The X-Ray Derived Cosmological Star Formation History in the Chandra Deep Fields North and South

MPE: G. Hasinger, G. Szokoly
Institut d’ Astrophysique: J. Bergeron
INAF – Bologna: A. Comastri
Osservatorio Astrofisico di Arcetri: R. Gilli
Osservatorio Astronomico: P. Tozzi
Leiden Observatory: A. Zirm

Background

- X-rays have been known to correlate with FIR since Einstein era (Fabbiano 1989; Griffiths & Padovani 1990; David, Jones & Forman 1992; Green, Anderson & Ward 1992).
- Natural explanation: X-rays are produced by massive stars, SN, SN-heated ISM, HMXRB that all track star-formation rate (SFR).
- Can X-rays be used as an effective cosmic SFR measure?
X-ray vs. FIR and Radio

From Ranalli et al. (2003)
Galaxy Luminosity Functions

• X-ray luminosity function (XLF) for “normal” star-forming galaxies should exhibit evolution consistent with SFR evolution.

• Galaxy XLF only measured to date for $z = 0$ (Hasinger 1998) using ROSAT (also indirectly in Georgantopoulos et al. 1999).
Galaxies in CDF North and South

• Chandra Deep Fields North and South have been observed for 2 and 1 Ms (limiting fluxes of \( \sim 3 \times 10^{-17} \) ergs cm\(^{-2}\) s\(^{-1}\) and \( 6 \times 10^{-17} \) ergs cm\(^{-2}\) s\(^{-1}\)).

• \( \sim 47 \) (CDF-S) and 62 (CDF-N) galaxies identified via optical spectra
  – More detailed analysis of CDF-S optical spectra resulted in a “conservative” sample with 29 galaxies
Bayesian Statistical Analysis

• Also selected galaxy candidates based on a Bayesian model
• Computed mean and standard deviation of various parameters: $L_X$, hardness (HR), $L_{\text{Radio}}$, R, K
• Best separation between galaxies, AGN1 and AGN2 was with $L_X$ and HR.
• Prob. of observed source parameters (including errors) being consistent with a model:
  $P(L, HR) = \int dL' \int dHR' P_M(L', HR') L(L | L') L(HR | HR')$
  $P_M(L', HR') = \text{“prior” = model parent probability distr.}$
  $L(HR | HR') = \text{likelihood function for observing HR}$
L_X vs. HR

Blue = AGN2
Red = AGN1
Purple = Galaxies
Cyan = Photometric sample

N.B. Spectroscopic IDs include low-quality spectra

Typical error in HR often >0.5
Z>0 Galaxy XLF

- Converted FIR LF to X-ray using Ranalli et al. (2003) log $F_{0.5-2.0 \text{ keV}} / \log \text{FIR}$ correlation and assuming a dispersion of 0.25.
- Also included effects of X-ray k-correction (minor since starburst X-ray SED is relatively flat) and $(1+z)^{2.7}$ luminosity evolution.
Z>0 CDF-N + CDF-S XLFs

“Liberal” Spectroscopic Sample

Bayes-selected Sample

Z=0 XLF from Schmidt, Boller, Voges (1996), adjusted by factor of 3 for local over-density
**Hα Comparison**

- Hα and X-ray (CDF-S + CDF-N Bayes sample) converted to SFR in order to compare luminosity functions
- z<0.5 XLF consistent with z=0 Hα LF, z>0.5 X-ray LF consistent with extrapolation of z ~ 1 Hα LF
X-ray SFR History

- SFR data courtesy of David Hogg
- X-ray points computed from average of direct integration of XLF and integration of $z=0.25$ and $z=0.75$ FIR models
Conclusions

• X-ray spectroscopic sample suffers from incompleteness at low luminosities, AGN contamination at high luminosities.
• X-ray Bayesian sample shows more agreement with FIR LF, particularly for z>0.5. AGN contamination is still a problem, particularly for z<0.5.
• SFR predicted from X-ray LF consistent with general trends from other band passes (see also Georgakakis et al. 2003).
• Factor of ~ 2 evolution due to LMXRB is also expected at z ~ 0.5 (Ghosh & White 2001; Ptak et al. 2001) and may be contributing (but evolution not observed in L_X/L_B).
• Future work will concentrate on improving Bayesian galaxy classification model to many dimensions, including, e.g., GOODS data.
• X-rays promise to be good SFR measure relatively unaffected by extinction issues for Chandra deep surveys and future wide-area X-ray missions.