Supernovae and Supernova Remnants in the IXO Era

Abstract
Supernova remnant (SNR) research aims to understand the mechanisms of explosion, constrain predictions of nucleosynthesis calculations, study the behavior of high-speed collisionless shocks, and investigate the injection of cosmic rays into the surrounding interstellar medium. X-ray studies offer a comprehensive picture of these high-energy processes in SNRs because of the high velocities involved, typically 1000-10000 km/s, the temperatures of 10^6 to 10^8 K, and the fact that highly ionized species of the abundant elements from C through Ni produce emission lines in the energy range between 0.2 and 10 keV.

The International X-ray Observatory (IXO), a joint mission under study by NASA, ESA, and JAXA, offers dramatic improvements over existing missions in terms of effective area and spectral resolution for the X-ray waveband. In this paper we present several studies that highlight the power of IXO to make fundamental advances in SNR research.

Type Ia SN: trace Fe-group nucleosynthesis

Type Ia SNs have different progenitors (Scannapieco & Bildsten 2005). X-ray spectra of the remnants can distinguish between SN Ia subtypes (Badenes et al. 2006, 2008). IXO simulations (below) show obvious differences between bright (Fe-rich) and dim (Fe-poor) ones (blue) in 100 ks long observations of 400-yr old SNRs. IXO will allow a statistical study of SN Ia progenitor properties in relation to stellar populations of M33.

SNRs in Nearby Galaxies (e.g., M33)
The image at left plots the deep Chandra images of M33 (Plucinsky et al. 2008) convolved with IXO’s PSF, showing that most X-ray sources are cleanly resolved. M33 and M31 will be fertile ground for X-ray spectral studies of many source populations, especially SNRs. For example, there is growing evidence that bright and dim Type Ia SNRs have different progenitors (Scannapieco & Bildsten 2005). X-ray spectra of the remnants can distinguish between SN Ia subtypes (Badenes et al. 2006, 2008). IXO simulations (below) show obvious differences between bright (Fe-rich) and dim (Fe-poor) ones (blue) in 100 ks long observations of 400-yr old SNRs. IXO will allow a statistical study of SN Ia progenitor properties in relation to stellar populations of M33.

Shock Physics: Thermal Particles
IXO studies of SNRs will help reveal how high Mach number collisions in SNRs operate. Recent studies show that electron-temperature equilibrium appears to be a function of shock velocity (Hwang & Laming 2003). Observations include:
- Electron temperature: constrained by thermal continuum and line ratios
- Ion temperature: constrained by line widths
- Non-Maxwellian components of electron distribution from line shapes.

Shock Physics: CR Acceleration
Efficient shock acceleration of cosmic rays (CRs) modifies SNR shocks by lowering the temperature and raising the density in the post-shock flow. Simulations to the right show spectra at IXO resolution of shocks evolving into different density regimes with, in each case, efficient red (curve) and no (black) acceleration. Combining electron and ion temperatures with gas velocities should reveal the hadronic component of cosmic rays (Hughes et al. 2000).