A Massive Star Odyssey, from Main Sequence to Supernova
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A high-resolution study of η Carinae's outer ejecta

Kerstin Weis[1,2,3], Michael F. Corcoran[4,5], Kris Davidson[2], and Roberta M. Humphreys[2]

[1] *Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, BRD*
[2] *Department of Astronomy, University of Minnesota, 116 Church Street SE, Minneapolis, MN 55455, USA*
[3] *Feodor-Lynen-fellow, Alexander-von-Humboldt foundation*
[4] *Universities Space Research Association, 7501 Forbes Blvd, Ste 206, Seabrook, MD 20706, USA*
[5] *Laboratory for High Energy Astrophysics, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA*

Abstract. η Car is a very luminous and unstable evolved star. Outflowing material ejected during the star's giant eruption in 1843 surrounds it as a nebula, which consists of an inner bipolar region, coined the *Homunculus*, and the *Outer Ejecta*. The outer ejecta is very filamentary and shaped irregularly. Kinematic analysis, however, shows a regular bi-directional expansion, despite of the complex morphology. Radial velocities in the outer ejecta reach 2000 km s^{-1} and give rise to X-ray emission, as first detected by *ROSAT*. We will present a detailed study of the outer ejecta based on *HST* images, high-resolution echelle spectra for kinematic studies, images from *Chandra*-ACIS and *HST*-STIS spectra.

1. Morphology, kinematics and the soft X-ray emission

The outer part of the nebula around η Car contains a countless number of knots, bullets and filaments and manifests the so-called Outer Ejecta (diameter 60″ or 0.67 pc). A kinematic analysis, using high-resolution echelle spectra, showed that the outer ejecta expand with velocities between -600 km s^{-1} and $+600$ km s^{-1} on average (*e.g.*, Meaburn *et al.* 1996; Weis 2001a,b). Various filaments nevertheless show much higher radial velocities, *e.g.*, $\sim$2000 km s^{-1} (Weis 2001a,b). It is still unclear what triggered the outburst in 1843 and which mechanism not only formed η Car's nebula, but also the amazingly high expansion velocities.

With velocities that high, X-ray emission from η Car is expected and was indeed detected (*e.g.*, Cheblowski *et al.* 1984; Corcoran *et al.* 1997). With *ROSAT* and *Chandra* we are now able to separate between a harder, nearly point-like emission from the central source and an extended softer emission from η Car's outer ejecta, which is roughly hook-shaped (*e.g.*, Weis *et al.* 2001). Interestingly, an overlay of the optical image and the X-ray emission shows only a few correlations between the optically emitting gas and the hot X-ray gas (see Figure 1).

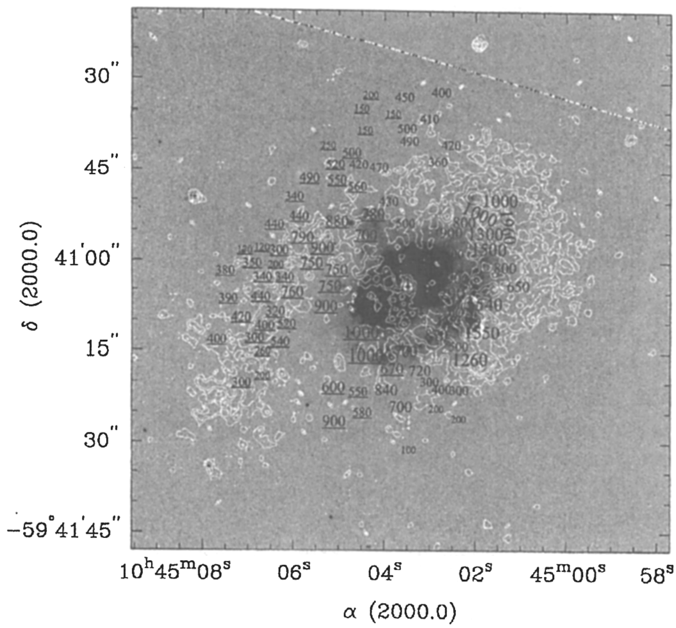

Figure 1. In grayscale the optical (F658N) *HST* image (WF chip) is shown and in contours the emission in the 0.6-1.2 keV band as detected with the *Chandra*-ACIS S3. Numbers indicate the expansion velocities of certain areas, underlined numbers are negative velocities, for better illustration the font size increases for higher velocities.

A much stronger conformance was found in comparison with the radial expansion velocities. The expansion velocities are derived from our optical echelle spectra (FWHM $\simeq 14$ km s^{-1}) and overplotted in Figure 1 with negative velocities underlined. Areas with higher X-ray emission show in general higher expansion velocities. The faster the gas is expanding, the more intense is the X-ray emission. The extended soft X-ray emission from η Car and especially the morphology of the X-ray nebula can, therefore, be explained by faster moving filaments which form X-ray emitting shocks. The temperature of the gas (using thermal equilibrium models) is ~ 0.65 keV (Weis *et al.* in preparation) indicating post-shock velocities of around 750 km s^{-1}, in very good agreement with the detected expansion velocities of the bulk of the gas.

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