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Eta Car: The Good, the Bad and the Ugly of Nebular and Stellar Confusion

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Abstract. Observations in the far-UV provide a unique opportunity to investigate the very massive star η Car and its hot binary companion, η Car B. η Car was observed with *FUSE* over a large portion of the 5.54 year spectroscopic period before and after the 2003.5 minimum. The observed spectrum is defined by strong stellar wind signatures, primarily from η Car A, complicated by the strong absorptions of the ejecta surrounding η Car plus interstellar absorption. The Homunculus and Little Homunculus are massive bipolar ejecta historically associable with LBV outbursts in the 1840s and the 1890s and are linked to absorptions at -513 and -146 km s^{-1}, respectively. The *FUSE* spectra are confused by the extended nebulosity and thermal drifting of the *FUSE* co-pointed instruments. Interpretation is further complicated by two B-stars sufficiently close to η Car to be included most of the time in the large *FUSE* aperture. Followup observations partially succeeded in obtaining spectra of at least one of these B-stars through the smaller apertures, allowing potential separation of the B-star contributions and η Car. A complete analysis of all available spectra is currently underway. Our ultimate goals are to directly detect the hot secondary star if possible with *FUSE* and to identify the absorption contributions to the overall spectrum especially of the stellar members and the massive ejecta.

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INTRODUCTION

Eta Car has bewildered astronomers since its sudden outbursts in the 1840s and 1890s. We now understand that η Car is in a short evolutionary stage referred to as the Luminous Blue Variable (LBV) phase. The LBV phase precedes the much longer Wolf Rayet phase and is characterized by repeated mass ejection events. The LBV phase is not fully understood. The reason for η Car's eruptions remains a mystery. However, LBV events are responsible for η Car's ejecta and its geometry as shown in Figure 1:left. Eta Car is located fairly nearby (2300 pc [1]), making it the best example of an object close to becoming a supernova. Consequently, investigations of η Car, can give insight about other peculiar objects such as supernova impostors and gamma ray bursters. Eta Car is a binary system with a spectroscopic period of 5.5 years [2], but the companion star, η Car B, has so far not been sufficiently characterized. The far-UV *FUSE* wavelength region is the best spectral region for detection the hot companion star. Iping et al. [3], in a previous *FUSE* spectrum analysis, observed far-UV flux that they attributed to η Car B. The analysis of the η Car *FUSE* spectra is not straight forward and includes many ob-

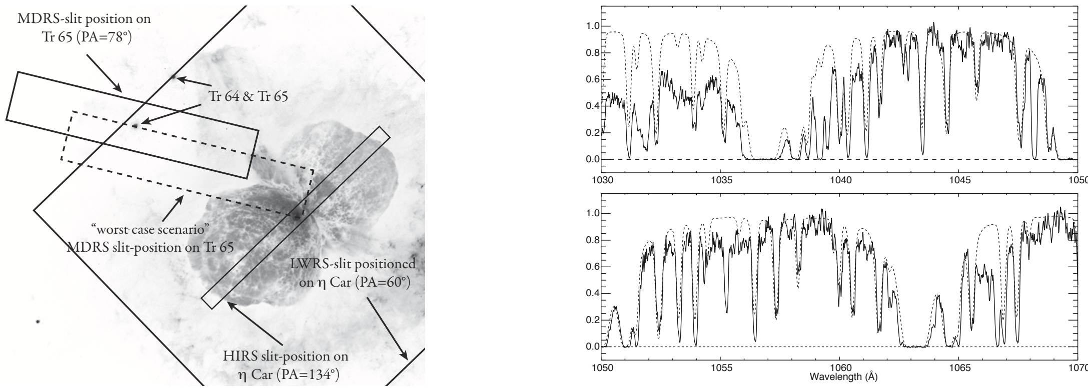

FIGURE 1. **Left:** *HST*/ACS Image of η Car with the *FUSE* apertures over-plotted. The η Car spectrum in Figure 2 (left) is recorded with the $1.''25\times20''$ HIRS aperture, while the adjacent B-star Tr 65 with the $4''\times20''$ MDRS aperture. With the MDRS aperture there may pointing problems as the aperture drifts to include flux from η Car. The $30''\times30''$ LWRS aperture engulfs the whole η Car system. **Right:** The spectrum of Tr 65 (solid), recorded with the *FUSE* MDRS aperture, can almost entirely be described by the ISM H_2 spectrum (dashed).

stacles. This paper discuss the current and future work on the η Car *FUSE* spectrum.

THE CURRENT STATUS AND THE FUTURE

The analysis of the η Car *FUSE* spectrum is challenged by factors that complicate and delay the analysis. The η Car *FUSE* spectrum must be corrected for space craft related effects including, but not limited to, drift of the *FUSE* apertures and the background radiation including the contribution from the nearby B-stars (see Figure 1:left).

The η Car spectrum, corrected for instrumental effects, is a composite of the wind spectrum from the central radiative source (including η Car A and B) with spectral features from the circumstellar nebulae and the interstellar medium (ISM) superimposed. Eta Car's dramatic history with eruptions in the 1840s and the 1890s formed the ejecta, including the Homunculus, the Little Homunculus and the Weigelt condensations. The large *FUSE* apertures include contributions from the surrounding nebulae. It is difficult to disentangle the spectral features originating from different parts of the η Car system.

To understand the influence of the ISM H_2, we used a H_2 template from McCandliss [4] with a *b*-values and column densities for the lowest energy states from Lee et al. [5]. Lee et al. investigated the ISM H_2 contribution in line-of-sight towards the Carinae nebula and reported two velocity components: one hot component at -20 km s^{-1}with b=5 km s^{-1} and N=7×10^{19} cm^{-2} and one foreground cool component at 4 km s^{-1}with b=4 km s^{-1} and N=1×10^{20} cm^{-2}. A template, to be applied to the η Car spectrum, was created by modeling the ISM H_2 spectrum towards the B-star Tr 65, as shown in Figure 1:right. Eta Car's spectrum can, as shown in Figure 2:left, only partly be explained by the ISM H_2. Metal absorption in the Homunculus and the Little Homunculus also modify η Car's spectrum [6]. In particular, the iron-group elements absorb a large portion of the η Car spectrum at *FUSE* wavelengths. Some absorption lines have been attributed to metals, and more lines are expected to be identified in the future analysis. Smith [7]

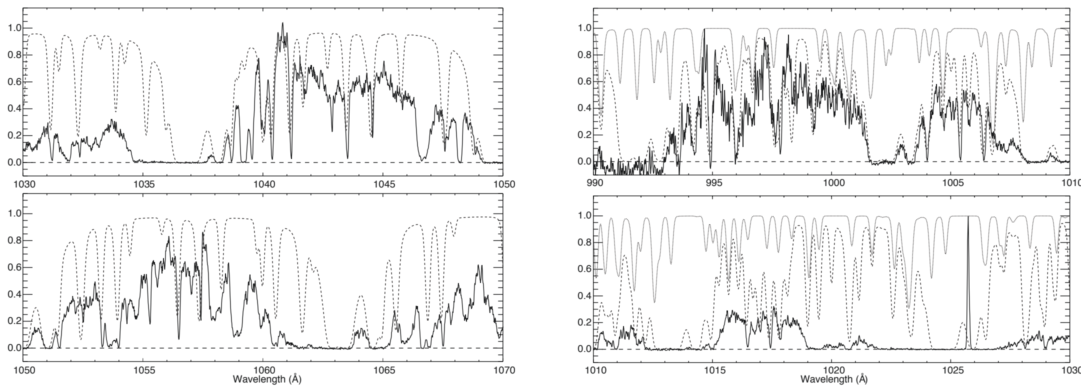

FIGURE 2. **Left:** η Car spectrum recorded with the *FUSE* HIRS aperture (solid). The η Car spectrum is fitted with an H_2 template [dashed, 4], similar to the one for Tr 65 (see Figure 1:right). The H_2 absorption does not explain the entire η Car spectrum. Additional absorption from the foreground ejecta plus the wind spectra are required to mimic the needed opacity. **Right:** HIRS η Car spectrum (solid) with H_2 model [3,4]. The H_2 spectrum has been observed at -513 km s^{-1}in the mid-UV [5] and is likely present in the *FUSE* spectrum. The dashed spectrum includes the ISM H_2 plus an H_2 column density of 10^{18} cm^{-2} and a b-value of 3 km s^{-1} at -513 km s^{-1}.

demonstrated the presence of H_2 in the Homunculus and Nielsen et al. [8] showed its impact in the -513 km s^{-1}spectrum at near-UV wavelengths. The H_2 spectrum is predicted to be strong in the *FUSE* spectrum, but so far, it is not established to what extent the H_2 ground transitions are present in the spectrum. A component with a total column density N=10^{18} cm^{-2} is used to see the potential H_2 contribution in the *FUSE* spectrum, as shown in Figure 2:right. We have used a b=3 for the -513 km s^{-1}H_2 spectrum. There are indications that the H_2 spectrum may have a velocity dispersion between -350 and -500 km s^{-1}.

The main goal of the analysis is to find spectral signatures from η Car B. When we master the contribution from the ejecta and the ISM, we can start the analysis of the underlaying wind spectrum and in particular spectral contributions from the companion star.

REFERENCES

1. K. Davidson, and R. M. Humphreys, *ARA&A* **35**, 1 (1997).
2. A. Damineli, *ApJL* **460**, L49 (1996).
3. R. C. Iping, G. Sonneborn, T. R. Gull, D. L. Massa, and D. J. Hillier, *ApJ* **633**, L37 (2005).
4. S. R. McCandliss, *PASP* **115**, 651 (2003).
5. D.-H. Lee, K.-W. Min, W. V. D. Dixon, M. Hurwitz, K.-S. Ryu, K.-I. Seon, and J. Edelstein, *ApJ* **545**, 885 (2000).
6. T. R. Gull, G. Vieira, F. Bruhweiler, K. E. Nielsen, E. Verner, and A. Danks, *ApJ* **620**, 442 (2005).
7. N. Smith, *ApJ* **644**, 1151 (2006).
8. K. E. Nielsen, T. R. Gull, and G. Vieira Kober, *ApJS* **157**, 138 (2005).