

The Interaction of Supernova Remnant Shocks with Interstellar Clouds

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Abstract

The feedback of energy and matter from stars to the interstellar medium (ISM) plays a crucial role in the evolution of the ISM within galaxies and in the evolution of the galaxies themselves. Supernovae (SNe) are arguably the most important contributors to energetic feedback in galaxies. The interfaces between the newly-ejected material from SNe and the surrounding ISM of a galaxy are supernova remnants (SNRs), which dictate the time and length scales over which matter from a SN is deposited into the ISM. We understand how highly idealized SNRs evolve, the interaction of an SNR with an inhomogeneous ambient ISM is not well understood. The regions where SN blast waves encounter density clumps, i.e. clouds, in the CSM/ISM are among the most interesting observationally, since they give rise to a plethora of diagnostic emission lines and complicated geometries. The Hubble Space Telescope, the Far Ultraviolet Spectroscopic Explorer, and an array of other instruments have been used to identify many such cloud-shock regions along the periphery of the nearby Cygnus Loop. This SNR is particularly interesting for studies of such interactions: the SN giving rise to this remnant exploded in a very low density cavity, and its blast wave has only encountered the cloudy walls of this cavity in the last ~ 1000 years. The archival HST and FUSE observations of this remnant are among the best available and can be used to constrain models of SNR-cloud interactions. We propose to carry out numerical simulations of SN shocks engulfing small, optically thin interstellar clouds. Our 3D adaptive mesh refinement (AMR) magnetohydrodynamic (MHD) simulations will incorporate an array of physics never before included in such models, such as non-equilibrium cooling, molecular hydrogen chemistry, and anisotropic thermal conduction (important in the presence of a magnetic field). Among the questions we hope to answer with these simulations are: 1) Can these models predict ionic emissivities that agree with HST and other observations? 2) Can they reproduce the observed distribution of shock velocities around an engulfed cloud? 3) Do the clouds fragment or are there other means of mixing their contents into the centers of SNRs? 4) Does such mixing adequately explain the presence of \tilde{O} -mixed-morphology \tilde{O} remnants? An important aspect of our work will be the direct comparison of predictions from our proposed simulations with HST imaging and spectroscopy of the Cygnus Loop. This comparison will allow us to test the numerical simulations so that they may be used to interpret observations of other SNRs.

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