The Galactic Ridge X-ray Emission

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Outline of Talk

• Introduction
  • History of GRXE has many similarities to that of CXRB.

• Early Results from HEAO A2
  • First instrument designed to measure diffuse X-ray emission.

• Recent Results
  • RXTE, Chandra, & Suzaku

• Future Work
Introduction

- X-ray emission from the plane of the Milky Way (Galactic Ridge X-ray Emission -- GRXE) was a long-time interest of E. Boldt.
  - His interest was, in part, motivated by his CR research.
- Boldt & Serlemitsos (1969) discussed X-ray bremsstrahlung from CR protons and speculated on emission in ISM; Pravdo & Boldt (1975) calculated line emission from CR oxygen.
- In a rocket flight Bleach et al. (1972) discovered GRXE & discussed possible emission mechanisms.
- Contributors could include discrete sources and diffuse mechanisms such as thermal bremsstrahlung, non-thermal bremsstrahlung (e & p), inverse Compton, and synchrotron.
- Subsequent observations with HEAO A2, RXTE, Suzaku, and other missions have greatly increased our knowledge, but the source(s) of the GRXE remains controversial.
HEAO A2

- E. Boldt was the PI of the HEAO A2 instrument, which was specifically designed to measure diffuse X-ray emission.
  - Launched in 1977, it scanned the sky for ~17 months.
  - It produced the first low-background, all-sky maps in the 2-60 keV band.
E. Boldt led the group that produced key papers on unresolved X-ray emission.

- (Extragalactic) XRB fluctuations (Shafer 1983).
- Thick disk GRXE (Iwan et al. 1982).
  - Pillbox model with $h > 1500$ pc; $R > 14$ kpc; $kT \sim 9$ keV.
  - Due to halo stars? Hot gas?
- Thin disk GRXE (Worrall et al. 1982).
  - $h \sim 241$ pc; $R \sim 3.5$ kpc;
  - Worrall & Marshall (1983) concluded that low luminosity stars such as CVs and RS CVn stars are the most important contributors.
Current Status

• Recent missions provided better measurements.
  • RXTE provided larger detectors and a smaller FOV (~1°).
  • Chandra took deep images of a small region.
  • Tenma and ASCA found a strong Fe-K line, which has now been resolved with Suzaku.
Valinia & Marshall (1998) found 2 components with scale heights of 70 and 500 pc. Images cover $l \in [56^\circ, -44^\circ]$ & $|b| < 1.5^\circ$ in 3 energy bands.

- The spectrum was a 2-3 keV thermal plasma + power-law tail.
- Thermal emission from SN + PL from CR bremsstrahlung?
Revnivtsev et al. (2006) noted the strong correlation between the surface brightness in X-ray & NIR bands and thus the GRXE traces the stellar mass distribution.

They concluded that the bulk of the GRXE is due to weak X-ray sources such as CVs.

A sensitivity of $2 \times 10^{-16}$ is needed to resolve 90% of the flux.

Contours: 3-20 keV X-ray

Image: 3.5 µm NIR
Ebisawa et al. (2005) took deep (~100 ks) Chandra images from the Galactic Plane near l=28°.

- Sensitivity is $3 \times 10^{-15}$ (cgs).
- Few point sources beyond expected from extragalactic.
- Point sources contribute small fraction of total flux.
- High luminosity sources ($L_x > 10^{33}$) cannot be significant contributors.

*red*: 0.5-2 keV; *green*: 2-4; *blue*: 4-8
Ebisawa et al. (2008) used Suzaku to resolve the Fe-lines from unresolved emission from the Galactic Plane near $l=28$.

Results indicate a multi-temperature plasma near collisional equilibrium.

- Cosmic-ray charge-exchange and non-equilibrium ionization plasma models are inconsistent with the observed narrow lines and line ratios.
- There is also an Fe fluorescence line.
Future

• Two approaches have been suggested to determine the main contributors to the GRXE.
• Deep exposures to resolve most of the flux into discrete sources.
  • Need to be able to detect sources at $\sim 10^{-16}$ (cgs).
  • Chandra could do this with very long exposures.
    • Elihu proposed this in a recent informal call for ideas for Chandra.
• High resolution spectroscopy to determine the density of the emitting gas.
  • Resolve He-like K-$\alpha$ triplet and compare strengths of forbidden (6634 eV) and inter-combination lines (6680 & 6665 eV).
  • Calorimeter on Astro H will be able to do this with very long exposures.
• Elihu’s ideas inspired many (including myself) and led to several decades of fascinating research.