NASA LAW, February 14-16, 2006, UNLV, Las Vegas

Targeting inaccurate atomic data in the η Car ejecta absorption

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ABSTRACT

The input from the laboratory spectroscopist community has on many occasions helped the analysis of the η Car spectrum. Our analysis has targeted spectra where improved wavelengths and oscillator strengths are needed. We will demonstrate how experimentally derived atomic data have improved our spectral analysis, and illuminate where more work still is needed.

1. Introduction

Eta Carinae (η Car) is one of the most massive and luminous known objects. It is a star in its late evolutionary stage and is targeted, for example, to gain better understanding of the preliminary stages before becoming a supernova, and possibly to give insight about other extreme objects such as hypernovaes and supernova impostors. Furthermore, it has recently been discovered that the absorption spectrum of η Car shows similar characteristics as observed in gamma ray burster (GRB) progenitors (Chen 2005). The knowledge of the

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η Car ejecta will serve as platform for future studies of the currently not well known GRBs.

η Car's past is characterized by events in the 1840s and 1890s. The major outburst in the 1840s created the 18$''$ bipolar Homunculus and an intervening disk (Davidson et al. 2001), while a second less dramatic event in the 1890s is responsible for the interior Little Homunculus and the Weigelt blobs (Ishibashi et al. 2003). For more information about η Car's geometry, see Gull & Nielsen in these proceedings.

The spectrum of η Car displays a great variety of spectral features ranging from emission originating from the surrounding of the star to molecular and atomic absorption formed in the ejecta in the line-of-sight toward the star. The absorption spectrum has been analyzed (Gull et al. 2005; Nielsen et al. 2005; Gull et al. 2006) and used to characterize the ejecta. The Homunculus and the Little Homunculus have different characteristics ranging from a 760 K environment consisting of molecules and neutral elements to a 6400 K inner ejecta observed in predominantly singly-ionized iron-group elements. The Homunculus and the Little Homunculus are measured to have different heliocentric velocities at -513 and -146 km s^{-1}, respectively. Analysis of the η Car ejecta has been impeded by the lack of accurate atomic wavelengths and oscillator strengths. Collaborations with laboratory spectroscopists have provided improved atomic data, utilizing a better understanding of the physical processes of these gaseous and dusty environments.

2. Data and Analysis

The analysis presented in this paper is based on data obtained with (*HST*/STIS) during GTO program 9242 and GO programs 9083 and 9973. The data is obtained with the E230H grating and a $0.''2\times0.''3$ aperture setting providing a spectral resolving power of $R\sim$110,000. The angular resolving power of *HST* STIS ($\sim0.''060$ FWHM) has been invaluable and utilized the use of a $0\farcs088$ subset of the aperture to avoid contamination from the nebula.

The analysis of the ejecta was performed with a standard curve-of-growth in combination with CLOUDY photo-ionization modeling. Physical parameters such as the excitation temperature, electron density and distance from the ionizing source were derived based on measured atomic level populations in the ejecta.

The analysis has repeatedly been challenged by errors that can be attributed the measurements and/or inaccurate atomic data. By estimating the measurement errors we have been able to target where there is a need for more accurate atomic data. Collaboration with the laboratory spectroscopy community has been very fruitful. New experimental atomic data has improved the accuracy of the derived radial velocities and column densities. Figure 1 shows an attempt to derive expansion velocity for the Homunculus using V II transitions from the lowest energy states. New experimental data (Johansson 2003; Arvidsson 2003) removed the major scatter in the plot and was the base for a single value heliocentric velocity.

The CLOUDY photo-ionizing modeling require input parameter defining the radiative source as well as well as the chemical structure of the ejecta. Therefore, it is essential

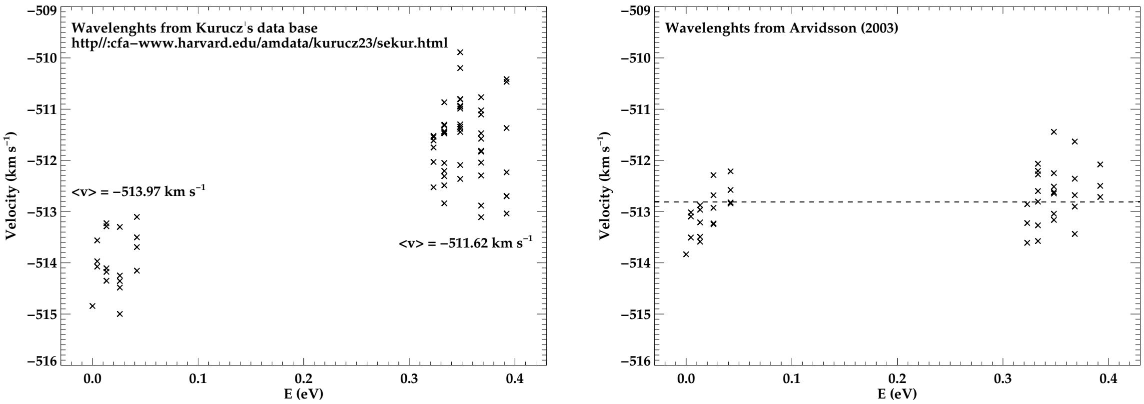

Fig. 1.— Radial velocity measurements for the Homunculus using lines from the lowest configurations in V II.

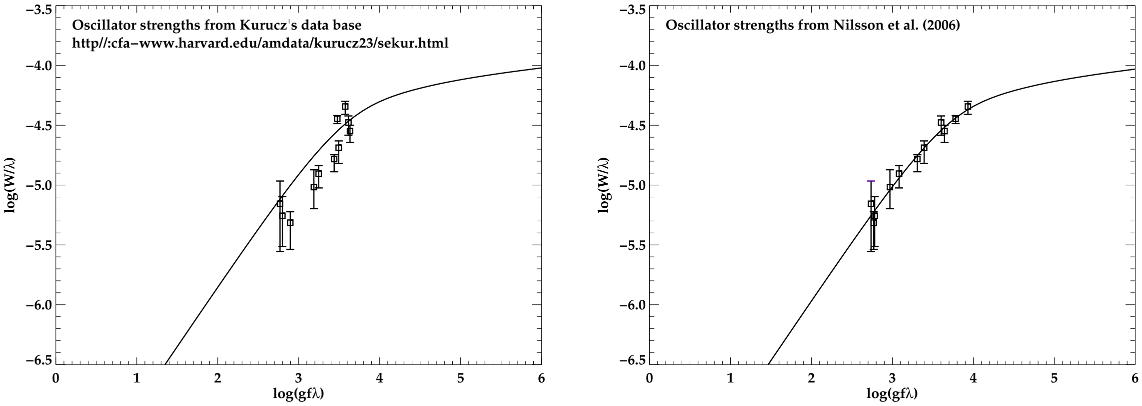

Fig. 2.— Column density measurements using a standard curve-of-growth, presented for the Cr II 4s a^{4}D term. The scatter was dramatically decreased when improved experimental loggf values were used.

to investigate the level populations for as many atoms/ions/molecules as possible. The modeling is highly dependent on the derived column densities and, hence the accuracy of the measurements as well as the available atomic data. Figure 2 present a curve-of-growth for one of the lower energy states in Cr II and how the new set of transition probabilities (Nilsson et al. 2006) has improved the fit of the theoretical curve-of-growth.

3. Summary

The variety of emission and absorption features, together with the angular resolving capabilities of *HST*/STIS, have utilized investigations of low and high density plasmas in the vicinity of η Car. The spectral analysis is highly dependent on accurate atomic data, whereas collaboration with the laboratory spectroscopy community is essential. We have targeted atomic data requirements, exemplified by V II and Cr II but important for other iron-group atoms/ions, and shown how the new laboratory data have helped improve the astrophysical analysis. The prevailing problems are, especially, oscillator strengths for the some of the neutral light elements, such as C I , N I and O I, but large scatter in Fe I curve-of-growth is also observed. Currently, we can not blame the inaccuracy of the latter on bad atomic data, since the excitation conditions in the analyzed gas may not be fully understood. Progress in the analysis of the η Car ejecta and the future understanding of the GRB progenitor spectra will depend on contributions from the laboratory spectroscopist.

This work is based upon observations made with the NASA/ESA *HST*, obtained at the Space Telescope Science Institute, under NASA contract NAS 5−26555.

REFERENCES

Arvidsson K. 2003, Masters Thesis, Lund University
Chen H. W. et al. 2005, ApJ 634, L25
Davidson K. et al. 2001, AJ 121, 1569
Ishibashi K. et al. 2003, AJ 125, 3222
Gull T. R. et al. 2005, ApJ 620, 442
Gull T. R., Kober G. V. & Nielsen K. E. 2005, ApJS 163, 173
Johansson S. 2003, private communication
Nilsson H. et al. 2006, A&A 445, 1165
Nielsen K. E., Gull T. R. & Kober G. V. 2005, ApJS 157, 138