COMPARISONS BETWEEN OPTICAL AND ULTRAVIOLET INTERSTELLAR LINES FORMED IN THE CARINA NEBULA (NGC 3372)

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ABSTRACT

Discovery of complex Ca II H and K interstellar line profiles towards stars embedded in the giant H II region surrounding Eta Carinae (ref. 1) led us to undertake a reconnaissance of the richer ultraviolet (UV) interstellar line spectrum. Single IUE spectra were secured for those stars exhibiting the greatest variety of structure in the optical interstellar lines, namely, HD 93130, 93160, 93162, 93204, 93205, 93206 and HDE 303308. While subject to confirmatory observations and future analysis, our initial appraisal of the spectra suggest that: (1) longwards of Lyman Alpha many of the interstellar lines, including an unidentified one, in the spectrum of Zeta Oph (ref. 2) seem to be present in the Carina Nebula spectra; (2) interstellar line structure varies widely in both velocity and intensity throughout the region, as well as along a given line of sight as the species change; (3) new high velocity components of UV lines appear to extend the total range of velocities in the nebular interstellar lines to about 400 km/s; and (4) lines of the high excitation species Si IV and C IV are strong and also structured in velocity space.

INTRODUCTION

Optical observations at 9 Å/mm with the CTIO coudé spectrograph (ref. 1) revealed that a marked decrease in the strength of the interstellar calcium lines between stars in the inner and outer portions of the Carina Nebula arises from complex structure within or associated with that giant H II region. This phenomenon apparently represents a fourth type of interstellar line structure. Among the six components identified in the optical study, a total velocity range of about 330 km/s was found (fig. 1). Only in the Vela Supernova Remnant (SNR) has comparable velocity structure been observed (refs. 3-5). Subsequent CTIO coude spectra of HD 92740, 93206 and 93250 in the blue at 4.5 Å/mm and in the visual at 9 Å/mm revealed additional components in Ca II and structure in the Na D lines. In recent years one of us (NRW) has been carrying out an extensive survey of the optical interstellar lines with the improved resolution of the CTIO 4-m echelle spectrograph. The wealth of new and complementary information available from the interstellar lines accessible to IUE makes extension of the observations to the UV seem particularly worthwhile at this time. In this brief report we shall describe some salient features arising from an initial appraisal of the IUE spectra, with the caveat that proper morphological and physical analyses may require additional observations to achieve a sufficient signal-to-noise ratio.

OBSERVATIONS

Some relevant parameters for our small aperture, high-resolution data secured in September 1979 are summarized in Table I. Reductions used wavelength calibrations recorded during the Carina observations. We have also made use of a spectrum obtained by Dr. P. Conti for HD 93131 (LWR 1527).

RESULTS

1. Examination of the 10 Å/in plots provided by the IUE Observatory shows that when resolution, S/N and exposure levels are taken into consideration most interstellar lines stronger than about 15 mÅ, including the unidentified one at 1317.14 Å, in the Copernicus spectra of Zeta Oph (ref. 2) can be plausibly identified in our spectra. Both velocity and intensity aspects of the profiles are, however, quite different from those of Zeta Oph.

2. Complex velocity structure similar, but not necessarily identical, to that of Ca II K is seen in lines of C I*, C II, O I, Mg I, Mg II and Fe II.

3. Profiles of C I**, O I**, Si II*, S II, Cl I, Mn II, Ni II and Zn II generally seem to be unresolved or, at least, much simpler than those of the Ca II H and K lines. For instance, the Cl I 1347.24 Å line (f=0.112, W_λ(Zeta Oph) = 20.3 mÅ; when available these data from ref. 2 for Zeta Oph - ZO - will be given), although weak, is present in all our spectra, where it generally has a full width at half depth of about 0.12 Å. The line appears symmetrical and unresolved with the possible exception of towards HDE 303308, where there is a weak suggestion of a component at -43 km/s.

4. Good correspondence between the principal velocity components in the Ca II K-line and those in the Mg I 2852.127 Å line (f=1.90, W_λ(ZO)=218 mÅ) is seen upon comparison of figs. 1 and 2. In fig. 2 components at about -190, -95, -30, +60, and +100 km/s are identifiable. As with the H and K lines the velocity and intensity structure vary greatly from star to star. It is particularly interesting to compare line profiles of HD 93204 and 93205 in the figures; these two stars are separated by 20 arcsec on the sky, corresponding to a projected linear separation of 0.25 pc. (Note that velocities mentioned herein are approximate and based upon measurement on the figures relative to an adopted central position of the maximum absorption dip. Also, horizontal alignment of the profiles has been made about the presumed zero velocity component.)

5. The Mg II 2795.528 Å (f=0.592, W_λ(ZO)=312 mÅ) line profiles shown in fig. 3 are so badly saturated and, presumably, blended in the center that information on components within 80 km/s of zero velocity is lost. However, high velocity components are visible at about -185, -85, +90, and +190 km/s. The newly discovered component at +190 km/s in HD 93160 and 93162, if correctly identified, raises the total range of velocities in the Carina Nebula interstellar absorption lines to about 400 km/s. Comparable interstellar line velocities (a range of 270, or possibly, 550 km/s) are known only for portions of the Vela SNR (ref. 3-5), an object of considerably different appearance than NGC 3372. Velocity structure over 60 km/s is also known along lines of sight towards the giant H II region 30 Doradus in the Large Magellanic Cloud (ref. 1,6,7).

6. Profiles of the Mn II 2576.107 Å (f=0.288, W_λ(ZO)=138 mÅ) line, fig. 4, show, with the possible exception of HD 93162, only positive velocity components (+65, +135, +175 km/s). The structural differences between the low-excitation lines in figs.2-4 are readily apparent.

7. As an example of high-excitation lines, fig. 5 shows the C IV 1550.774 Å (f=0.097) and C IV 1548.202 Å(f=0.194, W_λ(ZO)$\lesssim$ 12: mÅ) lines, which are very strong in the Carina Nebula and show some velocity structure.

8. The Al III lines, 1854.716 Å (f=0.539, W_λ(ZO)=57:mÅ) and 1862.790 Å (f= 0.288, W_λ(ZO)=34:mÅ)are identical in appearance. Shoulders indicative of an unresolved component around +30 km/s appear in HD 93204, 93205, HDE 303308 and, possibly, HD 93130, while one near -30 km/s is suspected in HD 93162.

9. No evidence for interstellar molecules has been noted.

Our first appraisal of the velocity and intensity structure of the UV interstellar lines along various lines of sight to the Carina Nebula dramatically confirms and extends the complexity first noticed in the Ca II H and K lines. Excitation conditions in the interstellar medium within this giant H II region vary greatly on very small scales and, not surprisingly, differ markedly from those towards Zeta Oph. The new UV observations appear to have extended the total range of velocities spanned by interstellar lines in the Carina Nebula to about 400 km/s. Only some paths through the Vela SNR are known to show comparable interstellar line velocity structure; 30 Doradus in the LMC may be the site of similar, perhaps less extreme, behavior, however. *Einstein* satellite X-ray observations by Seward, et al. (ref. 8) have recently demonstrated that the weak Carina Nebula X-ray emission is actually composed of both diffuse emission and many weak sources associated with its numerous early O stars. Their observations rule out the Carina Source being a single, conventional SNR, although they suggest that emission originating in a hot gas due to stellar winds or due to supernova(e) which occurred 10^6-10^7 years ago could account for the diffuse X-ray component. It is clear that studies of the rich interstellar line spectra in both the UV and optical regions will provide numerous invaluable insights into the origin and current state of the enigmatic nebula surrounding Eta Carinae.

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TABLE I. - OBSERVATIONS OF CARINA NEBULA STARS

HD NUMBER	SPECTRAL TYPE	V	B-V	E(B-V)	EXPOSURE INFORMATION LWR(Exp. Time)	SWP(Exp. Time)
Group A: NW of Eta						
93160	O6III(f)	7.81	0.17	0.49	5666 (60 min)	
Group B: Nearest Eta						
93204	O5V((f))	8.42	0.10	0.42	5669 (120)	6597 (150)
93205	O3V	7.75	0.05	0.37	5647 (45)	6611 (60)
93162	WN6-A	8.10	0.42	0.62	5667 (90)	6609 (240)
303308	O3V((f))	8.17	0.13	0.45	5649 (100)	6596 (200)
Group C: SW of Eta						
93130	O6III(f)	8.06	0.22	0.54	5646 (75)	6594 (100)
93206	O9.7Ib(n)	6.24	0.13	0.42	5670 (15)	6612 (25)
Group D: Outer Boundaries						
93131	WN6-A	6.48	-0.02	0.25	1527 (7)	

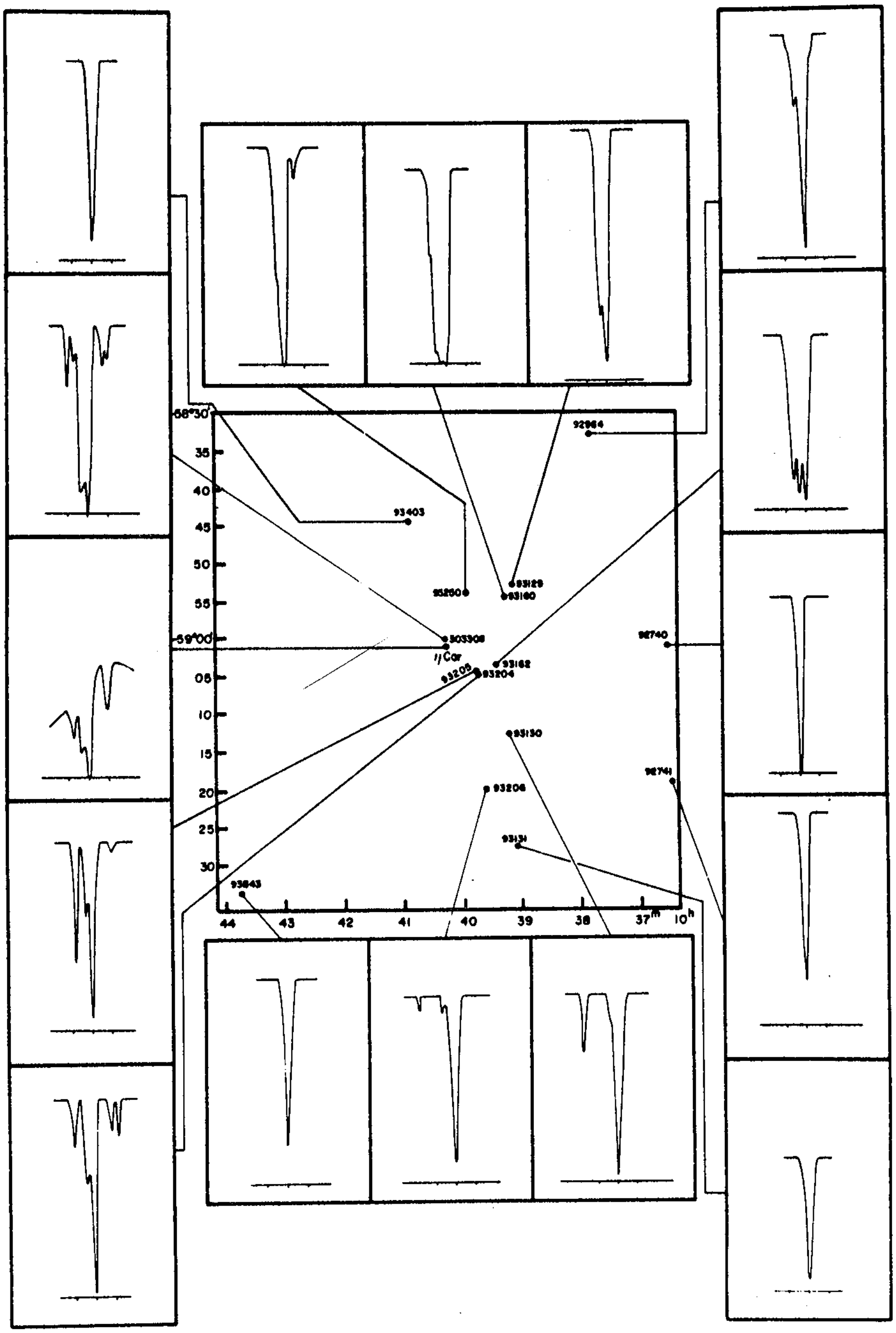

Fig. 1. The central part of this figure, which is from ref. 1, gives the distribution on the sky of the stars observed in the original CTIO coudé survey. The stars are identified by their HD or HDE numbers. The map is surrounded by the individual intensity profiles of the interstellar Ca II K line for each star. The vertical fiducial marks on the horizontal zero intensity line beneath each profile denote 0 and ± 100 km/s (heliocentric) velocity.

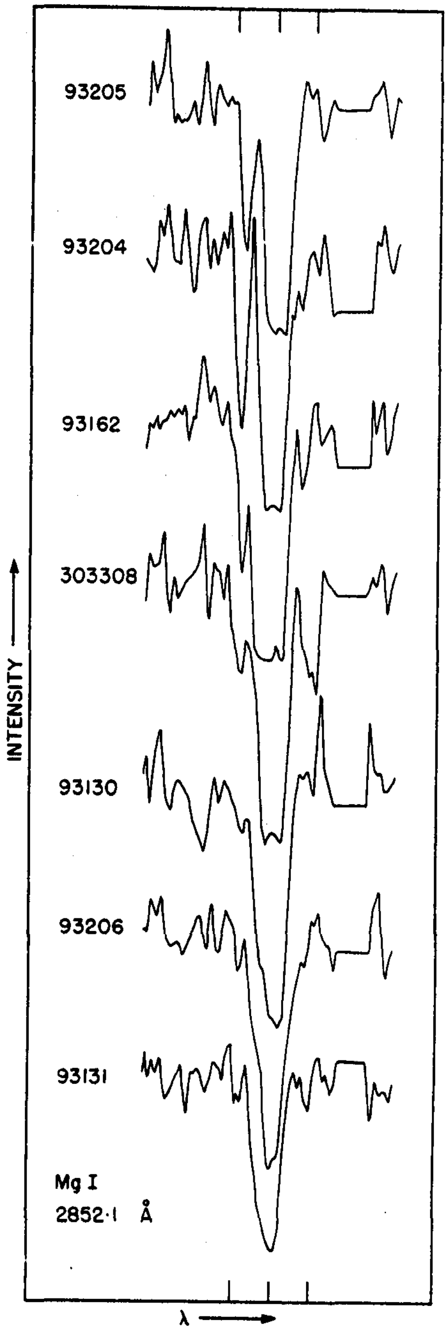

Fig. 2: Profiles of the Mg I 2852.127 Å line in seven Carina Nebula stars. For this, as well as the remaining figures, 6.0 Å of each spectrum are plotted. The fiducial marks on the abscissae indicate 0 and ± 100 km/s, although, as explained in the text, the zero point is somewhat arbitrary.

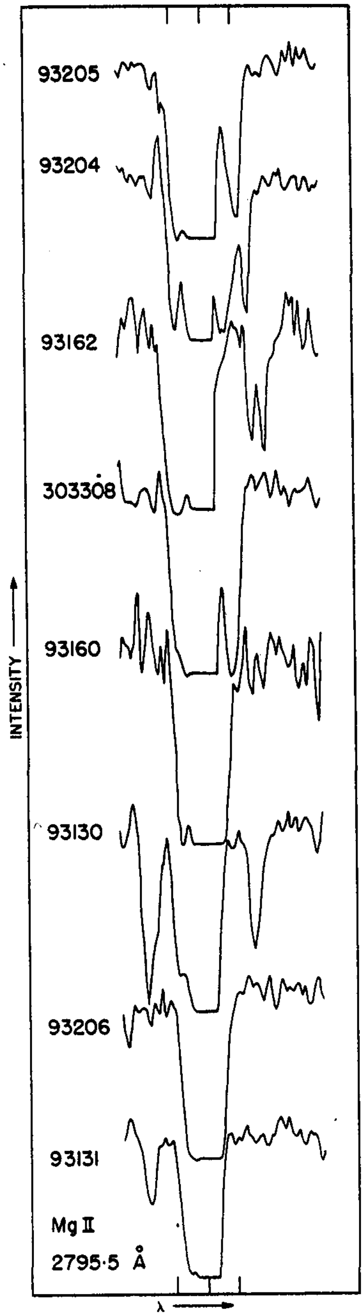

Fig. 3. Line profiles for the Mg II 2795.528 Å line; otherwise as in Fig. 2.

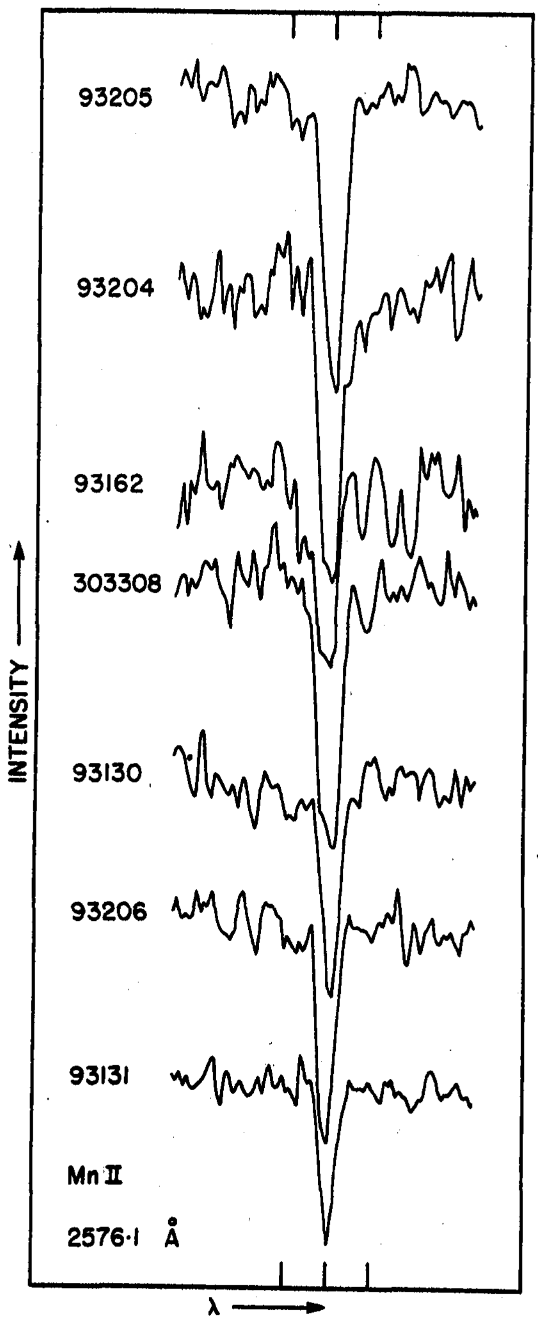

Fig. 4. Line profiles for the Mn II 2576.107 Å line; otherwise as in Fig. 2.

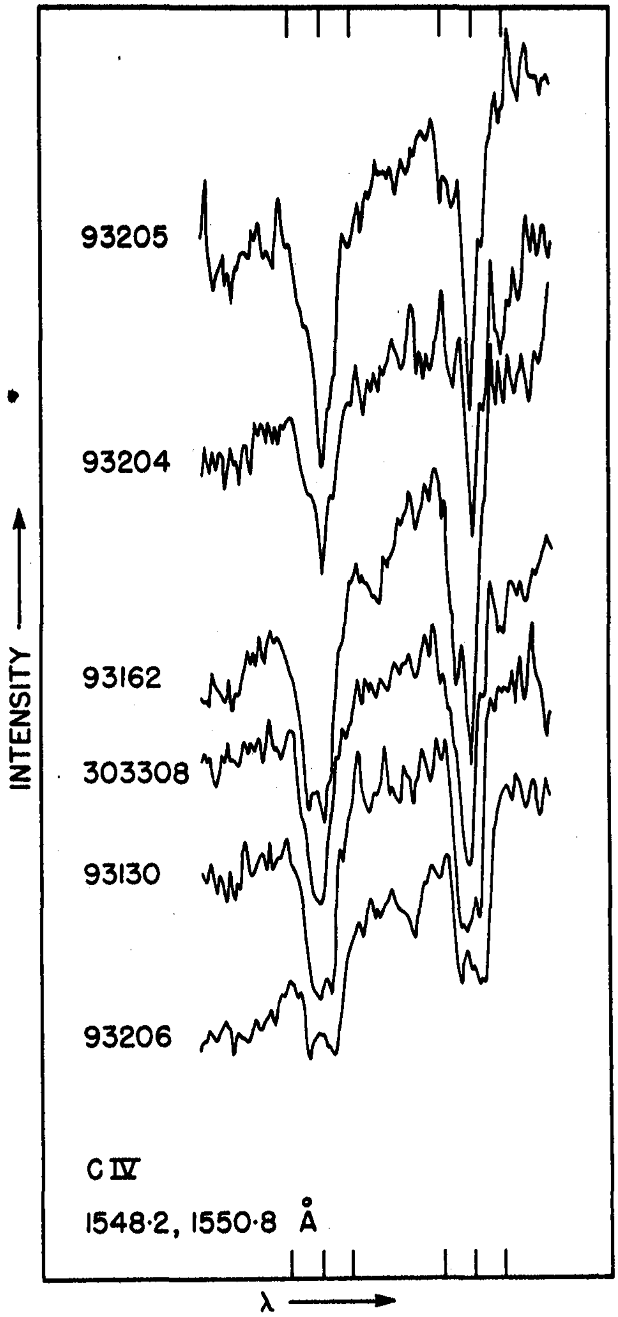

Fig. 5. Line profiles for the C IV 1548.202 Å and 1550.774 Å lines; otherwise as in Fig. 2.