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CPD −59°2857: A NEW RED VARIABLE STAR*

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Two (C3 and C4) of the four comparison stars monitored during the photometric study of the peculiar emission-line star GG Car have been found to be variable. Available photometric and spectroscopic data allow us to classify C4 ≡ CPD −59°2857 as a late-type giant (M3–4 III) belonging to the red variable stars of the semiregular or irregular type.

Key words: CPD−59°2857—variable star—photometry—spectroscopy

I. Introduction

During the period 1977–81, several extensive campaigns of photometric observations of the peculiar emission-line star GG Carinae have been organized at the European Southern Observatory (ESO) (see Gosset, Surdej, and Swings 1984, hereafter referred to as Paper I). Among the four comparison stars (see C1, C2, C3, and C4 in Fig. 1 and Table I) that were selected for their proximity to GG Car and similarity in brightness, C3 and C4 ≡ CPD −59°2857 turned out to be variable. Between 1978 March 31 and April 3, C3 (V = 9.10:, $(B-V)$ = $0^m.13$, $(U-B)$ = $-0^m.74$) has displayed light variations as large as $0^m.09$ in all three bands. Within a week of observations carried out in February 1977, the star CPD −59°2857 (V = 9.06:, $(B-V)$ = $1^m.78$, $(U-B)$ = $2^m.03$) has appeared to be slightly variable ($\Delta V \sim 0^m.06$).

Whereas these two variables were later discarded from the routine observations—since they were rejected for comparison with GG Car—the available photometric and spectroscopic data have proven to be sufficiently good in order to classify the red variable star CPD −59°2857.

II. Photometric Observations

Standard *UBV* photoelectric observations of CPD −59°2857 have been carried out with a single-channel photometer attached to the Cassegrain focus of the ESO 50-cm telescope during February and March 1978 and of the Bochum 61-cm telescope during February 1977 and April 1978. Since the observing procedure was exactly the same for CPD −59°2857 and GG Car, we refer the reader to Paper I (section 2) for all information and details concerning the observation and reduction techniques of the *UBV* photometric data.

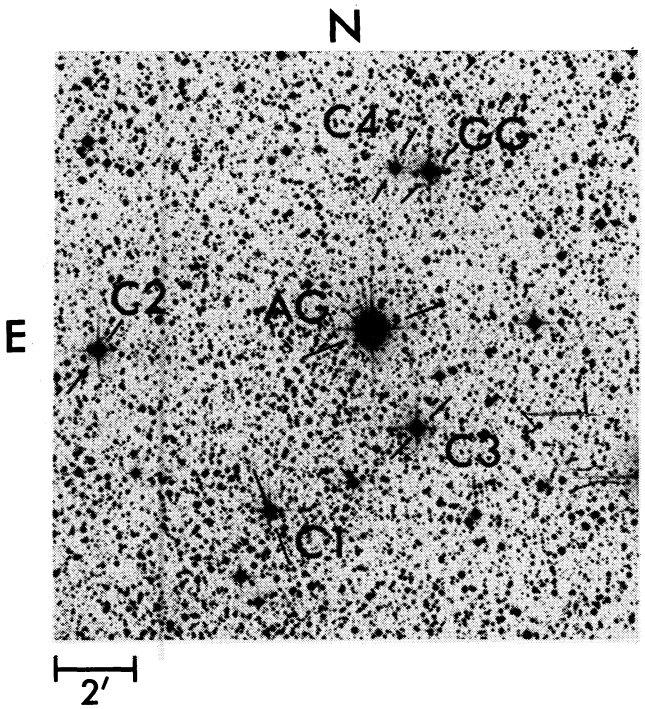

FIG. 1—Finding chart for the peculiar emission-line star GG Car and its four selected comparison stars C1, C2, C3 (variable), and C4 ≡ CPD −59°2857 (variable). AG Carinae is a well-known planetary nebula. Reproduced from the ESO Quick Blue Survey.

*Based on observations collected at the European Southern Observatory, La Silla, Chile.

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TABLE I

Spectral Type, V Magnitude, and Equatorial Coordinates of GG Carinae and Selected Comparison Stars

Identification	CPD number	Other number(s)	Sp. type(*)	V(*)	$\alpha_{(1950)}$(**)	$\delta_{(1950)}$(**)
GG	-59°2855	HD 94878	pec.	8.75(:)	$10^h53^m57^s.95$	-60°07'31".3
C1	-59°2861	---	M	9.33	10 54 15.85	-60 14 47.6
C2	-59°2873	HD 95018 CO 2999	B6V	9.33	10 55 03.41	-60 11 18.3
C3	-59°2856	HD 305773 CO 2993	BO.5	9.10(:)	10 54 03.01	-60 13 35.3
C4	-59°2857	---	M	9.06(:)	10 54 04.38	-60 07 23.4

(*) as derived from our UBV photometry

(**) Because of some confusion in the published equatorial coordinates of these stars, we have remeasured the positions of all these objects on a ESO 1m Schmidt Plate of the Quick Blue Survey. The listed equatorial coordinates, accurate to within 0.3", have been derived using the ESO Optronics measuring machine and the POS-programme package set up by R.M. West at the European Southern Observatory (Garching).

(:) variable

A. *Light Variations*

Using the DFT (Discrete Fourier Transform) algorithm described by Deeming (1975), we have made a Fourier analysis of the V measurements of CPD $-59°2857$ obtained in 1978. The results are shown in Figure 2. In that figure, the ordinates represent the power of the DFT in $(\text{mag})^2$ as a function of the frequency ν expressed in day^{-1}.

As can be seen from the spectral window (Fig. 2a), the one-day aliasing phenomenon is strong. The relevant critical frequency (i.e., the analogue of the Nyquist frequency with respect to the sampling) is found to be $\nu_c = 0.502\ \text{day}^{-1}$. Let us point out that, unfortunately, the main peak of the spectral window is shouldered.

The DFT (Fig. 2b) displays three outstanding peaks which are aliases of one another. The progenitor is the low frequency one at

$$\nu = 0.038\ \text{day}^{-1} \text{ with } \sigma_\nu = 0.003\ \text{day}^{-1} \quad .$$

The width of this peak is large ($\Delta\nu \sim 0.04\ \text{day}^{-1}$). We can readily conclude that on the basis of this unique set of data, it will not be possible to distinguish between a strictly periodic and/or quasi-periodic variation. The data collected in 1977 do not help at all in solving this problem.

A second family of aliases can be picked out. Once more, the progenitor appears to be the low-frequency

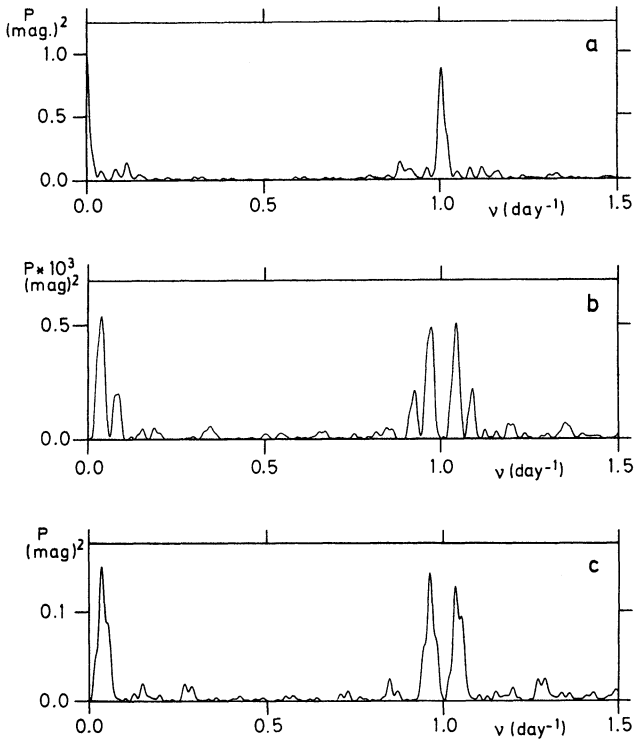

FIG. 2—Fourier analysis of the V magnitudes of CPD $-59°2857$ as observed in 1978. (a) Square of the full amplitude of the spectral window (as defined by Deeming (1975)); (b) square of the full amplitude of the DFT (as also defined by Deeming (1975)); (c) square of the full amplitude of the DFT for a pure cosine monochromatic wave (see text).

peak at $\nu \sim 0.081$ day^{-1}. From its location, we can safely state that it represents the second harmonic of the fundamental frequency. The relevant power is about 37% of the fundamental one, i.e., 61% in amplitude. However, the presence of some aliases of the fundamental frequency at the frequency of the second harmonic indicates that the 37% power is an upper limit. Therefore, a more accurate value consists of $\sim 25\%$ P_0, corresponding to $\sim 50\%$ in amplitude.

In Figure 2c, we have represented the DFT of a pure monochromatic cosine wave for a frequency $\nu = 0.038$ day^{-1}, an amplitude equal to one and sampled in exactly the same way as were the photometric observations of CPD −59°2857. The resulting DFT essentially confirms our previous conclusion. Let us remark that the shouldered shape of the peaks is also well apparent here. We can also see that the power leakage associated with the sampling is rather great. If we admit that there is about the same leakage for the star as for the cosine wave, the results shown in Figure 2b and Figure 2c are coherent with the observed peak-to-peak variation recorded in the V band, i.e.,

$$\Delta V_{pp} \sim 0^m.12 \quad .$$

Considering all photometric data collected in 1977 and 1978, and assuming that $P = 26.5$ days, we have illustrated in Figure 3 the mean composite V light curve of CPD −59°2857. In that figure, the epoch of the light maximum ($\phi = 0.0$) has been referred to JD2443624.5. The trend of light variations appears to be rather smooth and well defined.

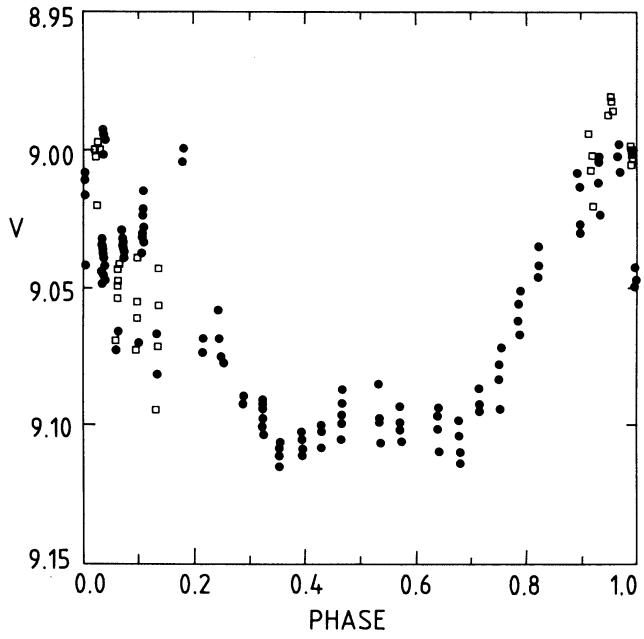

FIG. 3—Mean composite light curve of CPD −59°2857, adopting a period of 26.5 days. The epoch of the light maximum ($\phi = 0.0$) has been referred to JD2443624.5. The two different symbols are related to observations obtained in 1977 (□) and in 1978 (●).

In summary, during February 1977 and February–April 1978, the star CPD −59°2857 has displayed light variations ($\Delta V \sim 0^m.12$) that are at least quasi-periodic with a typical time scale of

$$P = 26.5 \text{ days and } \sigma_P = 2.0 \text{ days} \quad .$$

The V magnitude of the star at light minimum is derived to be $9^m.12 \pm 0^m.02$.

B. *Colors and Reddening*

The $(B-V)$ and $(U-B)$ color indices folded in a phase diagram do not show any trend of variation exceeding the mean scatter of the observations. Considering the whole set of data for 1977 and 1978, the mean values of the color indices are found to be

$$\langle B-V \rangle = 1.780 \text{ with } \sigma_{B-V} = 0.022 \quad ,$$
$$\langle U-B \rangle = 2.035 \text{ with } \sigma_{U-B} = 0.054 \quad .$$

The large observed standard deviations are partly due to the paucity of very red standard stars used when deriving the color transformation. In any case, we are dealing with an extremely red and/or reddened object. The relevant part of the $(U-B)/(B-V)$ diagram is not very well known. However, if we adopt a spectral type M3–4 III (see section III) and, consequently, intrinsic color indices equal to

$$(B-V)_0 \sim 1.6 \quad ,$$

and

$$(U-B)_0 \sim 1.9 \quad ,$$

we obtain the color excesses

$$E(B-V) = 0.18 \quad ,$$

and

$$E(U-B) = 0.14 \quad ,$$

leading to a reddening ratio

$$\frac{E_{U-B}}{E_{B-V}} \sim 0.75 \quad ,$$

i.e., a reasonable value characterizing the extinction in our galaxy. Adopting $m_v = 9^m.06$, $M_v = -0^m.7$ for an M3–4 giant (Allen 1973) and an absorption $A_v = 3.0 \times 0^m.18$, we find that the star CPD −59°2857 lies at an approximate distance

$$d \sim 698 \text{ parsecs} \quad ,$$

from the sun.

III. Spectroscopic Observations

In 1978, three medium-resolution spectrograms of CPD −59°2857 were obtained with the coudé spectro-

TABLE II

Characteristics of the ESO-Coudé Spectrograms Obtained for CPD -59°2857

ESO plate No.	Useful spectral range	Dispersion	Exposure	Emulsion	Date	Quality
F 6034	3550-4750 Å	20 Å/mm	80 min	IIa-O (Baked)	14/2/78	good
F 6035	5600-6800	20	30	098-04 (Baked)	14/2/78	underexposed
G 9279	3690-5190	12	175	IIa-O (Baked)	28/3/78	good

graph of the ESO 1.52-m telescope. The characteristics of these plates are summarized in Table II.

The blue spectrograms are dominated by the presence of TiO bands (see Fig. 4). The Balmer lines are faintly present in absorption. No emission line is visible. Using for comparison the Atlases of stellar spectra by Seitter (1970) and Keenan and MacNeil (1976), we have tentatively identified the spectrum of CPD −59°2857. From the presence of several TiO bands (e.g., at λ4584 and λ4626) as well as from the relative intensities of Ca I λ4226 and of the Cr I triplet at λ4275, we derive an M3–4 spectral type. Several adequate indicators such as the comparison of the Fe I lines at λ4326 and λ4376 with Hγ lead us to adopt a luminosity class III.

The red spectrogram (see Fig. 5) also contains absorption bands due to TiO, in good agreement with the proposed M3–4 III spectral type. Hα is seen as a pure absorption line.

Within the observational uncertainties (∼ 15 km sec^{-1}), no significant radial-velocity difference could be found between the two blue spectrograms of CPD −59°2857 that were taken 42 days apart.

IV. Classification

CPD −59°2857 appears to be a late-type giant (M3–4 III) displaying light variations with a total amplitude $\Delta V = 0^{m}.12$ and a typical time scale of 26.5 days. However, it is not possible to distinguish between a strictly periodic and/or quasi-periodic type of variation. On the other hand, no emission line and no radial-velocity shift were found. All these characteristics are compatible with the properties of the red variable stars of the semiregular and/or irregular type. Therefore, we classify CPD −59°2857 as a SR_b or a L_b variable star.

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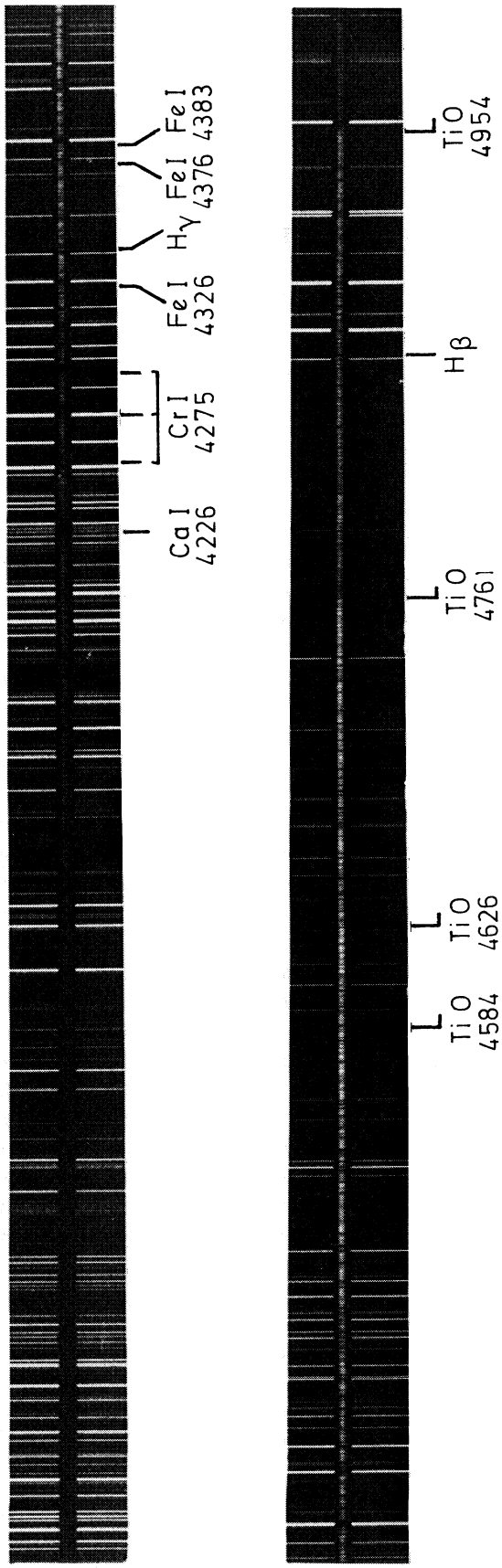

FIG. 4—The blue spectrogram of CPD −59°2857 (Plate No. G 9279; see text and Table II).

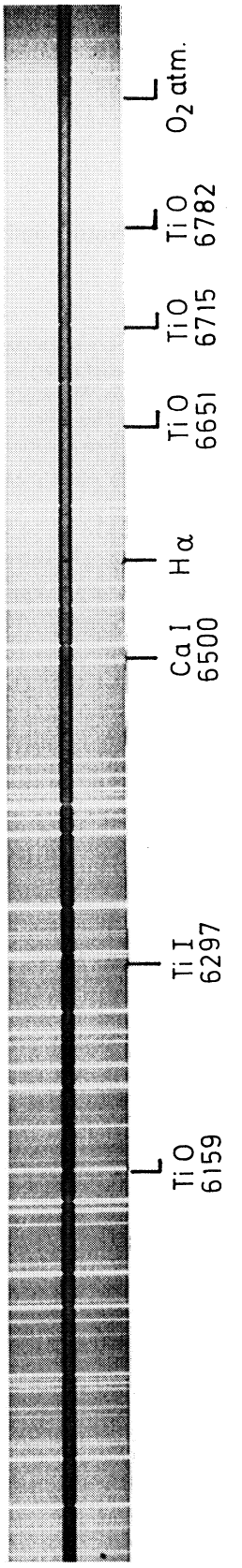

FIG. 5—The red spectrogram of CPD −59°2857 (Plate No. F 6035; see text and Table II).