The Fate of the Most Massive Stars
*ASP Conference Series, Vol. **VOLUME**, 2005*
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The Optical Variability of η Carinae Since 1950

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1. Introduction

The complex optical spectrum of η Carinae's central star originates in the photosphere of the substantial stellar wind. This light is scattered and reflected by many layers of circumstellar material before it emerges. The visual spectrum is characterized by several substantial emission features which are formed in both the stellar wind and the surrounding bright ejecta. These emission lines do not necessarily vary in phase with the continuum and they can substantially influence the total flux measured in some filters (see Figure 1 in Martin & Koppelman (2004)). For example, Balmer Hα (which varies significantly over time Davidson et al. (2004)) can account for as much as 30% to 50% of the total flux measured in the Cousins R filter.

The complex morphology of η Carinae's ejecta affects ground-based observations which lack the spacial resolution to separate the star from the surrounding nebulosity. The star itself is embedded in a large bipolar reflection nebula (the Homunculus) and there are also many bright knots within $1''$of the center which introduce many narrow nebular emission lines into the spectrum.

The Hubble Space Telescope has allowed us to view η Carinae with unprecedented spatial resolution at visual wavelengths, making it possible to measure changes in the brightness of the central star independent of the nebula (Martin & Koppelman 2004). These measurements have shown that the nebula and the central star change brightness roughly in phase. However, the changes measured in the brightness of the central star alone over the last six years are much more dramatic than the brightness changes implied by ground-based observations of the nebula and central star combined.

2. The Brightening of η Carinae

η Carinae's last fifty years of brightening can be separated into two categories: a long term trend (50+ years), and recent jumps in brightness over the last 6 years. The longterm trend was established following a sudden jump in brightness of at least one magnitude in the late 1940's and early 1950's (de Vaucouleurs & Eggen 1952; O'Connell 1956). This trend has continued upward to the present day at a rate of about 0.01 mag yr^{-1} (Mattei & Foster 1998; Feinstein 1967; Feinstein & Marraco 1974) and probably represents a steady clearing of obscuring material from a volume in the immediate vicinity around the star.

More recently, significant deviations from the long-term trend in 1998 and 2003 have been reported by Davidson et al. (1999) and Martin & Koppelman (2004). These episodes of rapid brightening differ from other episodes (like the one observed in ground-based photometry circa 1981) in that the these jumps in brightness have not been subsequently followed by a matching decrease in brightness several months later. Furthermore, both these episodes marked a dramatic increase in the apparent brightness of the central star without a comparable increase in the brightness of the surrounding nebula (Martin & Koppelman 2004).

This recent brightening has occurred almost entirely in the visual continuum flux from the central star (with no notable wavelength dependence). Balmer Hα and the other emission lines have not grown systemically brighter at the same time (Davidson et al. 2004). Therefore, we conclude that the recent brightening is probably due to a decrease in gray opacity primarily along our line of sight toward the central star.

3. The mid-2003 Spectroscopic Event

In mid-2003, visual ground-based observations recorded a drop in brightness of the *star plus ejecta* on the order of 0.1 to 0.2 magnitudes which coincided with the spectroscopic event (van Genderen, Sterken, Allen, & Liller 2003; Fernandez Lajus et al. 2003). These observations were made with wide-band filters which measured both continuum and emission lines.

Wide-band observations of the *central star* made with the STIS and ACS/HRC also showed a slight dip in brightness during the mid-2003 event (Martin & Koppelman 2004). However, closer inspection reveals that the drop in brightness was not observed at all wavelengths. While the continuum remained unchanged through the event, the prominent emission features (mostly H and He I) shrank significantly; accompanied by the growth of strong P-Cygni absorption for those lines Davidson et al. (2004) (Figure 1). Not surprisingly, the drop in strength of the H and He I features was completely in phase with the drop in UV flux.

Therefore, the dip in brightness observed at visual wavelengths during the spectroscopic event is *not* due to a continuous opacity source but rather single line opacities and line blanketing. This has important implications for models of the spectroscopic event since it makes it less likely that some kind of straight forward classical eclipse or geometric blocking is responsible for the observed dip in visual brightness.

4. Conclusions

- η Carinae's long-term brightening trend continues after fifty plus years.
- The recent brightening in 1998 and 2003 deviates from the long-term trend and could be due to a relatively sudden decrease in gray opacity along the line of sight toward the central star.
- The drop in visual brightness during the mid-2003 spectroscopic event was caused by a decrease in the strength of prominent emission features. The visual continuum flux was largely unchanged during that event, ruling out simple geometric blocking as the cause of the dip in brightness.

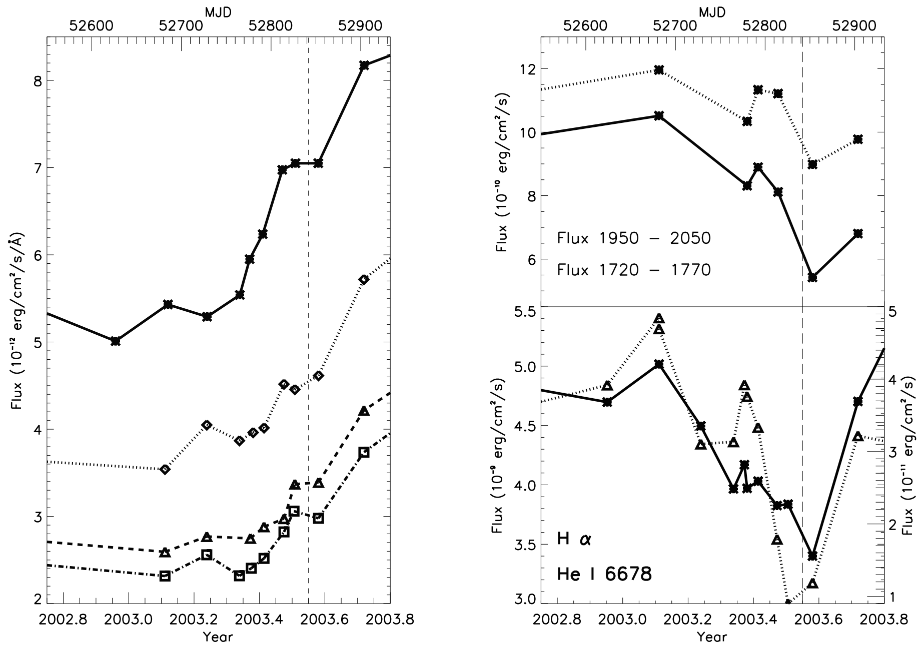

Figure 1. *Left Panel:* A plot of the continuum flux measured from the flux calibrated STIS spectra of the central star at 6770Å (stars + solid line), 5017Å (diamonds + dotted line), 4403Å (triangles + dashed line), and 4055Å (squares + dash-dot line). Note there is no significant dip in flux at the time of the spectroscopic event (vertical dashed line). *Right Panel:* The top is a plot of the NUV flux measured between 1950Å to 2050Å (dotted line) and 1720Å to 1770Å (solid line). The bottom is a plot of the flux measured in Balmer Hα (stars + solid line; read off the left axis) and He I λ6678 (triangles + dotted line; read off the right axis). Note that the emission line fluxes drop roughly in phase with the NUV flux through the spectroscopic event (vertical dashed line).

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Discusson

Discussion

Abraham: How sure can you be that the intensity decrease in the UV is only due to the lines and not also the continuum?

Martin: Work by Ted Gull and others analyzing the STIS/MAMA observations of the central star have identified a forest of ionized metal lines (referred to as the iron curtain) which rises in opacity during the spectroscopic events. Therefore, we are pretty certain that the increase in line blanketing opacity causes the decrease in UV flux during the spectroscopic event.