm this short-period variation.

Two spectrograms each were obtained of AG and HR Car in February 1968. The Cassegrain spectrograph attached to the 36-inch reflector of the CTIO was used at a dispersion of 62 \AA/mm . The spectra extend from the Balmer limit to about $\lambda 4600$. Plate I shows a spectrogram of each star.

TABLE I
UBV OBSERVATIONS OF AG CAR

JD _⊙	V	B - V	U - B
2439500. +			
36.63281	6.64	+0 ^m 59	-0 ^m 57
37.57617	6.66	0 .57	-0 .58
38.64691	6.63	0 .58	-0 .58
41.60374	6.68	0 .58	-0 .56
41.77234	6.65	0 .55	-0 .56
42.57580	6.68	0 .58	-0 .56
51.56997	6.65	0 .58	-0 .54
52.56773	6.74	0 .62	-0 .51
53.58831	6.72	0 .60	-0 .54
54.53530	6.75	0 .57	-0 .42:
55.54174	6.71	0 .56	-0 .53
56.74237	6.72	0 .58	-0 .53
57.55388	6.74	0 .57	-0 .53
57.71014	6.75	0 .57	-0 .55
58.56175	6.70	0 .58	-0 .53
59.56240	6.73	0 .56	-0 .53
61.56918	6.73	0 .55	-0 .54
62.58198	6.72	0 .58	-0 .51
63.60247	6.79	0 .57	-0 .53
64.54739	6.70	0 .57	-0 .52
66.58281	6.64	0 .59	-0 .53
67.53667	6.68	0 .59	-0 .54
68.57503	6.69	+0 ^m 57	-0 ^m 53

Although hydrogen emission in the spectrum of AG Car was noted on objective-prism plates as early as 1892 by Mrs. Fleming (1912), Thackeray (1950) apparently was the first to observe it with a slit spectrograph. He found the spectrum to show P Cygni-type profiles (i.e., emission bordered by violet-shifted absorption) at lines of H, He I, Mg II, Si II, and Fe II. Subsequently the Mg II and Si II features disappeared (Thackeray 1956).

TABLE II
UBV OBSERVATIONS OF HR CAR

JD _☉	V	B-V	U-B
2439500. +			
36.63813	8.51	+0 ^m 86	-0 ^m 24
37.57998	8.49	0.85	-0.24
38.64346	8.49	0.86	-0.26
41.60069	8.51	0.88	-0.24
41.76928	8.49	0.85	-0.25
42.57308	8.53	0.88	-0.24
52.57177	8.54	0.89	-0.24
53.59352	8.50	0.87	-0.25
54.53803	8.56	0.85	-0.24
55.54466	8.49	0.88	-0.26
56.74534	8.50	0.87	-0.27
57.55616	8.51	0.86	-0.25
57.71320	8.52	0.86	-0.26
58.56579	8.48	0.87	-0.26
59.56512	8.49	0.89	-0.27
61.57170	8.51	0.84	-0.26
62.58400	8.53	0.88	-0.25
63.60612	8.50	0.87	-0.26
64.55009	8.50	0.86	-0.24
66.57966	8.44	0.88	-0.27
67.53400	8.51	0.88	-0.25
68.57240	8.53	+0 ^m 87	-0 ^m 26

The 1968 observations show that the spectrum has continued to change. Sharp emission lines, with sharp violet-shifted absorptions, are still present at H γ , H δ , and H ϵ . However, He I is present in absorption only, the lines being fairly sharp on one plate and weaker and more diffuse on the other; N II λ 3995 shows the same behavior. Multiplet 1 of Si II is present as very sharp emission lines. Several faint and very broad lines of [Fe II] appear also to be present in emission. The velocity differences between the emission and absorption components are approximately 110 km/sec at H γ and 60 km/sec at H δ .

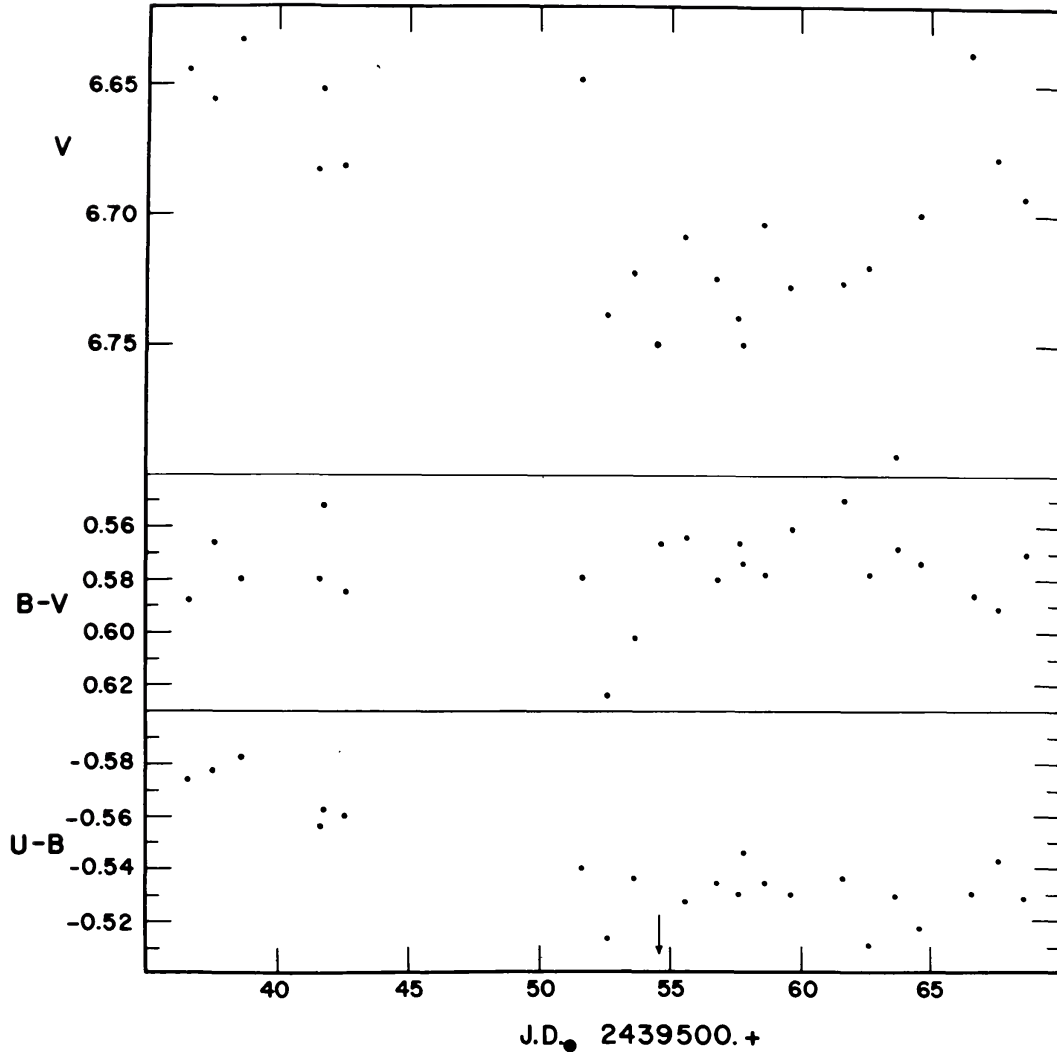


FIG. 1 — The light and color-index curves for AG Carinae.

Bright hydrogen lines in the spectrum of HR Car were discovered by Mrs. Fleming (1912) in 1901. The first slit spectrograms, obtained by Henize (1952), showed the presence of H, He I, Fe II, and [Fe II] in emission, with P Cygni-type profiles at H γ and H δ .

The 1968 spectra are rather similar to these earlier ones, except that helium now appears only as fairly sharp absorption lines. Slightly diffuse [Fe II] emission lines are present, but Fe II λ 4233, visible in emission on only one of the plates, is quite sharp. Si II multiplet 1 appears weakly in emission. Emission and absorption differ in velocity by 105 km/sec at H γ and 90 km/sec at H δ .

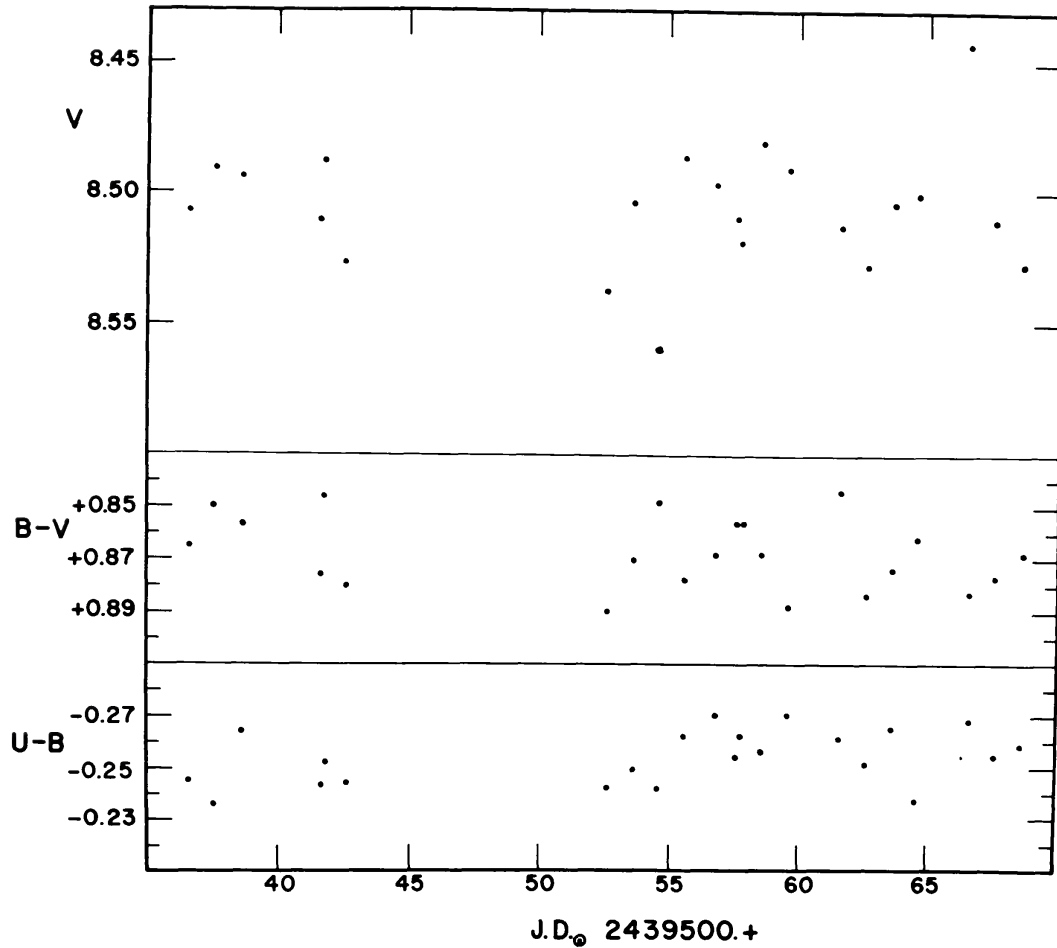


FIG. 2 — The light and color-index curves for HR Carinae.

One of the emission lines in HR Car marked in Plate I has been attributed to $[\text{Fe II}] \lambda 4352.78$. An alternative identification, as suggested by a referee, would be $\text{Fe II} \lambda 4351.76$. Although the line is surprisingly intense, we believe that the attribution to $[\text{Fe II}]$ is more plausible because (1) the line's measured wavelength in the velocity system of the other $[\text{Fe II}]$ lines is 4352.8 \AA and (2) no other lines of Fe II are definitely present on this plate. $[\text{Fe II}] \lambda 4352$ has been observed, for example, in the spectrum of χ Cygni (Merrill 1953).

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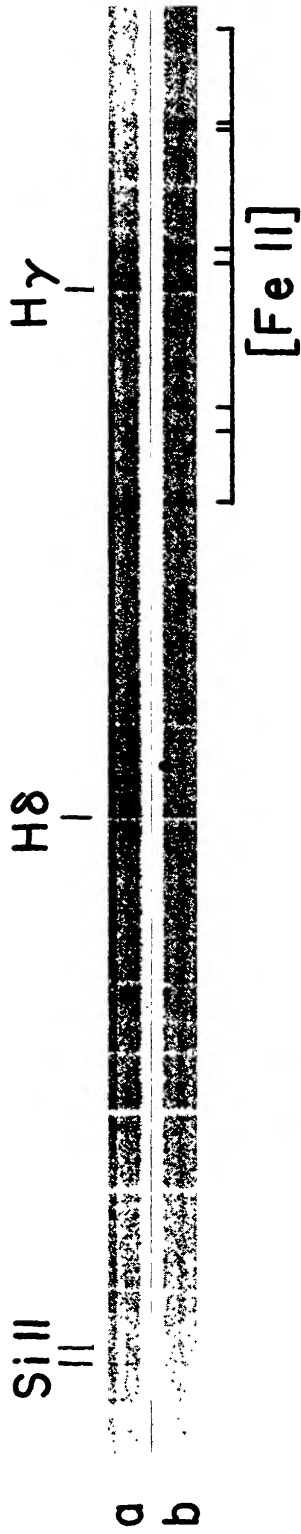


PLATE I

a) AG Carinae: Spectrogram No. 342*d*, February 8, 1968 U.T.; b) HR Carinae: Spectrogram No. 357*c*, February 13, 1968 U.T. Original dispersion 62 Å/mm, Cassegrain spectrograph, 36-inch reflector, CTIO.

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