X-ray Emission from Galaxies at High Redshift

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The mission that shall not be named
Summary

- High-redshift galaxy studies were not part of the Con-X science case (15” angular resolution precluded it)
- 5” angular resolution enables high-z galaxy science, but questions remain about sensitivity due to background
- *local* starburst galaxy studies can address fundamental questions in galaxy evolution/cosmology
Today’s Topics

- Starburst galaxy feedback
  (low redshift: hot gas)
  D. Strickland (JHU):
  Con-X Starburst
  Panel Chair

- X-ray emission from star-forming galaxies at high-z
  (X-ray binaries)
Life Cycles of Matter and Energy

ICM heating and metal “pollution”

Super-winds launched from galaxies

Star formation

Supernovae/Stellar winds
Life Cycles of Matter and Energy

ICM heating and metal “pollution”

Super-winds launched from galaxies

20% of local massive star formation in starburst galaxies with superwinds

At $z \sim 2-4$, vigorous starbursts, which dominate the star formation of Universe at these epochs, exhibit powerful winds

We see the impact of starburst winds through the galaxy mass-metallicity relationship (Tremonti et al. 2004)
Wind plasma diagnostics with high-resolution X-ray spectroscopy

M82 Chandra central 5x5 kpc
0.3-1.1 keV, 1.1-2.8 keV, 2.8-9.0 keV

Simulated ~20 ks IXO NFI northern halo observation, 0.3-2.0 keV.

O VII and O VIII region (including Ne IX and Ne X).
Well resolved triplet, high S/N in continuum.

Vel. Resolution $\sigma \sim 60$-85 km/s (escape speeds $\sim 300$-700 km/s)

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ESA-IXO Meeting, Garching

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Targets & Observational Strategy

- Starburst sample spanning broad range of galaxy mass.
- Typical angular scales of superwind X-ray nebulae: 0.5 – 10 arcmin.
- Measure velocities in multiple regions per galaxy -> PV diagrams.
IXO Local Starburst Sample

- Predicted total galaxy+wind 0.3-2 keV XMS count rates for diffuse thermal emission (excluding point sources, based on Chandra/XMM)
- 35 representative targets with D< 200 Mpc.
- For 50000 cts/galaxy (~ 5 high quality spectra): 1.3 Ms for all 35 starbursts.
The deepest X-ray survey (CDF-N)

CDF-N
(447 arcmin²)
1.945 Ms ACIS-I exposure

“True” color images
0.5-2.0 keV
2.0-4.0 keV
4.0-8.0 keV
Why study X-ray emission from galaxies?

- Star formation in heavily obscured areas
- Accreting binaries $\rightarrow$ emission persists for very long time (Gigayears), progenitors of GRBs and gravity-wave events
- Supernovae/winds enrich (add metals) to the ISM & IGM, affecting star formation and galaxy evolution

M83, nearby spiral galaxy with nuclear starburst

Soria & Wu (2003)
What influences accretion activity in the most general sense?

Accretion for luminous AGN has evolved little over past ~12 Gyr despite the strong evolution of host galaxies (Brandt et al....).
Little change over cosmic time in properties of binaries

Strong correlation between X-ray emission and SFR that appears to hold from $z=0 \rightarrow 1$ (Bauer et al. 2002, Ranalli et al. 2003, Rosa-Gonzalez et al. 2007)

Detailed analysis of late-type galaxies (Lehmer et al. 2008) shows mean $L_X$/SFR ratio constant over $0 < z < 1.4$ for galaxies with SFR = 1-100 $M_\odot$ yr$^{-1}$
**X-ray Emission from Starbursts at z~3**

- Only a few percent of the LBG population has been detected directly.
- Stacking analysis: 
  \[ \langle L_X \rangle \approx 1-3 \times 10^{41} \text{ erg s}^{-1} \text{ (2-8 keV; Brandt, Hornschemeier et al. 2001; Nandra et al. 2002; Lehmer et al. 2005)} \]
- Recently has been extended to even higher redshift (z~4) by Lehmer et al. (2005) and Laird et al. (2005).
- Laird et al. (2005) found deviation from linear X-ray/SFR correlation for galaxies near z~1: still dominated by AVERAGE detections (stacking hundreds of galaxies for effective exposures up to 500 Ms).

**IXO will not directly detect the Lyman Break galaxy population**
Galaxies become dominant below $5 \times 10^{-18}$ erg cm$^{-2}$ s$^{-1}$ (0.5–2 keV)

**Normal Galaxies and the X-ray Background**

- Galaxy number counts well-measured over 4 orders of magnitude in 0.5-2.0 keV flux (down to $\approx 2.5 \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$ (0.5–2 keV) (Hornschemeier et al. 2003; Bauer et al. 2004; Georgakakis et al. 2004)

- In the current deepest X-ray surveys, galaxies comprise a MINORITY of X-ray sources and make <5% of the diffuse XRB (e.g., Hornschemeier et al. 2002; Persic & Raphaeli 2003)

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Blank” field logN-logS from 1-2 Ms Chandra Deep Fields
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With a 5” PSF, Lyman Break Galaxies cannot be reached with IXO (with 2” it may be possible)

OPTICAL counterpart confusion starts becoming a problem for galaxies at \( f_x < 10^{-17} \text{ erg cm}^{-2} \text{ s}^{-1} \) (0.5-2 keV) : expect \( \sim 30\% \) of X-ray sources to have a R<24 souce within the IXO beam (e.g., Metcalfe et al. 2001)
Summary

- *Modest* exposures of 35 nearest starburst galaxies will answer the question of how mass/metals escape from galaxies
- 5” angular resolution enables high-z science, but just barely
- We should study our sensitivity to high-z galaxies but likely should focus on the local galaxy work in the proposals
Going deeper now to detect more galaxies: an important input to future X-ray missions

Bauer et al. (2004)

Ultra-deep X-ray survey ($\leq 10^{-18}$ erg cm$^{-2}$ s$^{-1}$)

Chandra background is less than 1 count per pixel every ten days. We can go deeper (>5 Ms) now.
Thank you!