Constraints on decreases in Eta Carinae's mass loss from 3D hydrodynamic simulations of its binary colliding winds

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Recent work suggests that the mass-loss rate of the primary star (Eta A) in the massive colliding wind binary Eta Carinae dropped by a factor of 2-3 between 1999 and 2010. We present results from large- (r=1545au) and small- (r=155au) domain, 3D smoothed particle hydrodynamic (SPH) simulations of Eta Car's colliding winds for 3 Eta A mass-loss rates (2.4, 4.8, and 8.5 x 10^-4 M_sun/yr), investigating the effects on the dynamics of the binary wind-wind collision (WWC). These simulations include orbital motion, optically thin radiative cooling, and radiative forces. We find that Eta A's mass-loss rate greatly affects the time-dependent hydrodynamics at all spatial scales investigated. The simulations also show that the post-shock wind of the companion star (Eta B) switches from the adiabatic to the radiative-cooling regime during periastron passage. This switchover starts later and ends earlier the lower the value of Eta A's mass-loss rate and is caused by the encroachment of the wind of Eta A into the acceleration zone of Eta B's wind, plus radiative inhibition of Eta B's wind by Eta A. The SPH simulations together with 1D radiative transfer models of Eta A's spectra reveal that a factor of 2 or more drop in Eta A's mass-loss rate should lead to substantial changes in numerous multiwavelength observables. Recent observations are not fully consistent with the model predictions, indicating that any drop in Eta A's mass-loss rate was likely by a factor < 2 and occurred after 2004. We speculate that most of the recent observed changes in Eta Car are due to a small increase in the WWC opening angle that produces significant effects because our line-of-sight to the system lies close to the dense walls of the WWC zone. A modest decrease in Eta A's mass-loss rate may be responsible, but changes in the wind/stellar parameters of Eta B cannot yet be fully ruled out. We suggest observations during Eta Car's next periastron in 2014 to further test for decreases in Eta A's mass-loss rate. If Eta A's mass-loss rate is declining and continues to do so, the 2014 X-ray minimum should be even shorter than that of 2009.

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