ON THE PHOTOMETRIC VARIATIONS OF THE IRREGULAR VARIABLE RED GIANT HD 65750 IN THE REFLECTION NEBULA IC 2220

J. Dachs
Astronomisches Institut der Ruhr-Universität Bochum
J. Isserstedt
Astronomisches Institut der Universität Würzburg
J. Rahe
Remeis-Sternwarte Bamberg
Astronomisches Institut der Universität Erlangen-Nürnberg/F.R.G.

Abstract

The light-curve between 1964 and 1977 for the variable M2II giant HD 65750 = V341 Car is derived from 77 photographic and 83 photoelectric UBV measurements and analyzed. It is concluded that the light variations of the star are irregular and due to variable extinction in the circumstellar nebula. The appearence of the visible reflection nebula IC 2220 into which HD 65750 is embedded, has been found to vary on a time scale of four years.

I. Introduction

HD 65750 (=HR 3126 = V341 Car) has been found by Dachs and Isserstedt (1973) to be a variable red giant of MK type near M2II, embedded into a peculiar, butterfly-shaped reflection nebula, IC 2220. Like other red giant stars, HD 65750 is losing mass at a rate of about 10^{-7} solar masses per year (Reimers, 1977). Therefore, this system of nebula and central star offers an outstanding opportunity to study the interaction of a red giant variable with its environment. In the present paper, new photometric measurements of the star and the nebula are reported. They allow to determine the nature of the light variations of the star and to suggest an explanation for their origin.

II. Measurements

From 26 photoelectric UBV and 27 RI observations of HD 65750 performed in 1968-70 and in 1973-74 as published by Eggen (1974), it could not yet be conclusively decided if the light variations

of this star are completely irregular, or if an underlying periodicity is present in the variations. In order to better determine the nature of the light variations by increasing the number of available measurements, a program was started in 1971 to study the light-curves of the star and the nebula both by iris diaphragm photometric measurements of the star on photographic plates found in existing plate collections, and by photoelectric UBV observations at the photometric 61-cm reflector of the University of Bochum at La Silla, Chile.

As a first step, photographic magnitudes could be measured for HD 65750 on 77 plates contained in the plate collection of Remeis Observatory at Bamberg. These plates had been taken between 1963 and 1972 for the variable star survey of the southern sky. In addition, 49 photoelectric UBV measurements of HD 65750 and 40 UBV observations of the main arc of the nebula IC 2220 were obtained at La Silla between 1971 and 1977. This brings the total number of known photoelectric UBV measurements of HD 65750 to 83 from 1966 until 1977.

In summary, the resulting light-curve of HD 65750 between 1963 and 1977 has the following properties (Dachs et al., 1978):

1. The brightness variations of HD 65750 are irregular. The presence of any underlying periodicity of less than 12 years in the variations can be excluded.
2. The V amplitude of the variations is about $0\overset{m}{.}9$. The star was near maximum light at V ≈ $6\overset{m}{.}2$ around 1964-66, and at minimum light (about V ≈ $7\overset{m}{.}1$) several times between 1969 and 1972. Variations of $0\overset{m}{.}5$ in V are observed within 200^{d} as well as night-to-night variations of $0\overset{m}{.}10$. The star had not yet returned to its maximum brightness by early-1977.
3. The photoelectric UBV measurements show a strong correlation between V magnitudes and (B-V) colours in the sense that the star becomes redder with decreasing brightness and vice-versa. The correlation coefficient between V and (B-V) equals 0.71±0.06, while the slope of the regression of V on (B-V) turns out to be 3.3±0.4 which happens to be in agreement with the ratio of visual interstellar extinction to (B-V) colour excess as due to interstellar dust ($R = A_V/E_{(B-V)} = 3.5$ for M giant stars).

Brightness variations are also found for the nebula IC 2220 which are, however, not correlated with those of the star. The (B-V) and (U-B) colours of the nebula are slightly bluer than those of the

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central star. This together with the fact that no emission lines could be detected on an unwidened, long-exposure, low-dispersion spectrogram obtained at the ESO 152 cm telescope for the main arc of IC 2220, confirms the conclusion of Dachs and Isserstedt (1973) that IC 2220 is a pure reflection nebula.

Finally, it may be noted that the shape of the nebula appears to be variable on a time scale of several years. This can be demonstrated by comparing direct plates of IC 2220 obtained in 1971 at the Curtis Schmidt telescope of Cerro Tololo Inter-American Observatory (Dachs and Isserstedt, 1973) with the corresponding plate of Field 124 of the European Southern Observatory Quick Blue Survey of the Southern Sky, taken in 1975 with the ESO Schmidt telescope. The most noticeable change is seen in the bright nebular spike arising at the northwestern side of the central star from the innermost part of IC 2220. Between 1971 and 1975, the position angle of this spike has changed from near 330° to about 320°.

The apparent rotation of this bright spike within a few years, if confirmed by future observations, can be taken as an indication either for mass motions of dust in IC 2220, or for varying conditions for the illumination of this part of the nebula by its central star.

III. Discussion

From our observations, the following conclusions can be drawn regarding the nature and the origin of the light variations of HD 65750:

1. HD 65750 is an irregular red giant variable with a light-curve similar to that of μCephei. No period or cycle shorter than about 12 years can be detected in the variations.
2. The strong correlation found between the V magnitudes of the star and its (B-V) reddening excludes the possibility that temperature changes of the star are causing the brightness variations in HD 65750, since the intrinsic (B-V) colours of early-M giants are only very little dependent on temperature as has been shown by Lee (1970). The correlation between stellar magnitude and reddening, however, supports the hypothesis that the light variations of irregular red giant variables are caused by variable ejection of dust from the star, as suggested by Polyakova (1975).
3. The structure of the nebula and its apparent variations may in-

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dicate an anisotropy of the outflow of mass from the star or of the dust formation in a circumstellar shell.

In order to test the hypothesis of variable dust extinction causing the brightness variations of HD 65750, polarimetric observations would be useful as well as a search for variability of the infrared λ 10 micron emission ascribed to silicate dust. This emission has been detected in HD 65750 by Humphreys and Ney (1974).

A detailed investigation of the structure of IC 2220 by surface photometry and its interpretation in terms of the distribution of dust in the nebula are also required in order to determine the mass of IC 2220 and to settle the question if the entire nebula can have been shed by mass loss from HD 65750.

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D I S C U S S I O N of paper by DACHS, ISSERSTEDT and RAHE:

MERRILL: Is the optical nebula strongly polarized?

DACHS: That is not yet known.

HABING: Could the variations in the magnitude per night be due to uncertain positioning of the diaphragm through which you did photoelectric observations?

DACHS: For the brightness variations of the star: definitely no, since the brightness of the surrounding nebula in a measuring diaphragm of 18" diameter is less than 1% of that of the star. For the nebular variations: also no.

REIMERS: The observed mass-loss rate cannot account for the reflection nebula, since usually M-type giants and supergiants are not surrounded by strong reflection nebulae.

DACHS: There still remains the problem to find another mechanism

to explain the shape of the reflection nebula which clearly indicates strong interaction between IC 2220 and its central star.

VOGT: What is the reddening and the range of the reddening variation?

DACHS: $E_{(B-V)}$ is variable between $0^m.24$ and $0^m.48$ with a mean value of $0^m.33$.

SURDEJ: What do your (U-B) data show? A similar correlation (V/B-V), explained in terms of circumstellar dust interaction, appears for the Be star HD 45677.

DACHS: The scatter in the (U-B) data is too large - due to time-dependent standardization errors for this extremely red star - as to permit determination of a similar correlation with V as shown by the (B-V) data.

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