A Massive Star Odyssey, from Main Sequence to Supernova
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Near-UV nebular absorption lines of η Carinae

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Abstract. The notorious η Carinae was observed with the STIS from 2380 Å to 3160 Å with a resolving power of ~130 000. Over 500 absorption lines have been identified as originating from Fe I, Fe II, Ti II, V II, Cr II, Ni II, Co II, Mn II, Mg I and Mg II. Most of the lines have multiple components ranging from $-145\,\mathrm{km\,s^{-1}}$, $-385\,\mathrm{km\,s^{-1}}$ to $-587\,\mathrm{km\,s^{-1}}$. Many interstellar absorption velocity systems, also found in the spectra of other Carina stars, are seen in the spectrum of η Car. While ISM absorption lines originate from the ground energy level, the nebular lines originate from energy levels well above the ground state. We are still evaluating the origin and location of these velocity systems in line of sight.

1. Introduction

The ultraviolet spectra of η Carinae is extraordinarily complex in nature. Previous spectral line identifications were provided by Viotti *et al.* (1989) for *IUE* spectra recorded with $R = 10\,000$ resolving power and a $10'' \times 20''$ aperture. Depending upon position angle, most or all of the visible Homunculus was included within the aperture. Spectroscopic observations have been done with *HST*-STIS with $R = 7\,000$ from 10 300 Å to 1640 Å and 0.″1 angular resolution (Gull *et al.* 2001). STIS, with resolving power $R = 30\,000$ and 0.″05 angular resolution (Davidson, *HST* 8327, 9083), recorded spectra from 1175 Å to 2350 Å. STIS resolves η Car from the nebula. Indeed overlap spectra between *FUSE* and STIS in the 1175 - 1185 Å region demonstrate that 95% of the far-UV is scattered by surrounding ejecta (Iping *et al.* 2001). The stellar spectrum below 2350 Å proves to be very complex due to a superimposed forest of narrow line absorptions. The large apertures of *FUSE* and *IUE* smear the spectrum due to the nebular scattered light. Moreover, the Baα P-Cygni line profiles, seen scattered off the Homunculus, change considerably with nebular position. Smith *et al.* (in preparation) interpret changes in the Balmer profiles as being due to the stellar wind being very different from the equatorial to the polar regions.

2. The observations and interpretation

The *FUSE* and the *HST*-STIS medium-resolution echelle data from 912 - 2350 Å prove to be very complex with many narrow absorption lines. In an attempt to resolve these absorptions, we obtained STIS observations in the high-dispersion echelle mode in the near-UV. The stellar spectrum changes less rapidly than in the far-UV, the interstellar absorption spectrum — known through comparison with nearby stars in the Carina complex — is very dull. However, we found a multitude of narrow absorption lines! Most do not correlate with classical ISM absorption lines. Only when we plotted known ISM line profiles, such as Mg I, Mg II, and normally weak ISM lines, did we realize that there were many distinct velocity components. Twenty nebular velocity systems were identified: one at $-145\,\mathrm{km\,s^{-1}}$, and rest between $-385\,\mathrm{km\,s^{-1}}$ to $-587\,\mathrm{km\,s^{-1}}$. The $-145\,\mathrm{km\,s^{-1}}$ system has an intrinsic line width of about $10\,\mathrm{km\,s^{-1}}$; the rest have line widths of a few $\mathrm{km\,s^{-1}}$. Then we found absorption lines arising from lower energy levels well elevated about the ground. For the $-145\,\mathrm{km\,s^{-1}}$ system, some of these lower levels appear to be as high as 4 eV! A high velocity system at $-513\,\mathrm{km\,s^{-1}}$ has many very narrow absorption lines with intrinsic widths of $2.3\,\mathrm{km\,s^{-1}}$ and with lower levels ranging from 0 to 0.1 eV. We found the following ions and atoms: $-147\,\mathrm{km\,s^{-1}}$: Fe II, Cr II, Ni II, Mn II, Co II and Mg II; $-513\,\mathrm{km\,s^{-1}}$: Fe I, Fe II, Ti II, Si I, Mg II, Mn II, V II, Ni I and Cr II. The presence of absorption lines from excited levels clearly indicates dense material close to the star!

η Car has a very strong stellar wind with terminal velocity $v_\infty = 550\,\mathrm{km\,s^{-1}}$. Likewise, much of the Homunculus outer structures, at 2.3 kpc distance, is consistent with a large shell ejected in the late 1840's (Morse *et al.* 2001). Weis, Duschl & Chu (1999) found long, nearly linear structures beyond the Homunculus with velocities as high as a few thousand $\mathrm{km\,s^{-1}}$. The Homunculus is very lumpy in character. Polarization measurements by King *et al.* (2002) indicate the shell thickness is thin, lending to single scattering events.

The $-145\,\mathrm{km\,s^{-1}}$ absorption system, with its $10\,\mathrm{km\,s^{-1}}$ width and with lower ionic energy levels as high as $46\,000\,\mathrm{cm^{-1}}$, is located close to η Car. The higher velocity systems are less easily placed. Their velocities are below the stellar wind terminal velocity, but the line widths and lower energy levels indicate that these systems must originate much further from the star. Likely, they exist within the Homunculus. However, a high dispersion spectrum of the blob Weigelt-D, $0\farcs2$ away from η Car, does not exhibit strong absorption systems. The presence of vanadium, which has never been seen in the ISM, and other species are rarely seen. Grain modification, or the lack of dust grains, is a strong possibility. Finally, we note that column densities derived from lines originating from the same lower levels do not appear to agree. This may indicate errors in *gf*-values, but could also indicate that the absorbing systems do not fully cover the star, *e.g.*, these may be small clumps with dimensions less that the stellar source. If true, we can anticipate dramatic variability in absorption with time.

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