X-rays from An "Imposter"

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Abstract. I review the X-ray emission from the supernova "imposter" η Carinae, and briefly discuss the possible role of a binary companion star on the observational properties of the system.

1. X-rays from η Carinae – Signs of a Companion Star?

The enigmatic star η Carinae is extremely luminous and believed to be very massive ($\sim 100 M_{\odot}$) and to lie very near the Eddington Limit. It serves as an example of a possible hypernova/Gamma-ray burst precursor (Heger et al. 2003) and as a crude example of the supermassive stellar objects thought to form first in the Universe (Abel, Anninos, Norman, & Zhang 1998).

Recent evidence (Whitelock et al. 1994; Damineli 1996; Duncan et al. 1995; Corcoran, Rawley, Swank, & Petre 1995) suggests strongly that η Carinae is a binary system with a 5.54-year period. Continued monitoring at optical, radio and X-ray wavelengths has shown that the emission in these wavebands is strongly correlated. Every 5.5 years the radio, IR, optical and X-ray emission all experience a brief minimum in intensity.

Figure 1 shows the X-ray brightness in the $2-10$ keV band since 1996 as observed by the Rossi X-ray Timing Explorer (*RXTE*). The start of X-ray minima is given by $1997.95 + 5.536E$ where E is the cycle count and the epoch is derived from daily monitoring observations with *RXTE* prior to the 1998 X-ray minimum. The period, $P = 5.536$ years, is the interval between the start of the consecutive minima. Given the *RXTE* sampling near the minima, the nominal uncertainty on the period is less than one day.

The X-ray emission is believed to arise from a wind-wind collision. The periodic behavior of the X-ray emission is a consequence of orbital eccentricity coupled with variation in the amount of absorbing material in front of the colliding wind shock. The maximum X-ray temperature is about 50 million K, suggesting that the companion's wind velocity is ~ 3000 km s^{-1} (much higher than the measured wind speed of η Carinae itself, ≈ 500 km s^{-1}, Hillier, et al. (2001)). The mass loss rates from the X-ray spectra are $\dot{M}_{\eta} \approx 10^{-4} M_{\odot}$ yr^{-1} for η Carinae (smaller than the mass loss rates derived from radio and millimeter observations) and $\dot{M}_{c} \approx 10^{-5} M_{\odot}$ yr^{-1} for the companion star.

There are discrepancies between the observed X-ray emission and the colliding wind models: 1) the X-ray flux is expected to be strictly periodic, yet the observed emission shows significant cycle-to-cycle variation; 2) the X-ray

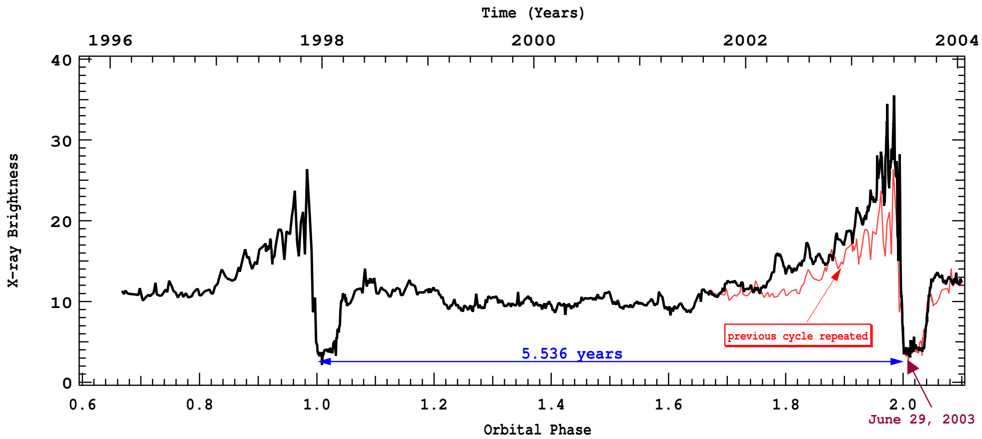

Figure 1. $2-10$ keV X-ray brightness of η Carinae as measured by the *RXTE* satellite from 1996-2003. The X-ray "lightcurve" shows a gradual increase in X-ray brightness prior to the decline to a minimum which lasts 3 months.

emission is expected to be more symmetric around periastron (Pittard, et al. 1998), yet the X-ray brightness prior to eclipse ingress is about a factor of 3 higher than the brightness after recovery from the eclipse; 3) unanticipated variations or "spikes" occur on a timescale of $\sim 80-100$ days (Ishibashi et al. 1997; Corcoran et al. 1997; Davidson, Ishibashi, & Corcoran 1998).

2. The Role of a Companion on the Evolution of η Carinae

A key question is what role the companion plays in the evolution of η Carinae in particular, and what role binarity plays in the evolution of extremely massive stars in general. Formation of extremely massive stars ($\sim 100M_{\odot}$) via competitive accretion of lower-mass stars ($\sim 10M_{\odot}$) in a dynamical collapse phase of a young cluster is one way to overcome radiative and angular momentum barriers (Bonnell, Vine, & Bate 2004) and some simulations have shown this process to result in creation of an extremely massive star orbited by a lower mass companion in a long-period elliptical orbit (Bonnell & Bate 2002). The evolution of binary systems in general differs from that of single stars due to exchanges of mass and/or angular momentum the system. For example, transfer of orbital angular momentum to rotational angular momentum of the primary could presumably cause large instabilities by reducing the effective gravity of the the primary, driving it closer to the Eddington Limit.

It is unclear what, if any, role the companion plays in the evolution of η Carinae. The star has undergone at least two major eruptions since the 1840's and it's an interesting question how the timing of these events relate to the X-ray minima. As noted in Damineli (1996) and by David Frew (this meeting) there is some circumstantial evidence that the timings of "spectroscopic events" are associated with these outbursts. Figure 2 shows the historical light curve of

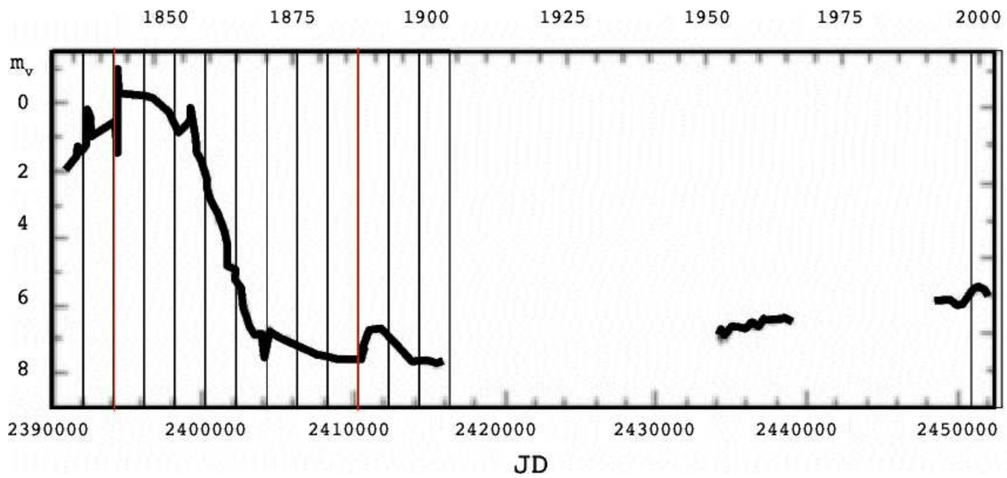

Figure 2. Times of X-ray minima compared to the historical V-band lightcurve. The start of the rapid brightenings of 1838 and 1843 (the "Great Eruption") apparently were associated with X-ray minima. In addition the 1890 "mini-eruption" was also apparently associated with an X-ray minimum (see also David Frew's contribution to this meeting), as were other times of rapid brightness variations.

η Carinae (Sterken 2000) with times of X-ray minima (based on the ephemeris given above) marked by vertical lines. X-ray minima are believed to be associated with periastron passages, so correlations between times of X-ray minima and large scale eruptions suggest a physical interaction between the two stars when the stars are close.

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