Particle Re-Acceleration in Colliding Winds Systems? Radio, X-ray, and Gamma-ray Emission Models of WR 140

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We present calculations of the spatial and spectral distribution of the radio, X-ray and gamma-ray emission from shock accelerated electrons in the wind-collision region (WCR) of WR140. Our calculations are for orbital phase 0.837 when the observed radio emission is close to maximum. Using the observed thermal X-ray emission at this phase in conjunction with the radio emission to constrain the mass-loss rates, we find that the O-star mass-loss rate is consistent with the reduced estimates for O4-5 supergiants by Fullerton et al. (2005), and the wind momentum ratio, eta = 0.02.

The observed low frequency turnover at approximately 3 GHz in the radio emission is due to free-free absorption, since models based on the Razin effect have an unacceptably large fraction of energy in non-thermal particles. A key result is the index of the non-thermal electron energy distribution is flatter than the canonical value for diffusive shock acceleration (DSA), namely p<2. It is argued that this requires re-acceleration of non-thermal particles in multiple wind-embedded shocks, which are then injected as seed particles for further acceleration at the global shocks bounding the WCR.

There are some tantalizing hints that shock modification occurs in these systems. For example, the estimated amount of energy placed into non-thermal particles is high enough that non-linear effects should be important, and changes in the degree of shock modification with orbital phase may account for the asymmetry of the radio lightcurve and the smaller than expected variation in the X-ray lightcurve. Shock modification also results in softer X-ray emission from the post-shock plasma due to a reduction in the velocity jump across the subshock. While this is also consistent with observations, the long timescale for energy transfer between the post-shock ions and electrons may be the dominant cause.

Tighter constraints on p and the nature of the shocks in WR140 will be obtained from future observations at MeV and GeV energies, for which we generally predict lower fluxes than previous work. Since the high stellar photon fluxes prevent the acceleration of electrons beyond gamma ~ 1e5-1e6, TeV emission from CWB systems will provide unambiguous evidence of pion-decay emission from accelerated ions. We finish by commenting on the emission and physics of the multiple wind collisions in dense stellar clusters, paying particular attention to the Galactic Centre.

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