X-ray Emission from Galaxies at High Redshift

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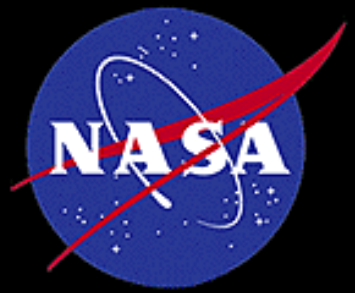


The mission that shall not be named

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

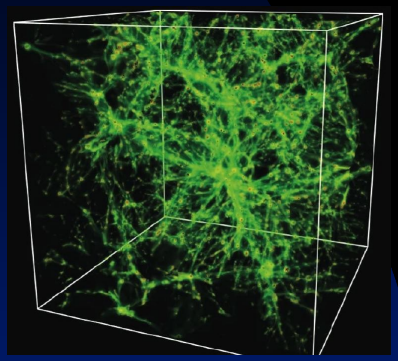
Today's Topics

- Starburst galaxy feedback (low redshift: hot gas)
- X-ray emission from star-forming galaxies at high-z (X-ray binaries)

D. Strickland (JHU): Con-X Starburst Panel Chair

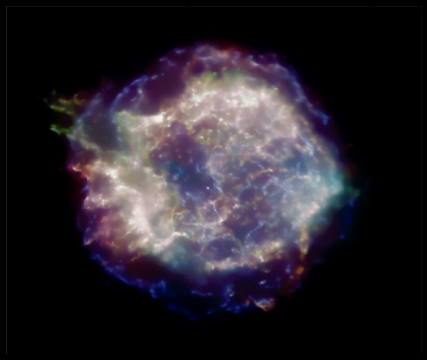
Life Cycles of Matter and Energy

ICM heating and metal “pollution”



Super-winds launched from galaxies

Star formation

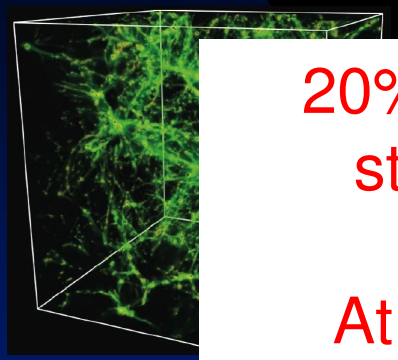


Supernovae/ Stellar winds

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

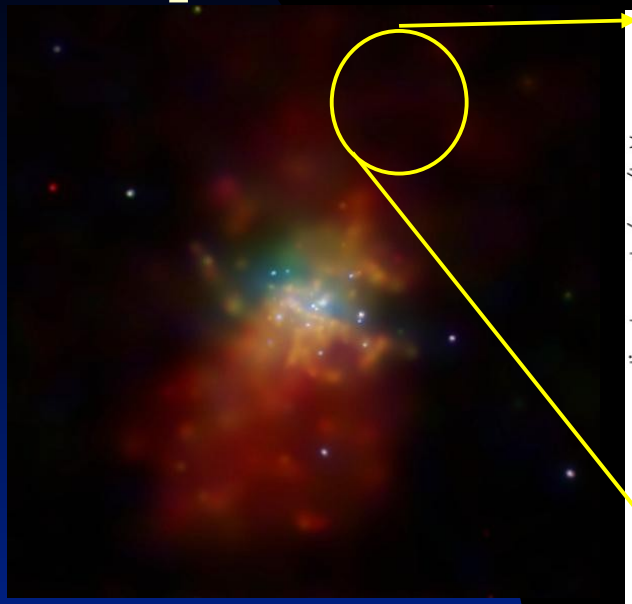
At z~2-4, vigorous starbursts, which dominate the star formation of Universe at these epochs, exhibit powerful winds

We see the impact of starburst winds through the galaxy mass-metallicity relationship (Tremonti et al. 2004)

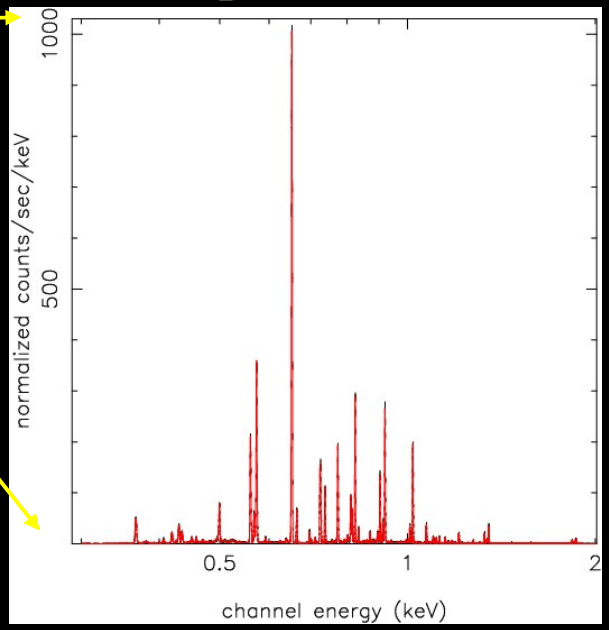
ovae/
winds

Wind plasma diagnostics with high-resolution X-ray spectroscopy

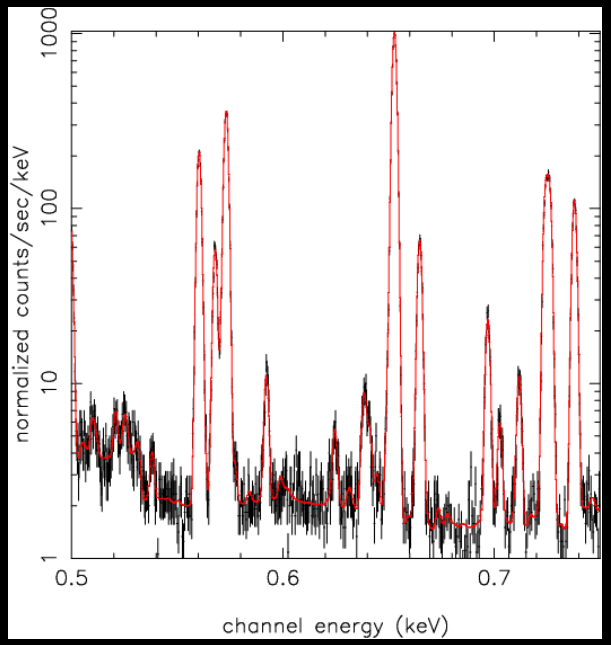
courtesy of D. Strickland (JHU)



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.

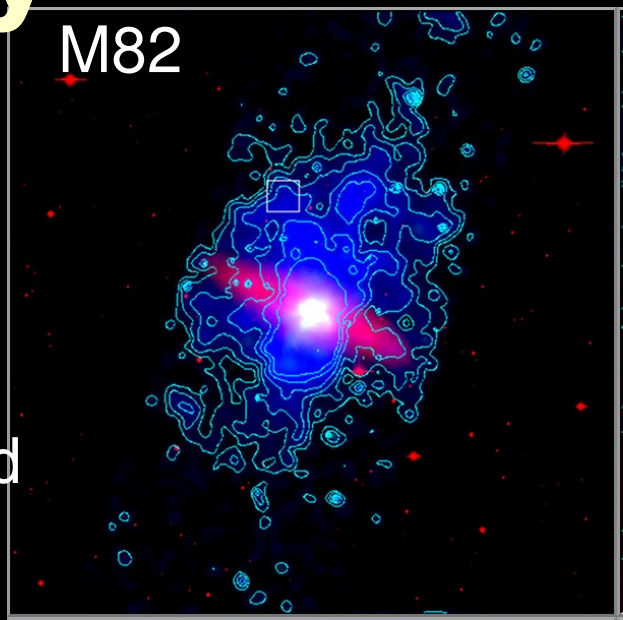


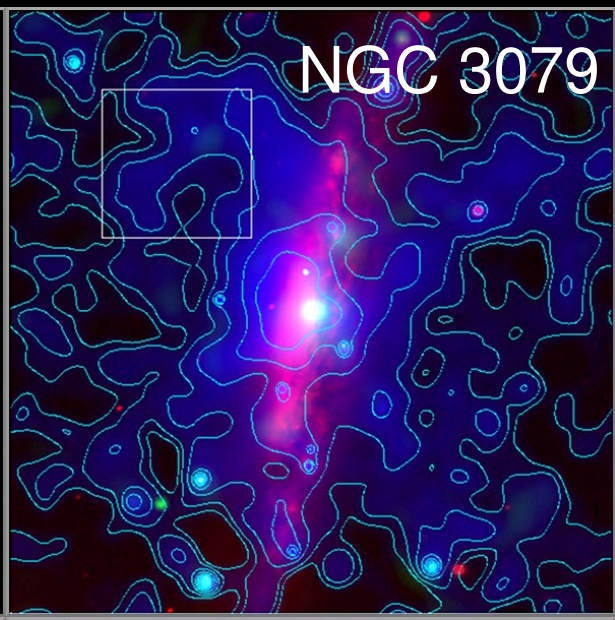
O VII and O VIII region (including Ne IX and Ne X). Well resolved triplet, high S/N in continuum.

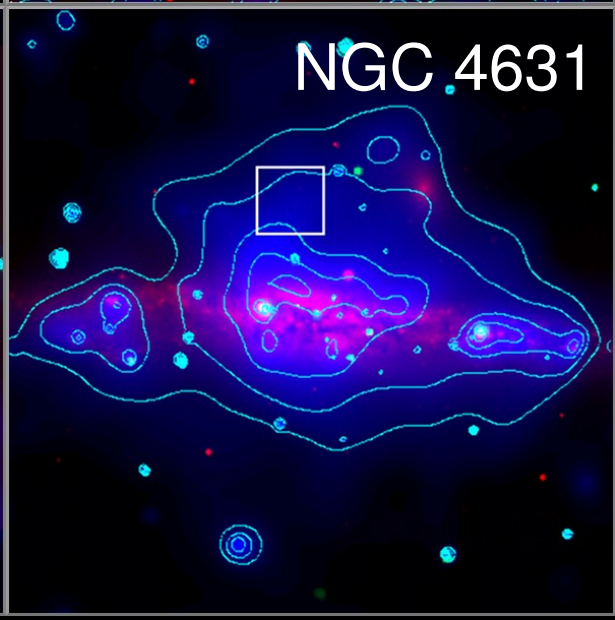
Vel. Resolution σ ~60-85 km/s (escape speeds ~300-700 km/s)

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.

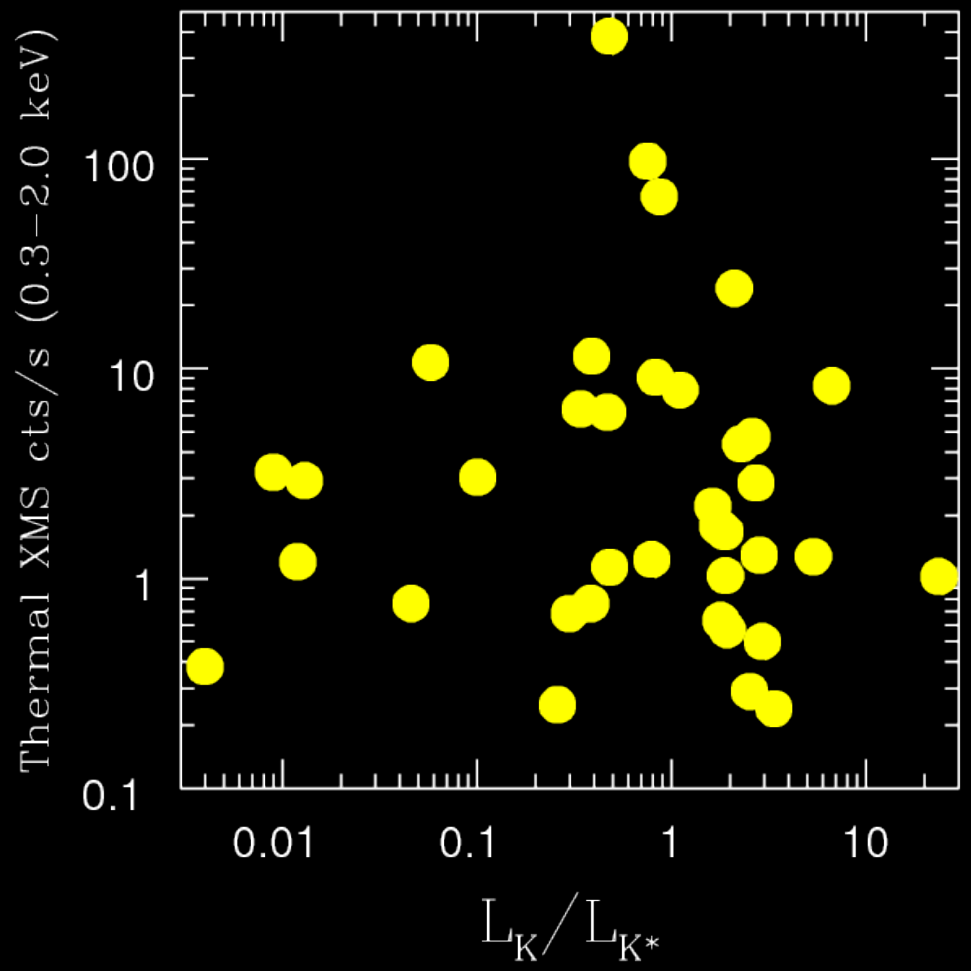




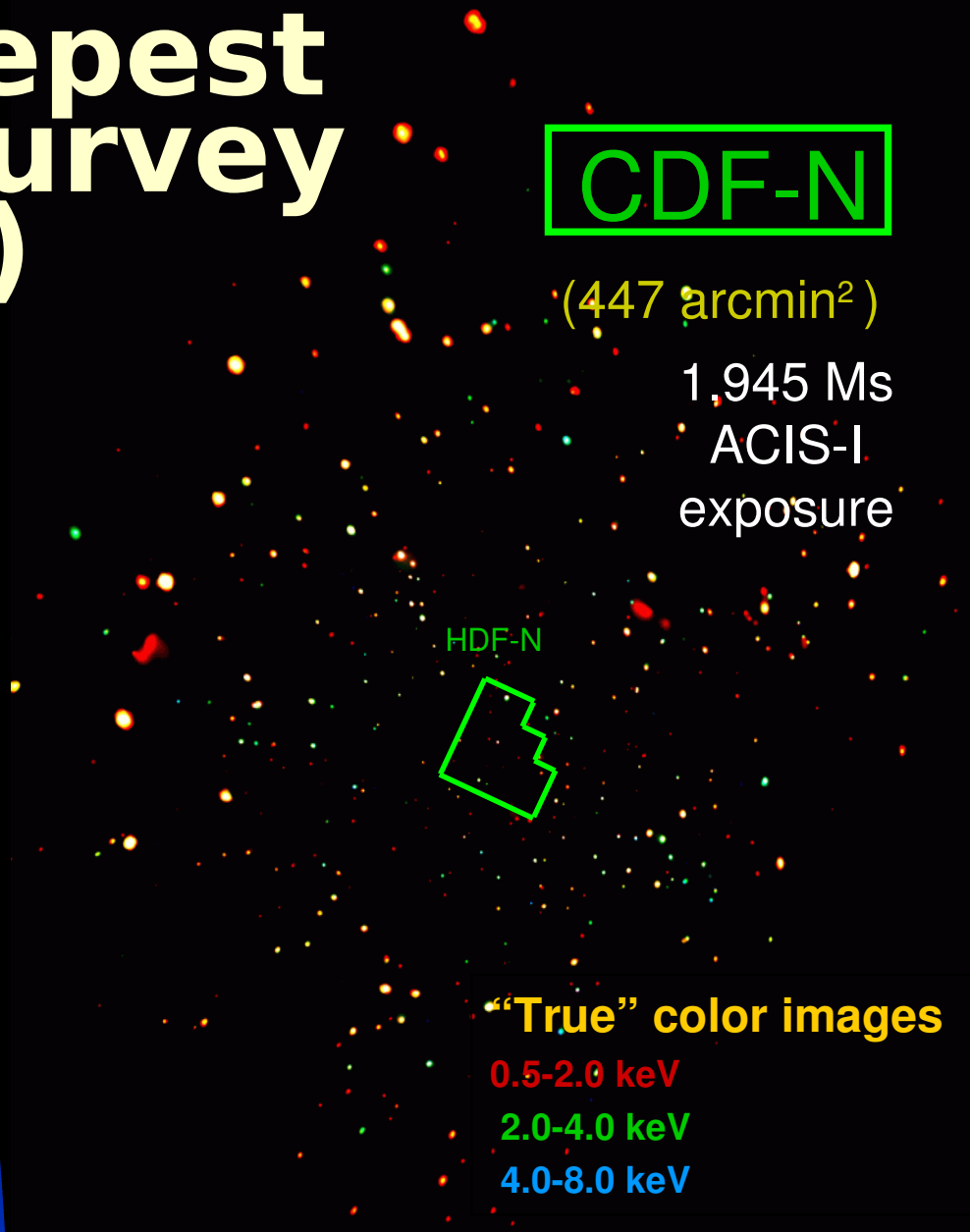


IXO Local Starburst Sample

- 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)



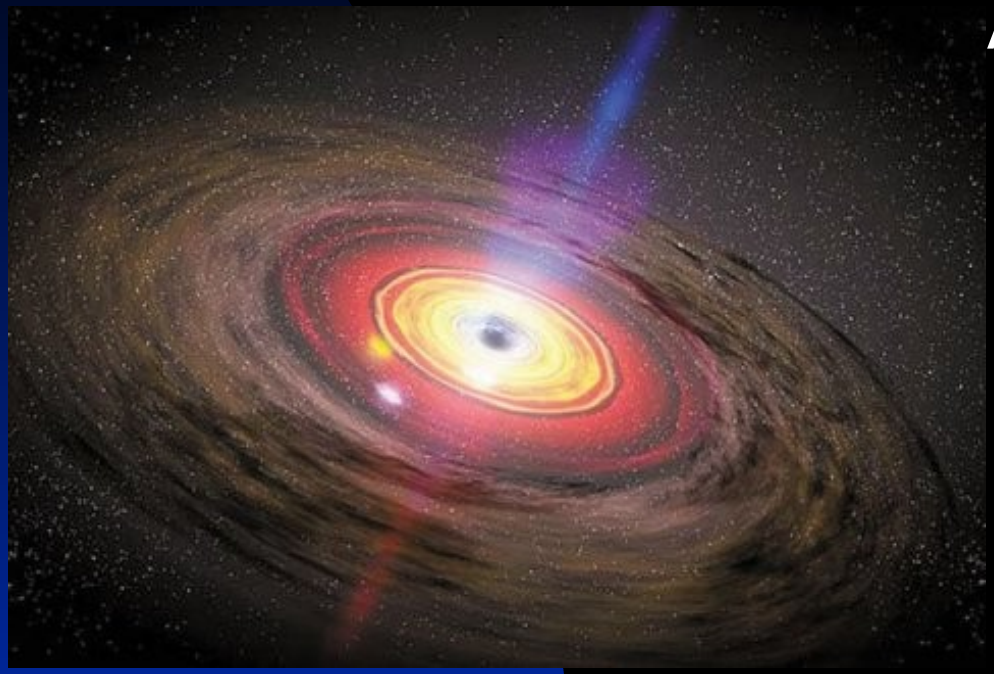
Why study X-ray emission from galaxies?

M83, nearby spiral galaxy with nuclear starburst

Soria & Wu (2003)

- Star formation in heavily obscured areas
- Accreting binaries → 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

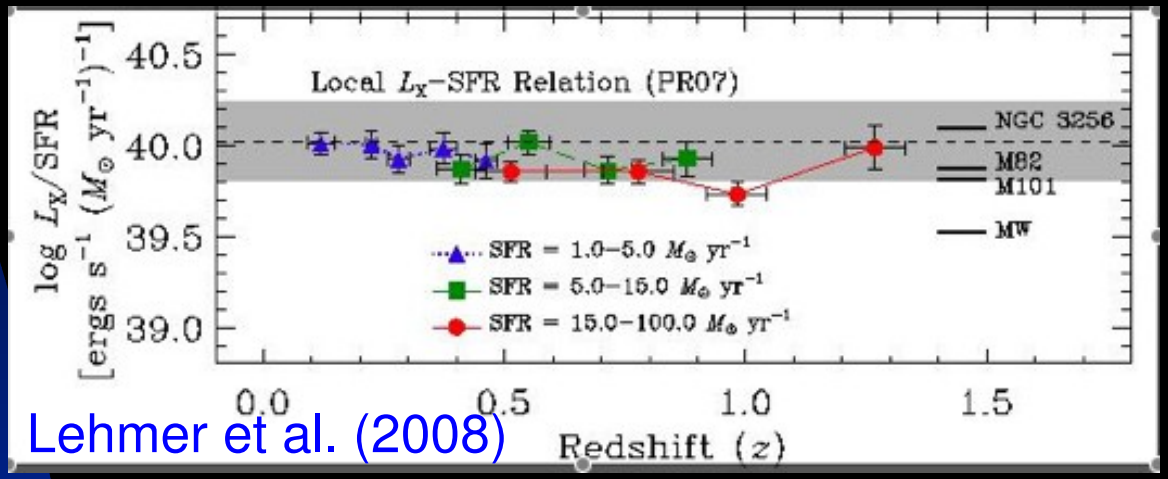
What influences accretion activity in the most general sense?



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 → 1 (Bauer et al. 2002, Ranalli et al. 2003, Rosa-Gonzalez et al. 2007)

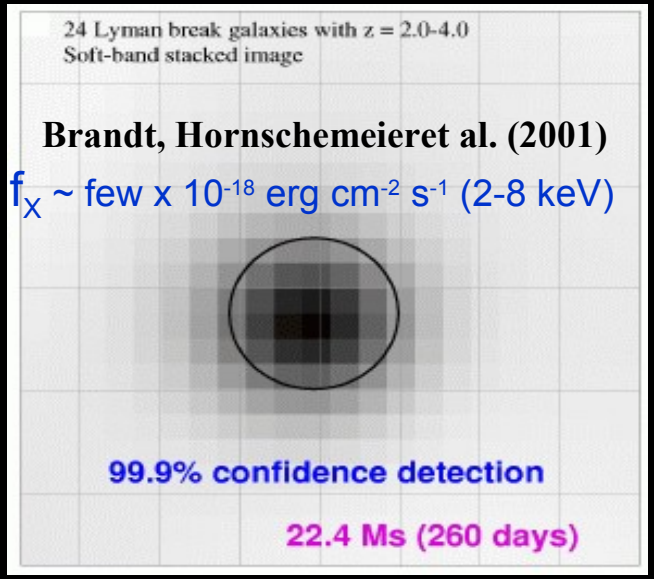


Lehmer et al. (2008)

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

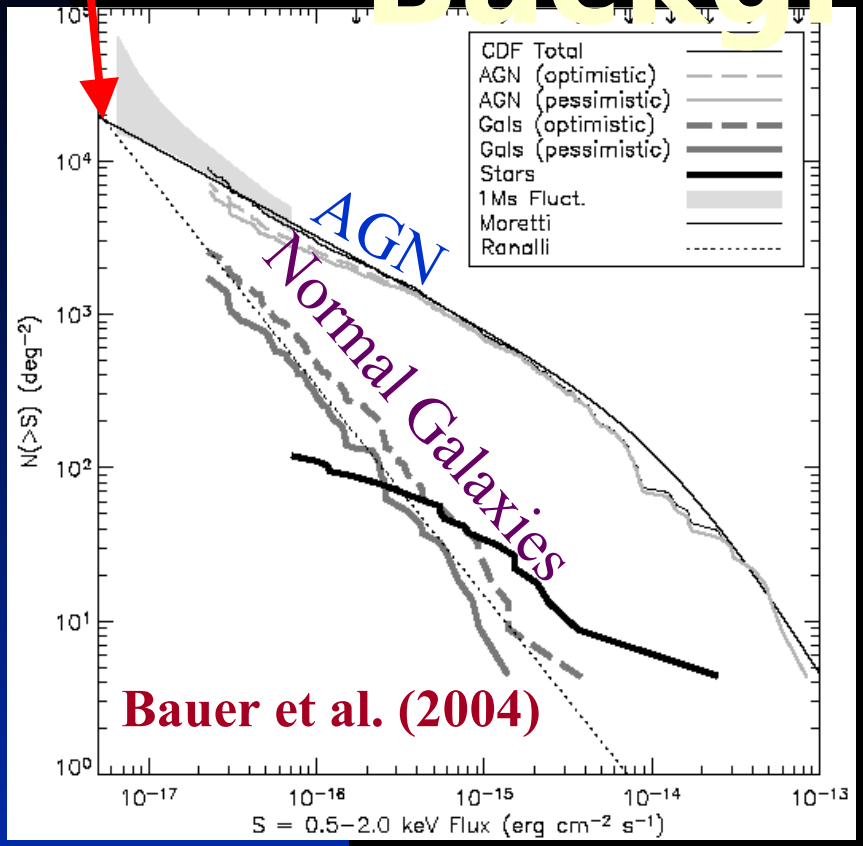
- Only a few percent of the LBG population has been detected directly
- Stacking analysis: $\langle L_X \rangle \approx$ 1-3 $\times 10^{41}$ erg s^{-1} (2-8 keV; Brandt, Hornschemeier et al. 2001; Nandra et al. 2002; Lehmer et al. 2005)
- Recently has been extended to even higher redshift (z~4) by Lehmer 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 5×10^{-18} erg cm^{-2} s^{-1} (0.5 –2 keV)

Normal Galaxies and the X-ray Background

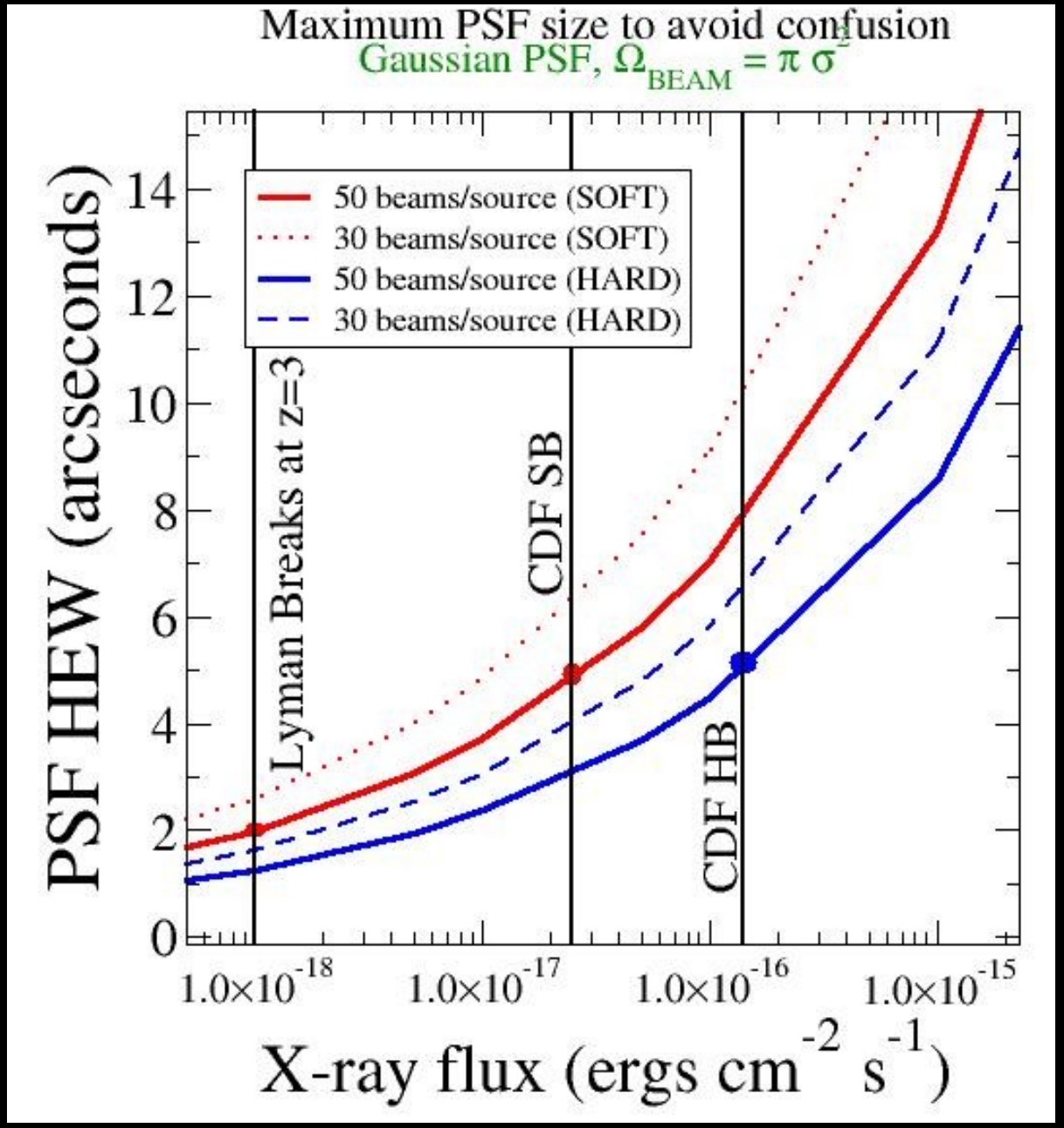


"Blank" field log*N*-log*S* from 1-2 Ms Chandra Deep Fields

- Galaxy number counts well-measured over 4 orders of magnitude in 0.5-2.0 keV flux (down to ~2.5×10^{-17} erg cm^2 s^{-1}(0.5 –2keV) **(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)**

With a 5” PSF, Lyman Break Galaxies cannot be reached with IXO (with 2” it may be possible)

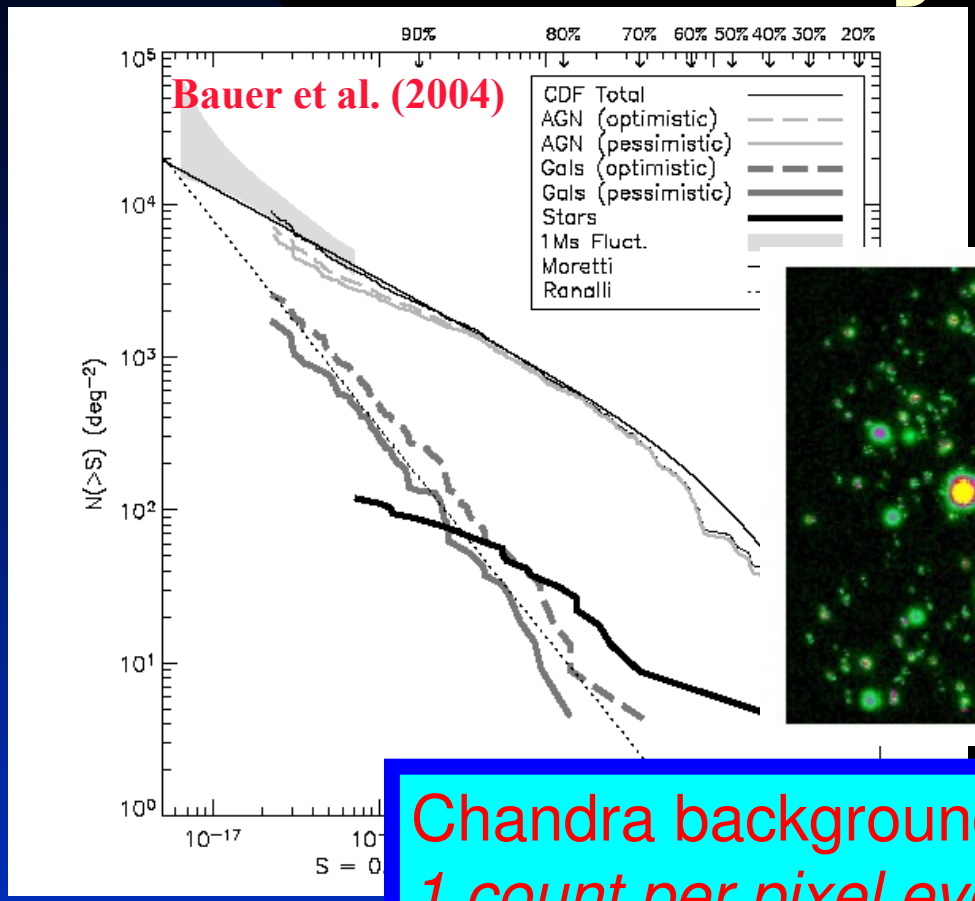
OPTICAL counterpart confusion starts becoming a problem for galaxies at $f_X < 10^{-17}$ erg cm^{-2} s^{-1} (0.5-2 keV) : expect ~30% of X-ray sources to have a R<24 souce within the IXO beam (e.g., Metcalfe et al. 2001)



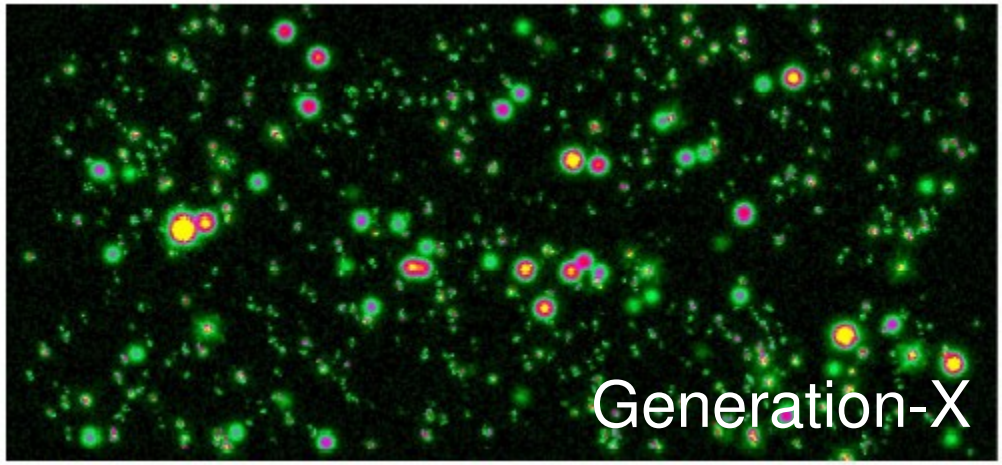
Summary

- *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



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!