CARBON ABUNDANCE IN THE WC 11 STAR CPD -56°8032

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1. INTRODUCTION

The star CPD -56°8032 is one of the few objects classified WC 11. First noted by Bidelman, MacConnell and Bond (1968), its blue-violet spectrum has been described by Cowley and Hiltner (1969), while the red/infrared region has been studied by Thackeray (1977). Infrared magnitudes have been measured by Webster and Glass (1974), and Aitken et al. (1980) have scanned the infrared spectrum from 8 to 13 μm. Cohen and Barlow (1980) have also published infrared fluxes from 3.45 to 20 μm. This star shows strong emission lines belonging to C II and C III, much sharper than the usual bands seen in WC stars. Bright lines of H, He I, O II, O III, Si III and Si IV are also present. O I λ 7774 triplet shows a P Cygni profile (Thackeray, 1977). Forbidden lines belong to [O I] (red lines), [O II] (violet and infrared doublets) [N II] (6548 and 6584 Å), and [S II] (4068 and 6716 Å).

2. IUE OBSERVATIONS

We have observed this star with the low resolution spectrograph of the IUE in the wavelength range 1200-3100 Å. Two spectra have been obtained. Details appear on table I. The data have been reduced according to the algorithm of Castella et al. (1980). Spurious emission features, due to "hot" pixels appear at 2195 and 2960 Å. Results are displayed on fig. 1.

Table I

Image n°	Date	Integration time	Aperture
SWP 8947	May 8, 1980	55 min	Large
LWR 7700	May 8, 1980	25 min	Large

3. THE CONTINUOUS SPECTRUM

Cowley and Hiltner report the following UBV magnitudes : V = 11.04, B-V = 0.44 and U-B = -0.24 (1969). The star is not known to be variable. When corrected for emission lines contributions, Aitken et al. (1980) find B = 11.7 and V = 11.4. Hence the B-V index for the continuum is 0.3. The visual absorption A_V is found to be 1.86 from the H_α to H_β flux ratio, while radio flux to H_β leads to 1.85 mag. These concordant

C. W. H. de Loore and A. J. Willis (eds.), Wolf-Rayet Stars: Observations, Physics, Evolution, 139–145.

https://doi.org/10.1017/S0074180900028825 Published online by Cambridge University Press

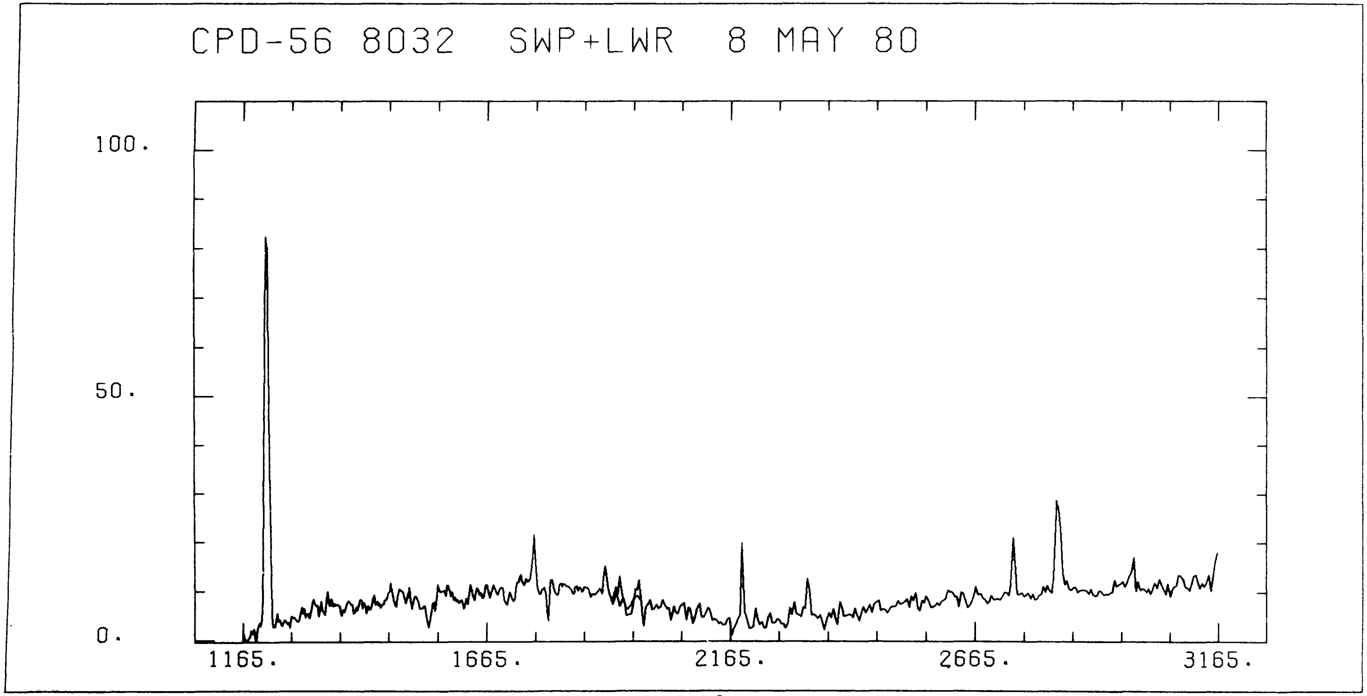

Fig.1. Abscissa: wavelength in Å. Ordinate: flux in 10^{-14} ergscm^{-2}s^{-1}Å^{-1}

Figure 1. The ultraviolet spectrum of CPD-56°8032

Abscissa: wavelength in Angströms; ordinate: flux in 10^{-14} erg.cm^{-2}.s^{-1}.A^{-1}

https://doi.org/10.1017/S0074180900028825 Published online by Cambridge University Press

values may be used to derived an E(B-V) excess of 0.6, if the value 3.1 is adopted for R = A_V/E(B-V). The value of E(B-V) may also be derived from ultraviolet fluxes. Nandy (1981) has shown that E(2190-2740) = 3 E(B-V). In CPD -56°8032 m(2190) - m(2740) = 0.87. Adopting -0.89 for the same colour index in from Nandy et al. (1976) for an unreddened B2V star (see below) we find E(B-V) = 0.59, in good agreement with the value obtained from A_V. Hence $(B-V)_\circ$ = -0.3. This result seems in agreement with the Zanstra temperature of 26 000°K, as determined by Aitken et al. (1980). The IUE continuous spectrum is measurable from 1260 to 3000 Å. The noticeable 2200 Å absorption feature indicates a fair amount of reddening. It is now customary to use Seaton's interstellar extinction curve (Seaton, 1979) for "dereddening" observed ultraviolet fluxes. The value of the c parameter corresponding to E(B-V)= 0.6 is 0.882. When dereddened in this way, the flux distribution presents a hump around 2180 Å, which would be quite unusual for a stellar spectrum in this wavelength range. Using Kurucz (1979) model atmospheres for log g = 4.5 and T_{eff} = 20 000, 25 000 and 30 000°K and a large number of absorption lines, we have computed emergeant fluxes and averaged them over 30 Å-wide bandpasses. The results have been converted to ultraviolet colours $(m_\lambda - V)_\circ$ (see fig. 2). We have then modified the extinction curve in order to obtain a flux distribution resembling model atmosphere results. Seaton's extinction has been replaced between $1/\lambda = 3.5\mu m^{-1}$ and $1/\lambda = 6.1\ \mu m^{-1}$ by the values given on table II, where $X(1/\lambda) = A_V/E(B-V)$.

Table II

$1/\lambda(\mu^{-1})$	$X(1/\lambda)$	$1/\lambda(\mu^{-1})$	$X(1/\lambda)$
3.5	5.85	4.75	8.50
3.75	6.35	5.0	7.90
4.0	7.05	5.25	7.55
4.25	7.90	5.50	7.55
4.5	8.60	5.75	7.65
4.6	8.75	6.00	7.75

The resulting curve is not unlike the one given by Nandy et al. (1976) for stars in the Carina-Sagittarius arm. We thus adopt this curve and this leads us for the star to an effective temperature between 20 000 and 25 000°K, say 22 000°K, adequate for a B2V star.

The stellar continuum fluxes are given in table III.

Table III

λ(Å)	F(λ)	$F(\lambda)^{corr.}$
	x 10^{12} erg cm^{-2} s^{-1} $Å^{-1}$	
1260	0.052	9.94
1300	0.060	9.41
1400	0.082	8.92
1500	0.096	8.68
1600	0.110	8.72
1700	0.116	8.20
1800	0.121	7.80
1900	0.106	6.90
2000	0.082	6.45
2100	0.056	6.14
2200	0.042	5.14

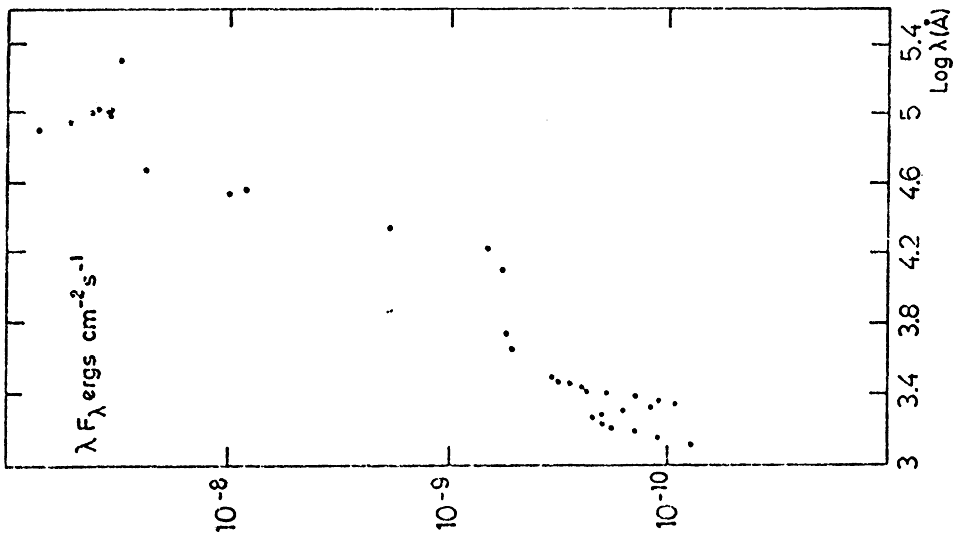

Figure 3

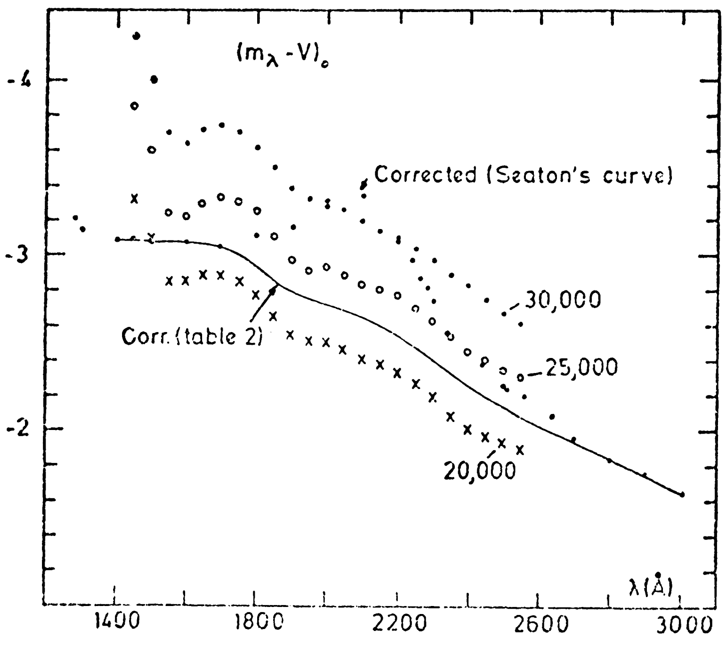

Figure 2

https://doi.org/10.1017/S0074180900028825 Published online by Cambridge University Press

Table III (continued)

2300	0.048	4.58
2400	0.060	3.82
2500	0.076	3.71
2600	0.092	3.43
2700	0.094	2.97
2800	0.100	2.75
2900	0.106	2.62
3000	0.108	2.35

Taking into account the fluxes, magnitudes and colours quoted above, it is possible to plot the uncorrected flux distribution of the object between 0.126 and 20 μm. Figure 3 shows such a plot of λF_λ (in ergs cm^{-2} s^{-1}) versus log λ (Å). It is clear that most of the star's energy is radiated in the infrared.

4. LINE SPECTRUM IN THE ULTRAVIOLET

IUE spectra exhibit mostly emission lines. The only strong photospheric absorption clearly identified is C IV 1550 Å, whose profile is asymetric, the red wing being narrower than the blue one. Other absorption features, both stellar and interstellar might be present but their identification is uncertain on the presently available material. Emission lines include : λ 1335 C II, λ 1751 [N III], λ 1908 [C III], λ 2297 C III (uncertain), λ 2326 [C II], λ 2385 He II, λ 2470 [O II], λ 2740 He II, λ 2836 C II (+ O III ?) and λ 3160 ?

5. CARBON ABUNDANCE

Let us assume that $N(A^+)$ is the volumic density of ions of species A, N_e the volumic electron density, V the emitting volume, supposed to be large with respect to the star's volume. If D is the distance to the star, the number of quanta received in an optically thin spectral line excited by electron collisions, corrected for interstellar extinction is

$$P(\lambda) = \frac{1}{4\pi D^2} \int_V N(A^+)\, N_e\, q(\lambda)\, dV ,$$

q(λ) being the excitation rate coefficient for the line concerned. If a line is produced by recombination of an ion B^+ of specie B, we shall write similarly,

$$P'(\lambda) = \frac{1}{4\pi D^2} \int_V N(B^+)\, N_e\, \alpha_{eff}(\lambda)\, dV ,$$

where $\alpha_{eff}(\lambda)$ is the effective recombination coefficient, which includes both direct and dielectronic recombinations contributions. If now we admit that the emitting regions for the lines formed by recombination and by electronic collisions are identical and that the medium is homogeneous and isothermal, we can write

$$\frac{P(\lambda)}{P'(\lambda)} = \frac{N(A^+)}{N(B^+)}\ \frac{q(\lambda)}{\alpha_{eff}(\lambda)}$$

q(λ) and $\alpha_{eff}(\lambda)$ depend mainly on T_e, the electron temperature. Since we cannot resolve the components of the observed ultraviolet doublets, it is difficult to estimate this temperature. From the general appearance of the spectrum, we may infer a value of about 10^4°K. We shall now estimate the carbon abundance in using the collisionally excited lines [C III] at 1908 Å and [C II] at 2326 Å for which the q(λ)'s may be computed from data given by Harrington et al. (1980). On the other hand, the recombination cross section for the hydrogen H_β line may be taken from Brockelhurst (1971). The observed H_β flux is given by Aitken et al. (1980). We summarize the available data below :

Line		$F(\lambda)^{corr.}$ in ergs cm^{-2} s^{-1}	P(λ)	q(λ)	α(λ)
[C III]	1980	$2.8\ 10^{-11}$	2.7	$4.81\ 10^{-11}$	-
[C II]	2326	$4.5\ 10^{-11}$	5.3	$4.67\ 10^{-11}$	-
H_β	4861	$8.55\ 10^{-12}$	2.1	-	$3.04\ 10^{-14}$

Using these numerical values we find :

$N(C^{++})/N(H^+) = 8.13\ 10^{-4}$; $N(C^+)/N(H^+) = 1.65\ 10^{-3}$

Assuming that all carbon is in the form of C^+ and C^{++}, as hydrogen is completely ionised, we find $N(C)/N(H) = 2.46\ 10^{-3}$. This leads to log {C} = 9.39, compared to log {C} = 8.55 for the Sun. This is a provisional estimate of the carbon overabundance in the WC 11 star. More accurate determination might be made when more ultraviolet data and quantitative data in the visual spectrum will be available. The other ultraviolet carbon lines would not help very much as the λ 1335 line is quite weak, whereas for the λ 2297 and λ 2836 lines the identification is uncertain. This object clearly deserves new quantitative observations.

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DISCUSSION

Van der Hucht: It is important to note that the star you discussed is the central star of a compact planetary nucleus and classified by Karl Henize as WC 11 (viz. van der Hucht, Conti, Lundstrom, and Stenholm, 1981, Space Sci. Rev., 28, 227).