213. *Classification of Carbon Stars by Spectroscopic Scanning*

By Yoshio FUJITA, M.J.A.

Department of Astronomy, University of Tokyo

(Comm. Dec. 12, 1967)

In our previous paper (Fujita, 1967) it was suggested that a role of (6, 1) and (7, 1) bands of CN red system ($A^2 \Pi - X^2 \Sigma$) on the classification of carbon stars should be of some importance. With some additional observational data obtained by spectroscopic scanning using the same instrument described in our previous paper, this problem will be re-considered in this note.

As some spectral features characterizing carbon stars are remarkable even if the spectral range investigated is rather limited, this method of spectroscopic scanning may be reasonably favourable for the purpose of spectral classification of these stars.

Generally speaking, in the spectral range considered following six features seem to represent most remarkable characteristics of carbon stars from the view point of spectral classification:

4737 $C_2(1, 0)$, 5165 $C_2(0, 0)$, 5239 CN(7, 1), 5635 $C_2(0, 1)$, 5730 CN(6, 1), and 5890-96 Na.

As the symbols of criterions which represent the appearance of these features, ○ indicates that the feature of the absorption band or the line considered is clearly recognized, × indicates that the feature of the absorption band or the line considered disappears or is very weak, and ● indicates that the band sequences considered partly disappear or are partly very weak.

Seventy-two carbon stars have been investigated according to the various combination of these three criterions which are arranged in order of Na, C_2 , and CN. Two typical examples of tracing by spectral scanning are shown in Figs. 1 and 2. After some careful trial, it was clarified that these carbon stars should be reasonably classified into eight types of spectral appearance. The results of assignments of seventy-two carbon stars observed to these types are summarized in Table I. The tentative assignment by the C-classification is indicated by bracket. It should be mentioned that additional observational data necessitated to revise the assignment of some stars which had been tried in our previous paper and the suffix showing the intensity of C_2 band was omitted, because the estimation of C_2 intensity from the spectroscopic scanning is sometimes very difficult.

TU Gem N3 C5₃

V Ari R8 C5p5

Fig. 1. Typical example of tracing by spectral scanning: TU Gem.

Fig. 2. Typical example of tracing by spectral scanning: V Ari.

The graphical representation showing the correlation between the C-classification and eight types of spectral appearance is shown in Fig. 3. Fig. 4 shows the similar representation by changing the abscissa from the C-classification to the R-N classification. In Fig. 4 the spectral types assigned to Na, Nb, and Nc are excluded.

Comparing these two figures, it should be mentioned that the C-classification shows rather better correlation than the R-N classification with the criterion represented by eight types of spectral appearance. The appearance of CN red system seems to be more sensitive to the C-classification than that of C₂ band. The physical explanation of the comparatively good correlation which is shown in Fig. 3 seems difficult. Why the variation of the relative intensity of C₂ sequences (1, 0), (0, 0), and (0, 1) and of CN sequences (7, 1), and (6, 1) may respectively occur among carbon stars? As there are some stars the spectral features of which are very difficult to make clear distinction among these eight types, it should be understood that such a graphical representation as Fig. 3 is ambiguous and it is possible to find some intermediate types which might be more suitable for representing real situation. The scattering of plots in Fig. 3 will explain such a circumstance. Furthermore, if some

Table I

Star	Spectral Classification	Type of Appearance Na C ₂ CN	Star	Spectral Classification	Type of Appearance Na C ₂ CN
W CMa	Na (C ₅)	○ ○ ○	Y Hya	N3 C ₅ ₄	× ● ●
T U Gem	N3 C ₅ ₃		B D +24°1686	R9 C ₆ ₂	
U U Aur	N3 C ₅ ₃		T Lyr	N3 C ₆ ₅	
U V Cam	R8 C ₅ ₃		S Z Sgr	Nb C ₇ ₃	
A Q And	Nb C ₅ ₃		AW Cyg	N3 (C ₇)	
S Sct	N3 C ₅ ₄		V Oph	Nb C ₇ ₄	
B D -16°5272	N2 (C ₆)		S V Cyg	N3 (C ₅)	× ○ ○
T T Tau	N3 (C ₆)		X Sge	N (C ₅)	
19 Psc	N0 C ₆ ₂		S T Cas	Nb (C ₆)	
D S Peg	N1 C ₆ ₃		HD 189711	Nb (C ₅)	
T T Cyg	Nb C ₆ ₄		VW Gem	Na (C ₅)	
S T Cam	N5 C ₆ ₄		T X Aur	Nb (C ₆)	
T Sct	N3 (C ₇)		W Ori	N5 C ₅ ₃	
Z Psc	N0 C ₇ ₃		R V Mon	Nb C ₅ ₄	
U X Dra	N0 C ₇ ₃		S U And	Nb C ₅ ₄	
U Hya	N2 C ₇ ₃		R T Ori	Nb (C ₆)	
Y Tau	N2 C ₇ ₄		V Y UMa	Na C ₆ ₃	
R S Cyg	N0 _{pe} C ₈ ₂		HK Lyr	N4 C ₆ ₄	
W Z Cas	N1 _p C ₉ ₁		HD 137613	R3 C ₁ ₂	× ○ ●
HD 215484	Nb (C ₆)	○ ○ ●	C G Vul	N (C ₄)	
A Q Sgr	N3 (C ₆)		R Y Dra	N4 _p C ₄ ₄	
R T Cap	Nb (C ₆)		B D -3°1685	R5 C ₄ ₄	
B L Ori	Nb C ₆ ₂		B D +57°702	R5 C ₄ ₅	
B D +38° 955	N0 (C ₈)		X Cnc	N3 C ₅ ₄	
R R Her	R5 _{ep} C ₇ ₂		Y CVn	N3 C ₅ ₄	
S Cep	N6 _e C ₇ ₄		V X And	N7 C ₅ ₄	
R V Cyg	N5 C ₆ ₄	○ ● ○	R X Peg	N3 C ₅ ₅	
V Aql	Nb C ₆ ₄		RU Cam	R0 C ₀ ₁ -	× ○ ×
TW Oph	Nb C ₆ ₅		B D -13°3407	R0 C ₀ ₂	
R Y Mon	N5 C ₆ ₅		B D +51°1462	R5 C ₁ _p ₂	
A X Cyg	Nb C ₇ ₄		B D -10°5057	R0 C ₁ ₂	
S S Vir	Np C ₆ ₃	○ ● ●	B D +42°2811	R1 C ₁ ₂	
U Cam	N5 C ₆ ₄		Y Per	Nbe (C ₂)	
R Lep	Nbe C ₇ ₄ ⁺		B D +23°123	R3 C ₂ _p ₂	
V Hya	Nb C ₇ ₅		B D -10°513	R3 C ₂ ₃	
			HD 223392	R3 C ₃ ₂	
			V Ari	R8 C ₅ _p ₅

Fig. 3. Correlation between the C-classification and eight types of spectral appearance in the spectroscopic scanning investigated.

Fig. 4. Correlation between the R-N classification and eight types of spectral appearance in the spectroscopic scanning investigated.

quantitative consideration could be added in connection with the relative intensity of C_2 and CN band sequences, it might help our idea of spectral classification above described.

In conclusion, I wish to express my special thanks to members of the staff of the Okayama Astrophysical Observatory for their assistance in observations. My thanks are also due to Miss M. Matsugaki for her assistance in preparing this manuscript.

Reference

Fujita, Y. (1967): Proc. Japan Acad., **43**, 472.