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X-Ray modeling of η Carinae & WR 140 from SPH simulations

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Abstract. The colliding wind binary (CWB) systems η Carinae and WR140 provide unique laboratories for X-ray astrophysics. Their wind-wind collisions produce hard X-rays that have been monitored extensively by several X-ray telescopes, including RXTE. To interpret these RXTE X-ray light curves, we apply 3D hydrodynamic simulations of the wind-wind collision using smoothed particle hydrodynamics (SPH). We find adiabatic simulations that account for the absorption of X-rays from an assumed point source of X-ray emission at the apex of the wind-collision shock cone can closely match the RXTE light curves of both η Car and WR140. This point-source model can also explain the early recovery of η Car's X-ray light curve from the 2009.0 minimum by a factor of 2-4 reduction in the mass loss rate of η Car. Our more recent models account for the extended emission and absorption along the full wind-wind interaction shock front. For WR140, the computed X-ray light curves again match the RXTE observations quite well. But for η Car, a hot, post-periastron bubble leads to an emission level that does not match the extended X-ray minimum observed by RXTE. Initial results from incorporating radiative cooling and radiative forces via an anti-gravity approach into the SPH code are also discussed.

Keywords. X-rays: binaries, stars: individual (η Carinae), hydrodynamics

1. Point-Source Emission Model

Our initial attempts to model the 2-10 keV RXTE light curves of both η Car and WR140 have applied a simple model of point-source emission plus line-of-sight wind absorption to 3D, adiabatic, smoothed particle hydrodynamics (SPH) simulations of the binary wind-wind interaction (see Okazaki *et al.* 2008 for details). To match the recent shorter minimum of η Car (Corcoran *et al.* 2010), the primary mass loss rate is reduced by a factor of 2.5 at phase 2.2. Many of the light curve's features are reproduced, including the shorter recent minimum. The WR140 light curve matches remarkably well.

2. Extended Emission Model

Our more recent efforts to model the RXTE light curves of η Car and WR140 relax the point-source approximation. The extended emission comes from the entire wind-wind collision region according to $\rho^2\Lambda(E,T)$, where ρ is the density and $\Lambda(E,T)$ is the emissivity as a function of energy E and temperature T obtained from the MEKAL code (Mewe *et al.* 1995), and the extended wind absorption is now energy dependent. We then use the SPH visualization program SPLASH (Price 2007) to calculate the ray-tracing through the system, which generates images in various X-ray bands that combine to make a 2-10 keV X-ray light curve. Once again, the WR140 light curve matches well (assuming the opacity is 10× the opacity of an O star wind at solar abundances, an assumption that

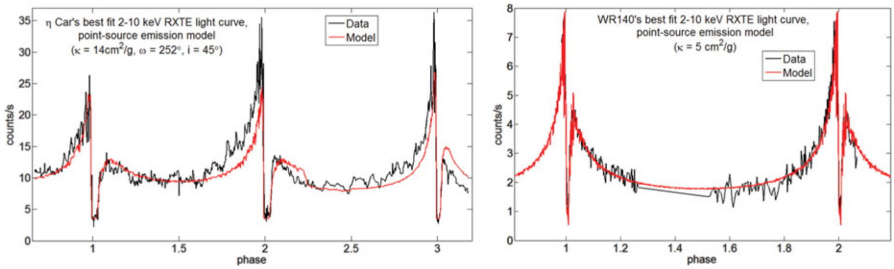

Figure 1. η Car and WR140's best fit RXTE light curves.

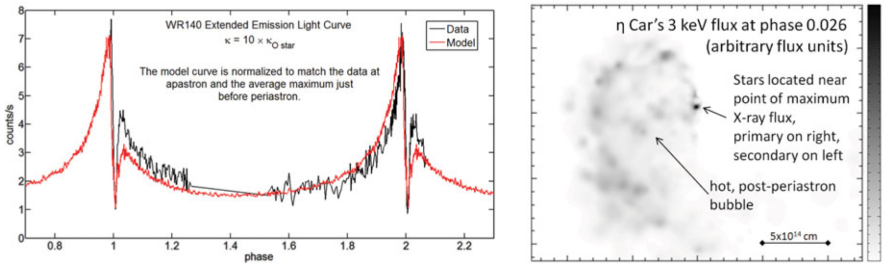

Figure 2. Left: WR140 extended emission light curve. Right: η Car flux at phase 0.026.

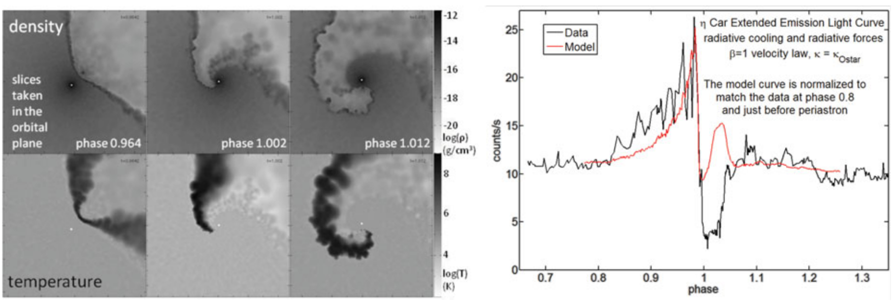

Figure 3. Left: Density and temperature maps. Right: η Car extended emission light curve.

will be relaxed in future work). The same is not true for η Carinae, however, where a hot, post-periastron bubble blown into the slow, dense primary wind by the much faster companion wind prevents the reproduction of the X-ray minimum.

Radiative cooling, via the Exact Integration Scheme (Townsend 2009), and radiative forces, via an anti-gravity approach, have been implemented to improve the SPH code. The acceleration of the secondary wind drastically decreases as the system approaches periastron, so the high temperature shock cone of η Car collapses, but the post-periastron bubble still prevents the reproduction of the minimum of the RXTE light curve with the extended emission model. However, outside the minimum, the model matches fairly well.

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