International X-ray Observatory (IXO)

Supernovae and Supernova Remnants in the IXO Era

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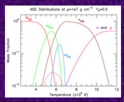
Abstract

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 metals and energy into the surrounding ambient medium.

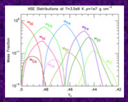
X-ray studies offer a comprehensive picture of these high energy processes in SNRs because of the high velocities involved, typically 100's to 1000's km/s (temperatures of 10^5 to 10^8 K), and the fact that highly ionized species of the abundant elements from C through Ni produce emission lines in the 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 poster we present several studies that highlight the power of *IXO* to make fundamental advances in SNR research.

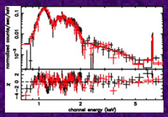
Trace Fe-group nucleosynthesis



In general nucleosynthesis at nuclear statistical equilibrium (NSE) depends on density, temperature, and Y_e



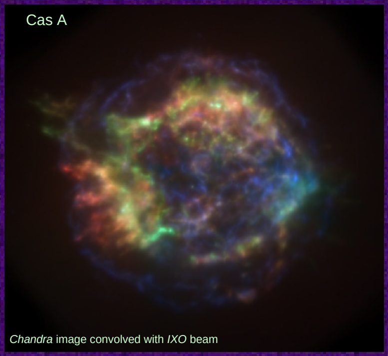
Cas A: Fe-rich knots



Chandra spectrum of nearly pure Fe knot in Cas A

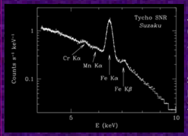
IXO can resolve many spectrally distinct knots in Cas A (see image simulation to right) to obtain line widths, velocities, and abundances

Expect count rate of ~0.25 *IXO* cts/s for inner shell K lines of ^{44}Sc and ^{44}Ca from ^{44}Ti decay



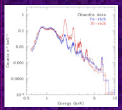
Chandra image convolved with *IXO* beam

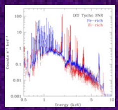
Type Ia SN: trace Fe-group nucleosynthesis



Suzaku detection of Cr (>10σ) and Mn (>7σ) Kα emission lines from Tycho SNR ejecta (Tamagawa et al. 2008)

Mn/Cr mass ratio in SNIa explosion a strong function of the progenitor's metallicity (Badenes, Bravo, & Hughes 2008)





(Left)-*Chandra* spectra of Fe- and Si-rich knots on eastern rim of Tycho

(Right)-*IXO* simulation

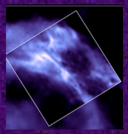
IXO can detect the Mn and Cr Kα lines in Tycho on spatial scales of 15" in exposures of 200 ks or less

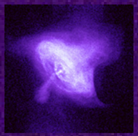
Will map the spatial distribution of Fe-group trace elements in ~10 remnants of SN Ia's

Chandra image convolved with *IXO* beam

X-ray Polarization

SNRs like RXJ 1713.7-3946 (below left) and pulsar wind nebulae like the Crab Nebula (below right) are dominated by nonthermal synchrotron X-ray emission and therefore are prime targets for X-ray polarization studies.





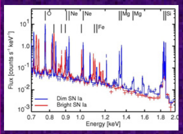
By examining how the polarization fraction varies across the shock in RXJ 1713.7-3946 we may be able to test whether the amplified magnetic field (turbulent) decays away post-shock (Pohl et al. 2005). The polarization fraction as a function of energy may help identify the thermal emission.

Chandra image convolved with *IXO* beam

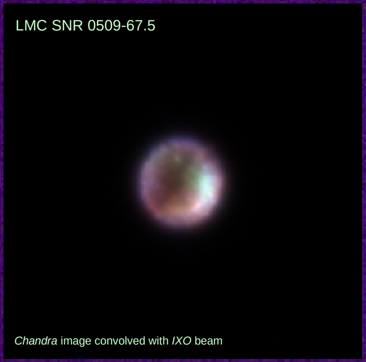
SNRs in Nearby Galaxies (e.g., M33)

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 SNe have different progenitors (Scannapieco & Bildsten 2005). X-ray spectra of the remnants can distinguish between SN Ia subtypes (Badenes at al. 2006, 2008). *IXO* simulations (below) show obvious differences between bright (Fe-rich) subtypes (red curve) 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.



Chandra image convolved with *IXO* beam

Shock Physics: Thermal Particles

IXO studies of SNRs will help reveal how high Mach-number collisionless shocks operate. Recent studies show that electron-ion temperature equilibration appears to be a function of shock velocity (Ghavamian et al. 2001).

These studies require SNRs with thermally-dominated shocks (e.g., the Cygnus Loop, parts of RCW 86, and G292.0+1.8, simulated *IXO* image shown below).

Observables include:

Electron temperature: constrained by thermal continuum and line ratios

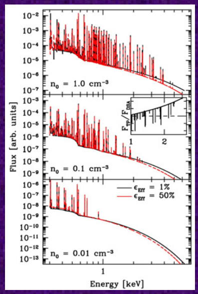
Ion temperature: constrained by line widths

Non-Maxwellian components of electron distribution from line shapes.

Shock Physics: CR Acceleration

Efficient shock acceleration of cosmic rays (CR) 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 regions with, in each case, efficient (red curves) and no (black) acceleration.

Combining electron and ion temperatures with gas velocities should reveal the hadronic component of cosmic rays (Hughes et al. 2000).



References

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