1990PASP..102...99H

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
102: 99–101, January 1990

PHOTOMETRY OF HD 50064: A Be SUPERGIANT STAR WITH A P CYGNI PROFILE AT Hα

ELAINE M. HALBEDEL*
Corralitos Observatory, P.O. Box 16314, Las Cruces, New Mexico 88004

Received 1989 June 15, revised 1989 October 4

ABSTRACT

Photometric and spectroscopic observations of the B1 I*a* star HD 50064 (NGC 2301 No. 3) are presented. It is found to be irregularly variable and to possess a P Cygni profile at Hα. The star has been found unlikely to be an actual cluster member.

Key words: Be star–supergiant–open cluster–photometry

1. Introduction

HD 50064 was first noted to possess emission by Merrill and Burwell (1943) and denoted as MWC 536. It is the third-brightest star in NGC 2301. Spectral types for the star are rare and contradictory. Serkowski, Gehrels, and Wisniewski (1969) and Blanco *et al.* (1970) give B6 I*a*, while Svolopoulos (1962) gives B9ne, implying a lower luminosity class. The most recent spectral type is B1 I*a* (Jacoby and Hunter 1984). Its photometric history is similarly sparse, but it was placed in a catalog of suspected variable and microvariable stars (Rufener and Bartholdi 1982). Whittet and van Breda (1980) found no variability over four years in *JHKL* magnitudes. Wackerling (1970) gives it a classification of cB, thereby removing it from the classical Be stars which usually only include stars of luminosity classes III–V.

2. Photometry

HD 50064 has been observed by differential photometry primarily with the 0.6-m telescope of the Corralitos Observatory in *B* and *V* colors. The photometer used an ambient temperature EMI 9924A photomultiplier. Additional magnitudes were obtained with the Kitt Peak Observatory No. 2 0.9-m telescope and its automated filter photometer and cooled 1P21 photocathode. Comparison stars used were HD 50086 ($V = 8.226$; $(B-V) = -0.061$; B8 III, B8 V, B9 V) and HD 51596 ($V = 7.494$; $(B-V) = +0.300$; A2). These magnitudes were arrived at from all-sky photometry at the Kitt Peak telescope. They are in good agreement with previously published values for HD 50086 of $V = 8.23$ and $(B-V) = -0.06$ (Buscombe 1977). Consistency of ΔV and $\Delta(B-V)$ magnitudes between the Corralitos and Kitt Peak telescopes was good, with there being a magnitude difference of 0.003 in both ΔV and $(B-V)$ between the two. This was not considered significant. The average standard errors observed in V and $(B-V)$ for the difference in magnitude of the standard stars were 0.019 and 0.022 in V and $(B-V)$, respectively.

Thirty-two magnitudes were obtained for HD 50064 over the time period JD2446776–7594, a total of three observing seasons. These values appear in Table 1 and graphically in Figure 1, showing that the star is an active variable. The mean V magnitude of 8.209 is not dramatically different from some of those previously obtained for the star: 8.180 (Rufener and Bartholdi 1982) and 8.21 (Blanco *et al.* 1970). However, Hoag *et al.* (1961) give $V = 8.29$, considerably fainter, as does Fernie (1983) with $V = 8.30$. Therefore, it is not likely that the variability is a recent phenomenon. The behavior of the $(B-V)$ colors is somewhat ambiguous, though there seems to be a trend toward bluing when the star decreases in V magnitude. Undoubtedly, some of the scatter in the observed $(B-V)$ is a function of the unsuitability of the companion stars in terms of $(B-V)$. They are too blue for this reddened star. The total V range observed for this star was 0.270 magnitude while that of $(B-V)$ was 0.145.

A periodicity search was carried out using the discrete Fourier transform method of Deeming (1975). A range of possible periods from 0.5 to 408 days was searched. No conspicuous evidence for strict periodicity or regularity was indicated from the power spectrum. However, one must consider the cautions required in the interpretation of any period search. Deeming's algorithm selects for simple, sinusoidally based light curves, a type which HD 50064 may not possess. Short periods are not necessarily excludable due to the manner in which the observations were obtained (magnitudes from a single site at long intervals). Also, magnitudes were not treated seasonally but with equal weight.

If HD 50064 is indeed a B-type supergiant, then previ-

*Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

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1990PASP..102...99H

TABLE 1

Photometry for HD 50064

HJD	V	B-V
6776.8755	8.126	0.842
6799.7878	8.284	0.810
6816.7466	8.222	0.835
6833.7487	8.023	0.82
6868.747	8.155	0.734
6869.6289	8.140	0.759
7087.9774	8.242	0.822
7167.8204	8.215	0.800
7173.7391	8.253	0.836
7182.8515	8.231	0.800
7185.8341	8.231	0.856
7211.7181	8.194	0.817
7230.7071	8.166	0.873
7234.7165	8.206	0.827
7236.7052	8.215	0.846
7259.6344	8.212	0.835
7472.9048	8.206	0.790
7474.8938	8.217	0.818
7475.8515	8.224	0.786
7478.8629	8.247	0.802
7516.8085	8.227	0.779
7516.8161	8.238	
7525.8878	8.219	0.799
7526.7715	8.219	0.813
7540.7842	8.103	0.743
7540.8315	8.128	0.757
7560.7045	8.259	0.785
7591.7004	8.283	0.770
7591.7032	8.276	0.879
7592.6514	8.277	0.840
7593.6808	8.293	0.781
7594.6245	8.154	0.818

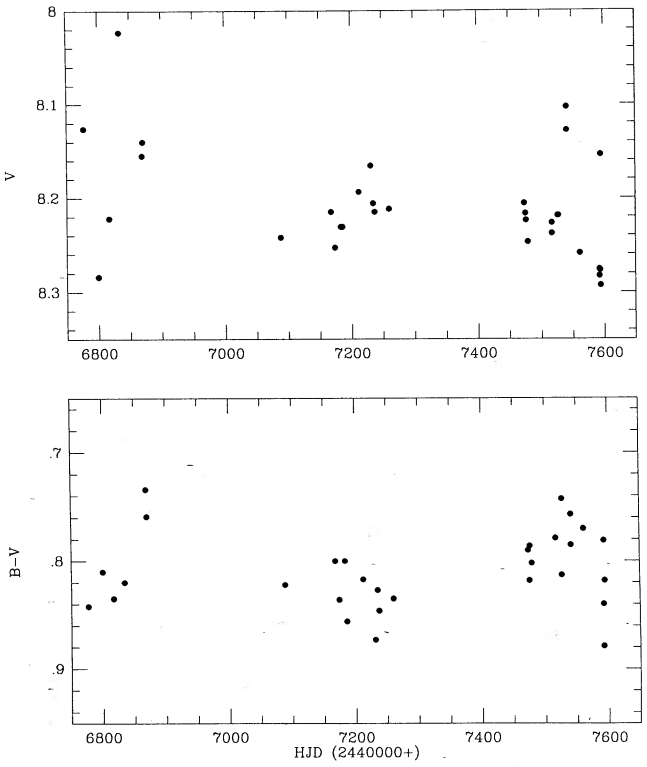

FIG. 1–Photometric behavior of HD 50064.

ous investigations suggest that this class of stars is likely to be variable. Percy (1981) found variability of a few hundredths of a magnitude on a time scale of days for 12 B0–A3 supergiants. Maeder (1980) empirically found a local maximum for the peak-to-peak variations in the *B* spectral types and predicts a range of 0.072 for B1–B5 and 0.060 *V* magnitude for B6–B9 I*a* stars. The variability is typically ten days or longer. He also notes that short-term variations on the order of 0.015 magnitude are present in some supergiant stars with P Cygni profiles. HD 50064 would seem to be a prime candidate for both or either of these variations. However, while nonetheless varying on a time scale of days to weeks it does not subscribe to strict periodicities on the order of days. It is likely, therefore, that the optical variability of HD 50064 is of an irregular nature, related perhaps to mass-loss events or inhomogeneities of the surrounding circumstellar material. Shorter-term variations cannot be ruled out at this time due to the inherent unsuitability of observations taken at such long intervals being used to search for short periods. This behavior is quite suggestive of that observed by Percy *et al.* (1988) for P Cygni, a spectroscopically similar star whose light variations are of approximately the same *V* range and also of an irregular nature, with a time scale of days to months. In the case of P Cygni, explanations of the optical variations have ranged from multiple shell ejection to duplicity, rotation, or nonradial pulsation. It is possible that a similar mechanism(s) may be operating for HD 50064.

3. Spectroscopy

A spectrum of HD 50064 centered on Hα was obtained with the coudé feed telescope of the Kitt Peak Observatory on JD2447120.94931. It was obtained with an RCA2 CCD and had a resolution of 0.89 Å per two-pixel linewidth. This may be seen in Figure 2. Hα showed a P Cygni profile with $V/R = 0.23$ and full width of emission at the continuum level of 53.1 Å (2426 km s^{-1}). The maximum intensity of the red component was 4.2 × that of the continuum. The equivalent width of the line was 9.7 Å. The radial velocity of the central absorption with respect to the Sun was +8.0, while that of the entire emission complex was +80.2. Several other sharp absorption lines appear in this region of the spectrum, most notably λλ6579 and 6583 of C II and λ6614 of Fe I.

4. Cluster Membership

The correct spectral type of HD 50064 is of particular interest since its cluster membership depends on it. If it is truly a B1 or B6 I*a* star, then its inferiority in terms of magnitude to stars 1 (G8 IV) and 2 (B8 III) can only be the result of greater distance. Distances for NGC 2301 range from 300–1950 parsecs (Alter, Ruprecht, and Vanysek 1970) with most values hovering just over 700 parsecs. Svolopoulos (1962) quotes a distance for HD 50064 of

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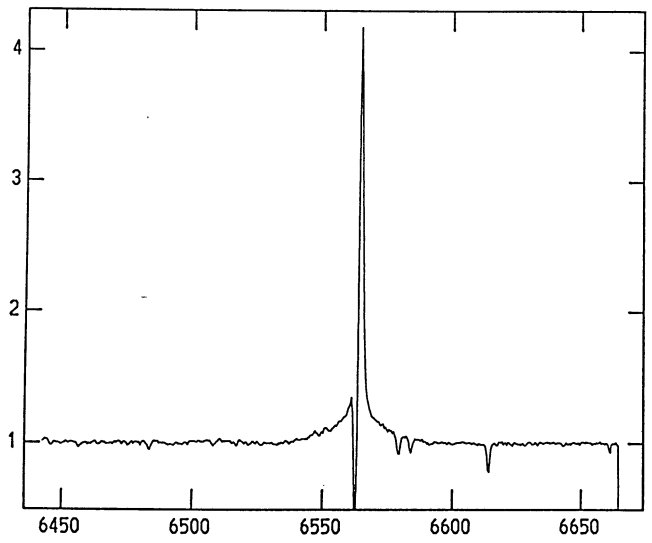

FIG. 2–Spectrum scan of the Hα region of HD 50064. The abscissa is in Å units, the ordinate in intensity times the continuum.

2900 parsecs or greater when considering the radial-velocity measures of interstellar lines given by Merrill and Burwell (1949), while giving a cluster distance of 700–790 parsecs. He also gives a spectral type of B9ne. An earlier study by Code, Whitford, and Morgan (1952) considered HD 50064 to lie behind a remote dust cloud in an outer spiral arm. They based this on the observation that the region in Monoceros in which the star lies has very little reddening, while HD 50064 itself has a color excess > 0.4 magnitude.

With this in mind, the spectrum scan in the region of Hα previously discussed was examined for spectral classification. It was compared with the standard stars HD 36371 (B5 I*ab*), HD 34503 (B5 III), and HD 4727 (B5 V). This is not an ideal portion of the spectrum from which to make classification decisions, particularly since λ6678 He I was not included. Several conclusions were obvious. There is no question that the star is above the main sequence since the C II lines near Hα are strong and deep, though not as deep as in the I*ab* standard. This may be due to the fact that they are actually contained within the emission wings of Hα. The lines in HD 50064 are certainly equally sharp and Fe I λ6614 is stronger than in the I*ab* star. Clearly, HD 50064 is a supergiant, though the subtlety of deciding whether or not it is actually a I*a* star is not possible from the spectrum of this limited region. The previous spectral type of B9ne assigned by Svolopoulos remains somewhat unlikely, therefore.

Assuming, then, that the type of B1 I*a* is reasonable, the highly reddened $(B-V)$ magnitude denotes great distance. It does complicate matters to subtract the contribution toward this reddening which results from the circumstellar matter. However, even a simple calculation shows that HD 50064 lies considerably beyond the outer fringes of NGC 2301 and, therefore, represents a fortuitous coincidence of a background supergiant in the optical field of the cluster. Humphreys (1970) would seem to imply this by not mentioning the star as a cluster member. An examination of the V, $(B-V)$ diagram for NGC 2301 in Hoag *et al.* (1961) would also suggest nonmembership since the star is in the wrong position in the diagram to be a B supergiant star, if it is a cluster member. Clearly, the weight of evidence from the cluster distance, large color excess, high luminosity from the spectral type, and the velocity of the interstellar lines persuasively argue for the > 2.9 kpc distance and noncluster membership of HD 50064.

The author would like to most gratefully acknowledge the referee's helpful suggestions, particularly for further references.

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