The Galactic Ridge X-ray Emission

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Elihu Boldt Memorial Symposium

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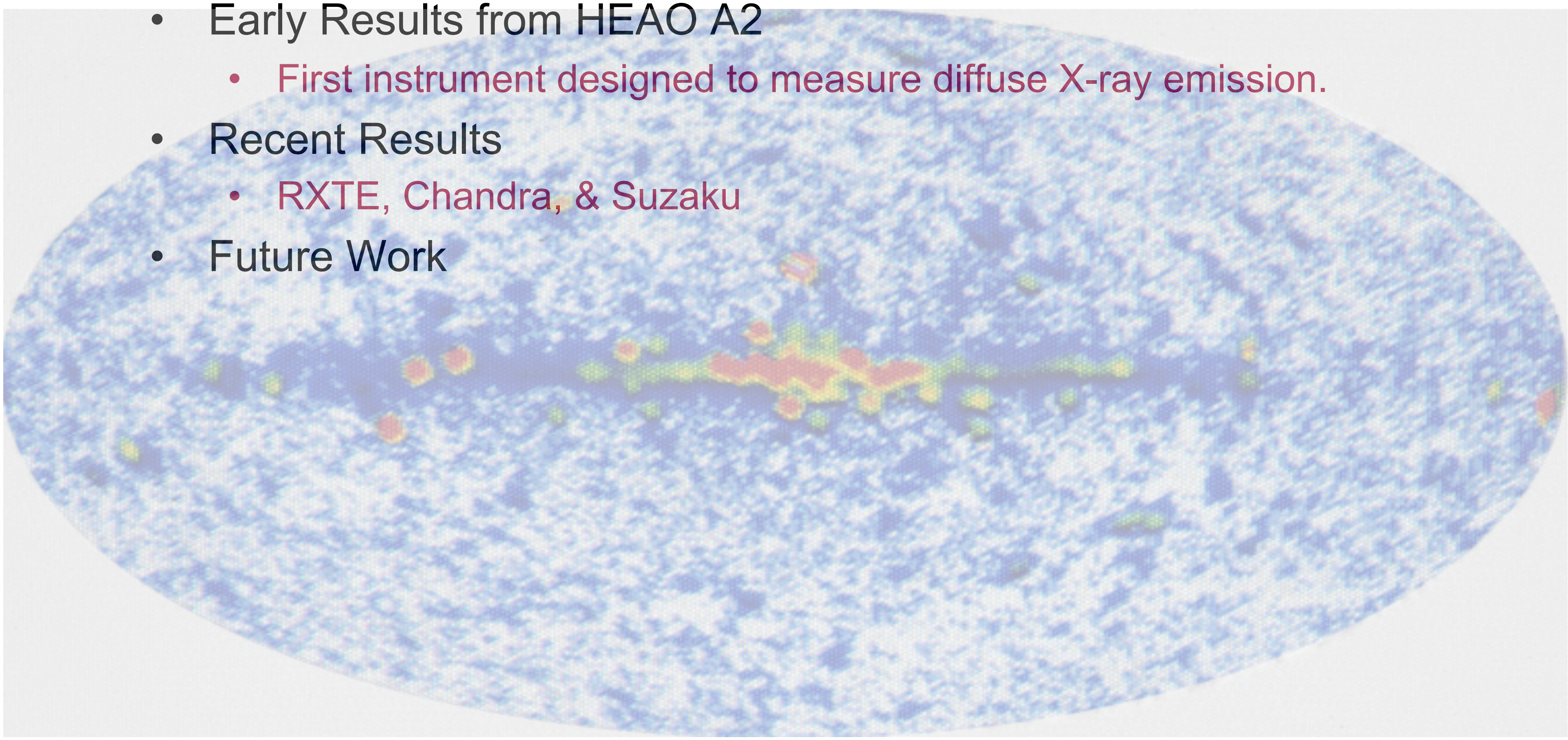
Outline of Talk

- 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



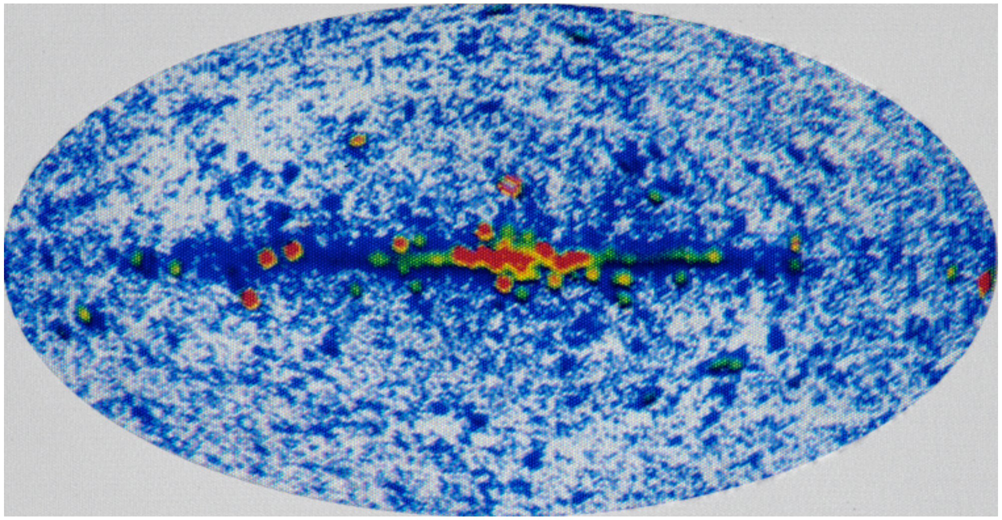
Introduction

- 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 bremstrahlung, non-thermal bremstrahlung (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.

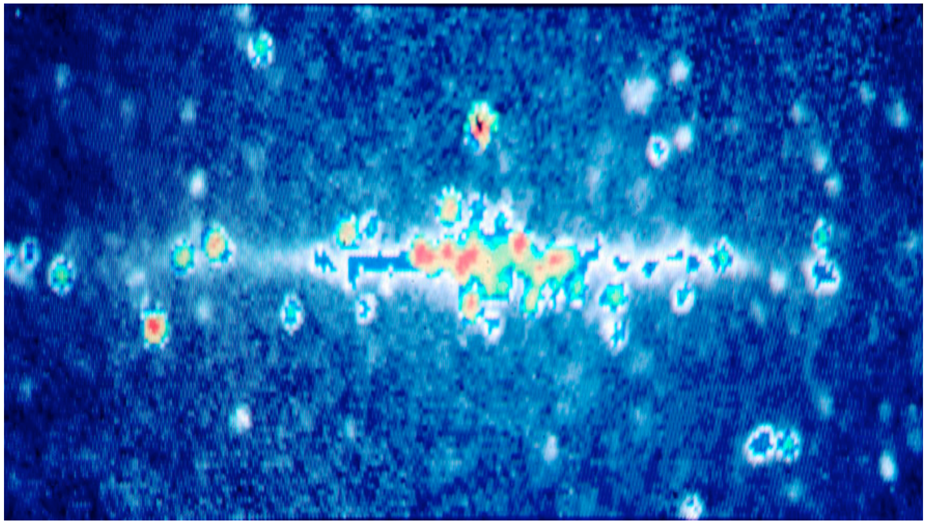
HEAO A2

- 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.

HED 1



MED: $l=\pm128°$ $b=\pm45°$



B E

GRXE

HEAO A2

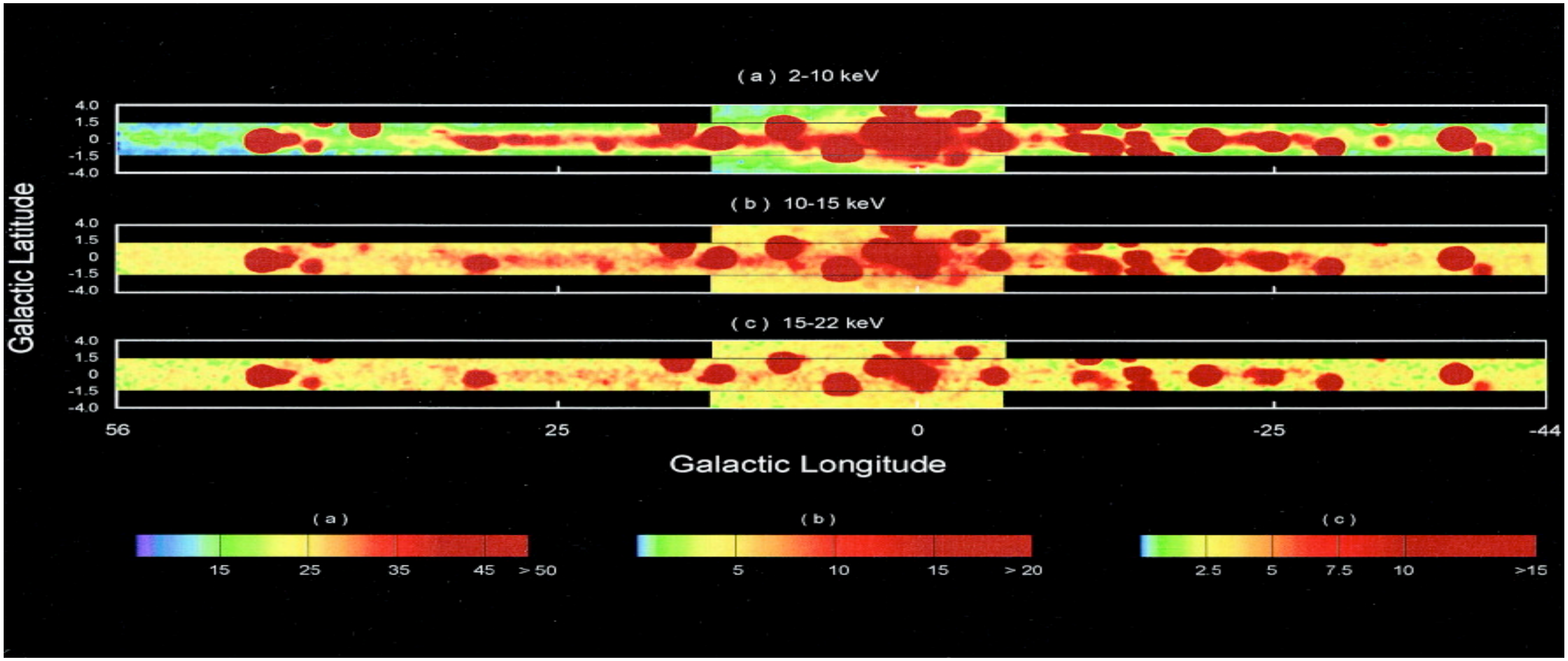
- E. Boldt led the group that produced key papers on unresolved X-ray emission.
  - (Extragalactic) XRB spectrum (Marshall et al. 1980).
  - (Extragalactic) XRB fluctuations (Shafer 1983).
  - Thick disk GRXE (Iwan et al. 1982).
    - **Pillbox model with h > 1500 pc; R > 14 kpc; kT ~ 9 keV.**
    - **Due to halo stars? Hot gas?**
  - Thin disk GRXE (Worrall et al. 1982).
    - **h ~ 241 pc; R ~ 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 (~1º).
  - Chandra took deep images of a small region.
  - Tenma and ASCA found a strong Fe-K line, which has now been resolved with Suzaku.

RXTE - I

- Valinia & Marshall (1998) found 2 components with scale heights of 70 and 500 pc. Images cover l ∈ [56°,-44°] & |b| < 1.5° in 3 energy bands.
- The spectrum was a 2-3 keV thermal plasma + power-law tail.
- Thermal emission from SN + PL from CR bremsstrahlung?

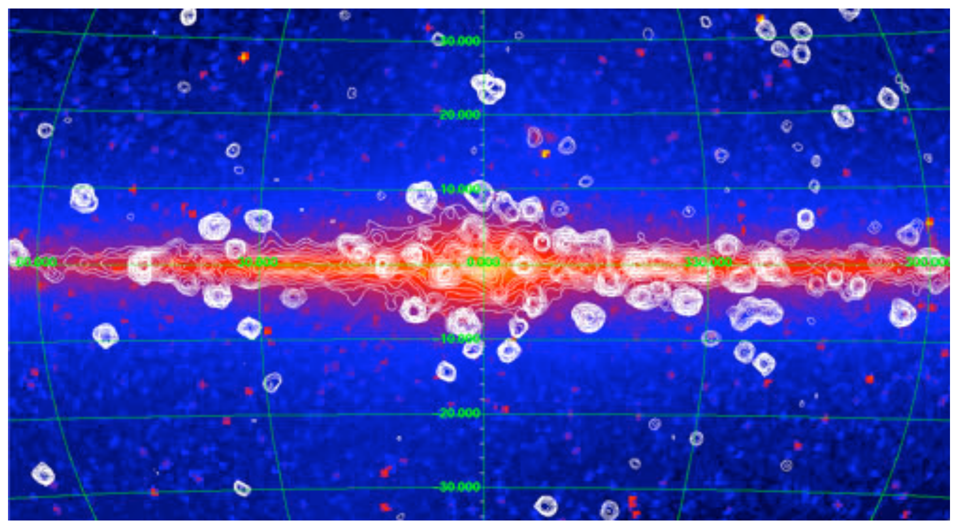


RXTE - II

- 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 2×10^{-16} is needed to resolve 90% of the flux.

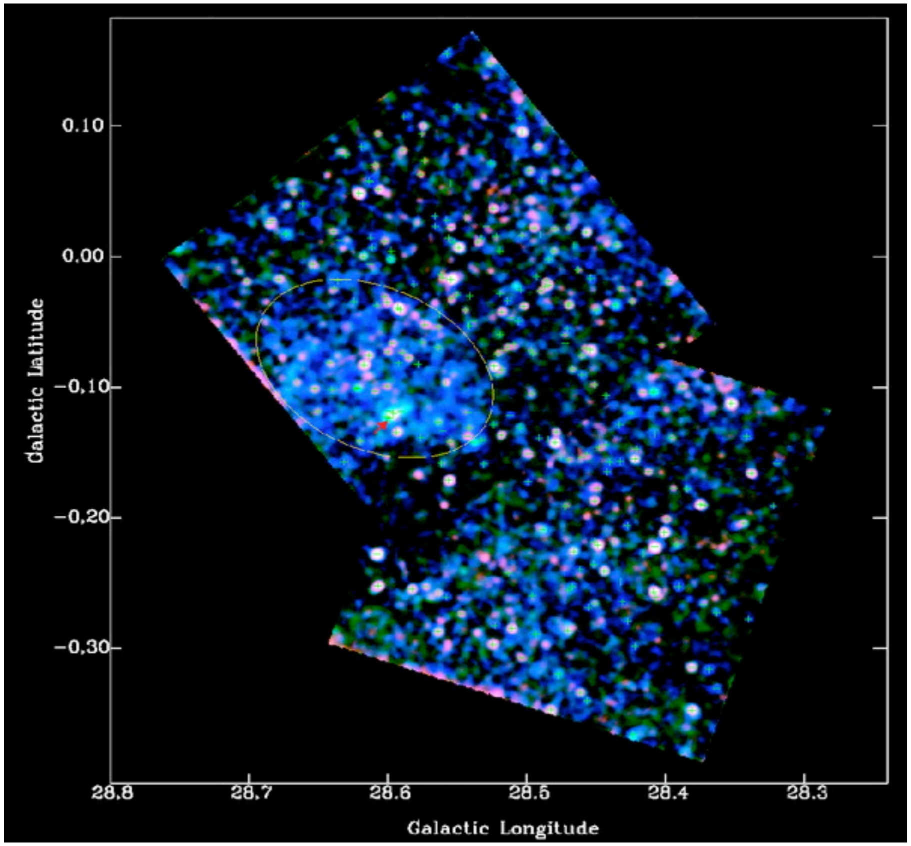
Contours: 3-20 keV X-ray

Image: 3.5 μm NIR



Chandra Deep Images

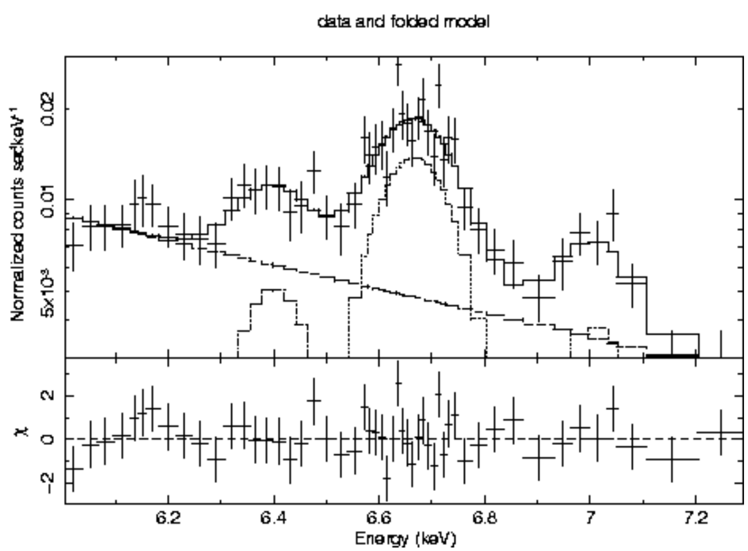
- Ebisawa et al. (2005) took deep (~100 ks) Chandra images from the Galactic Plane near l=28º.
- Sensitivity is 3×10^{-15} (cgs).
- Few point sources beyond expected from extragalactic.
- Point sources contribute small fraction of total flux.
- High luminosity sources (L_x > 10^{33}) cannot be significant contributors.



red: 0.5-2 keV; green: 2-4; blue: 4-8

Better Spectra with Suzaku

- 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.



GRXE

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 ~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-α 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.