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Eclipse and Collapse of the Colliding Wind X-ray Emission from Eta Carinae

Kenji Hamaguchi[*,†] and Michael F. Corcoran[*,**]

[*]*CRESST and X-Ray Astrophysics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA*
[†]*Department of Physics, University of Maryland, Baltimore County, 1000, Hilltop Circle, Baltimore, MD 21250, USA*
[**]*Universities Space Research Association, 10211 Wincopin Circle, Suite 500, Columbia, MD 21044*

Abstract. X-ray emission from the massive stellar binary system, η Carinae, drops strongly around periastron passage; the event is called the X-ray minimum. We launched a focused observing campaign in early 2009 to understand the mechanism of causing the X-ray minimum. During the campaign, hard X-ray emission (<10 keV) from η Carinae declined as in the previous minimum, though it recovered a month earlier. Extremely hard X-ray emission between 15-25 keV, closely monitored for the first time with the *Suzaku* HXD/PIN, decreased similarly to the hard X-rays, but it reached minimum only after hard X-ray emission from the star had already began to recover. This indicates that the X-ray minimum is produced by two composite mechanisms: the thick primary wind first obscured the hard, 2−10 keV thermal X-ray emission from the wind-wind collision (WWC) plasma; the WWC activity then decays as the two stars reach periastron.

Keywords: Stars: individual (η Carinae) — stars: early-type — stars: winds, outflows — binaries: general — X-rays: stars
PACS: 97.10.Cv, 97.10.Me, 97.20.Pm, 97.80.Fk

SUMMARY

Eta Carinae is, arguably, the most massive star in our Galaxy, with the mass of $\sim 90 M_{\odot}$. It is in an unstable mass ejection (*LBV*) phase and is accompanied by an unseen main-sequence O star orbiting with a 5.54 year (2024 day) period [1]. Collision of winds from these stars (Wind-Wind Collision: WWC) produces hot plasma ($kT \sim 4$ keV) and emits thermal X-rays. The *RXTE* X-ray observatory, which has been continuously monitoring the star since 1996, demonstrated that the X-ray emission gradually increased toward periastron passage, following the prediction of the WWC theory, but that the emission suddenly dropped around the periastron passage [1, 2, 3].

To understand the X-ray minimum, we launched a focused observing campaign for η Carinae around the last periastron passage in early 2009 with the *RXTE*, *Chandra*, *XMM-Newton*, *Swift* and *Suzaku* observatories. Figure 1 shows light curves of η Carinae in the 2−10 keV and 15−25 keV bands, obtained with *RXTE*/PCA and *Suzaku*/PIN. Far from the periastron passage around phase 1, the 15−25 keV flux varied similarly to the 2−10 keV flux, since the 15−25 keV flux represents the tail of $kT \sim 4$ keV thermal emission [4]. Around X-ray minimum, however, the 15−25 keV flux is still significant, while the 2−10 keV flux reached its minimum level at phase ~ 1 (which we call the deep X-ray minimum); the 15−25 keV flux only reached its minimum level ~ 2 weeks after

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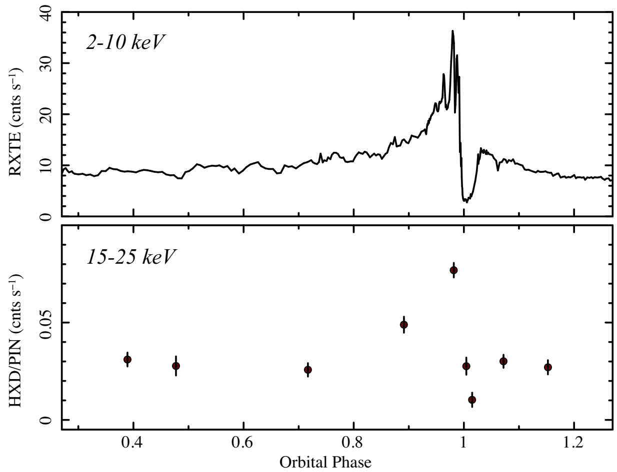

FIGURE 1. X-ray light curves obtained between 2005−2010. Phase 1 is defined such that the X-ray flux reached its bottom in the *RXTE* light curve.

the 2−10 keV flux minimum, during the "shallow" phase of the 2−10 keV minimum. A combined fit of the *Suzaku*/PIN and *Chandra*/ACIS spectra during the deep minimum requires strong absorption of $>\sim 3\times10^{24}$ cm^{-2}, suggesting that the deep minimum is caused by an eclipse of the WWC plasma by primary winds at superior conjunction. The cause of the abrupt decline in X-ray activity must indicate a sudden change in the WWC shock. A likely cause of this change may be radiative braking of the secondary's wind by the primary, or the sudden onset of radiative cooling in the shocked wind of the secondary. In either case, this indicates that the onset of the "shallow" phase of the X-ray minimum represents the time when the stars are at periastron, when the cooling rates in the shocked companion wind and radiative deceleration of the companion's wind is at maximum.

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