# Cosmic Star Formation History and Chandra Deep Field Surveys

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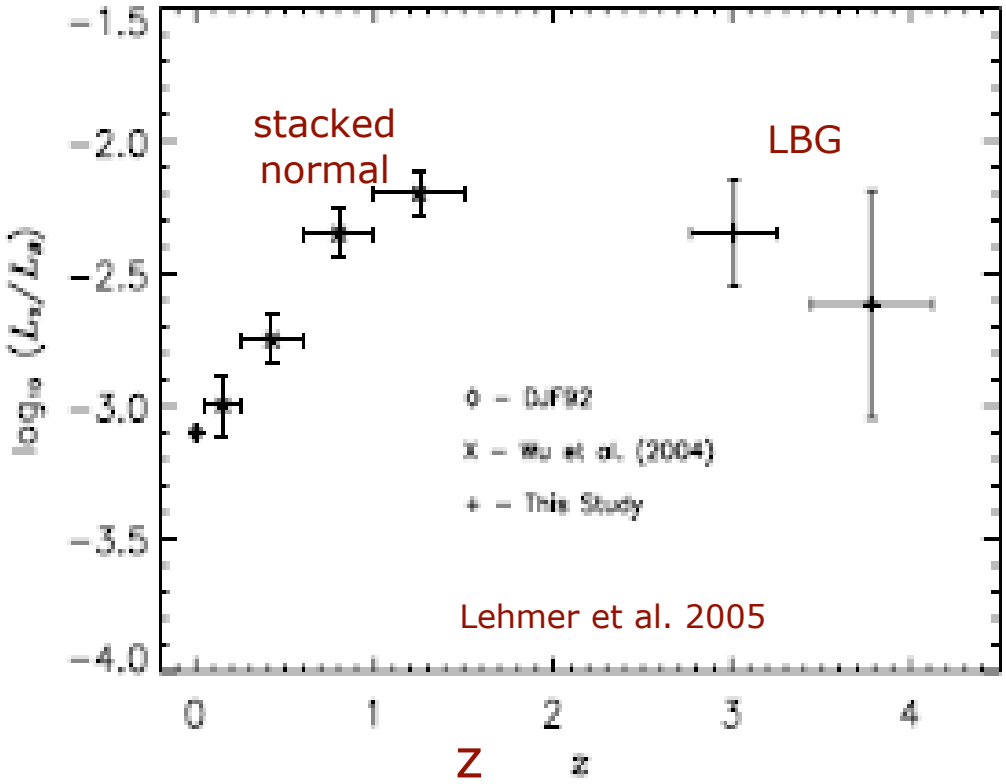
# Plan

- Evolution of X-ray luminosity
- Role of cosmic star formation history
- Status of understanding
- logN-logS plots: X-ray diagnostics
- Normal/Starburst galaxies vs. AGN
- Correlations between X-rays & other wavebands: Optical, IR, Submm, Radio

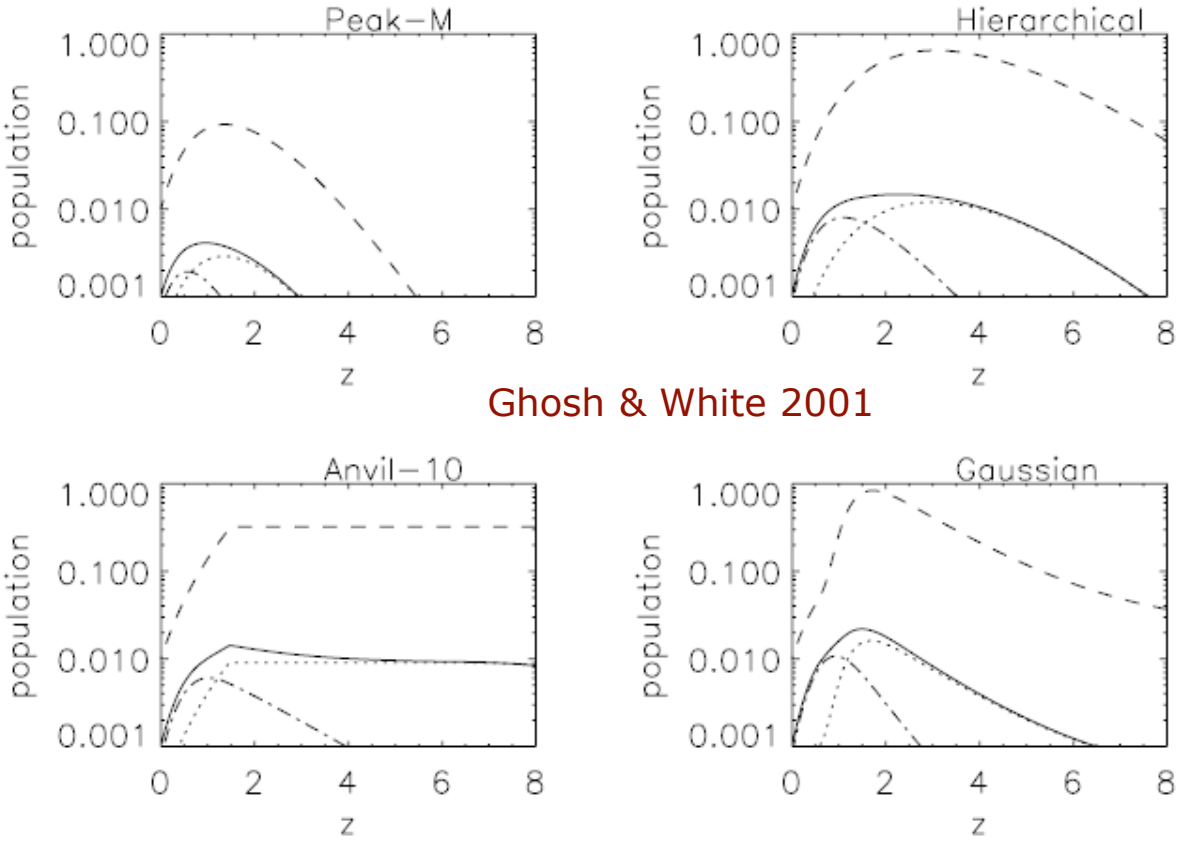
# Evolution of $L_x$ & $L_x/L_B$

$\log(L_x/L_B)$



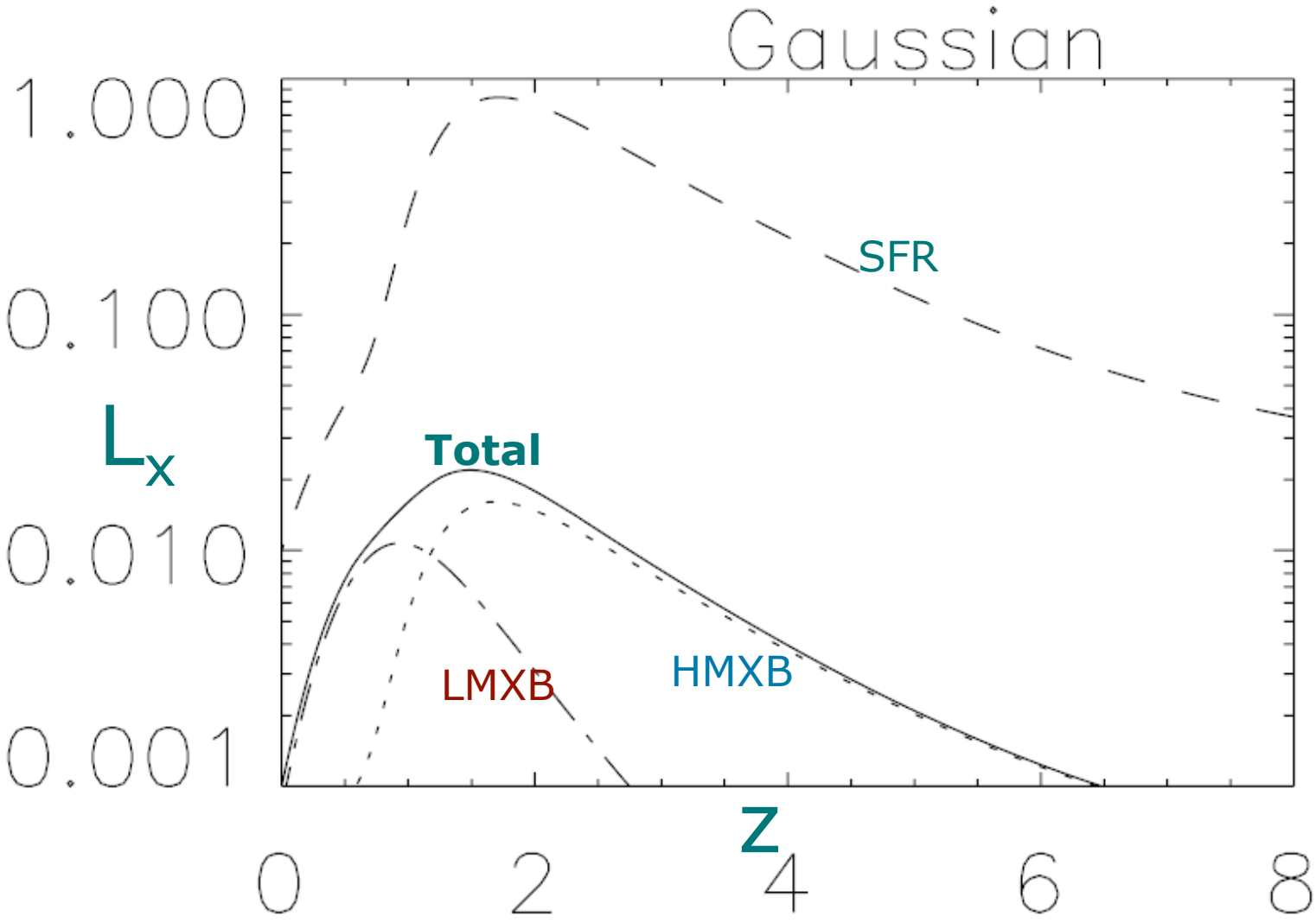

$L_x/L_B$ rises by ~10 from z=0 to z~1, falls for z = 3→4

# $L_x$ Evolution: Star Formation History




Ghosh & White 2001

# $L_x$ Evolution: Detail



# $L_x$ Evolution: Understanding

## Theory:

- $L_x$ rises by ~10 as z=0→1 for typical LMXB lifetimes:

$\tau_{PSNB}$ ~ 2 Gyr

$\tau_{LMXB}$ ~ 1 Gyr

- $L_x/L_B$ rises by ~10 only if $L_B$ has little evolution

## Observation:

- $L_x/L_B$ rises by ~10 as z=0→1
- But $L_x$ rises by ~3 ?

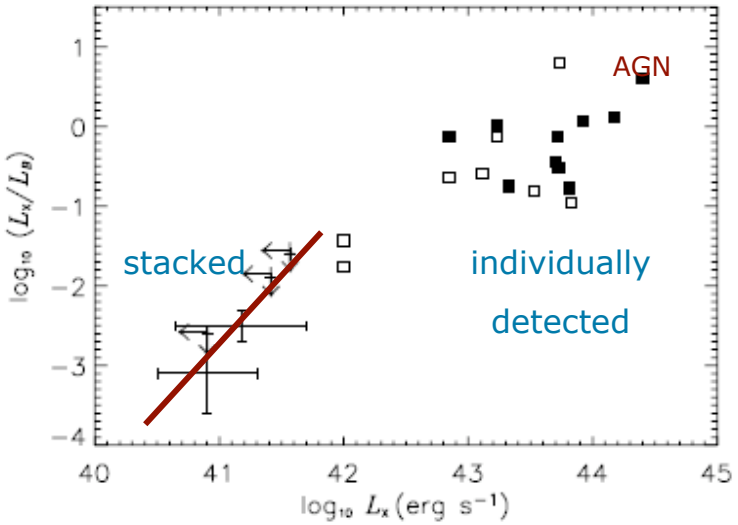
  Brandt et al. 2001

  Hornschemeier et al. 2002
- Then $L_B$ falls by ~3 as $L_x$ rises ??

# $L_x$ Evolution: Understanding

Lehmer et al. 2005

$\log(L_x/L_B)$




$\log L_x$

$L_x/L_B \sim L_x^{2.5}$

How to understand rise of $L_x$ by ~3 in z=0→1 ?

# $L_x$ Evolution: Understanding

- LMXB evolution slower?

  $\tau_{LMXB} \sim 2$ Gyr ?

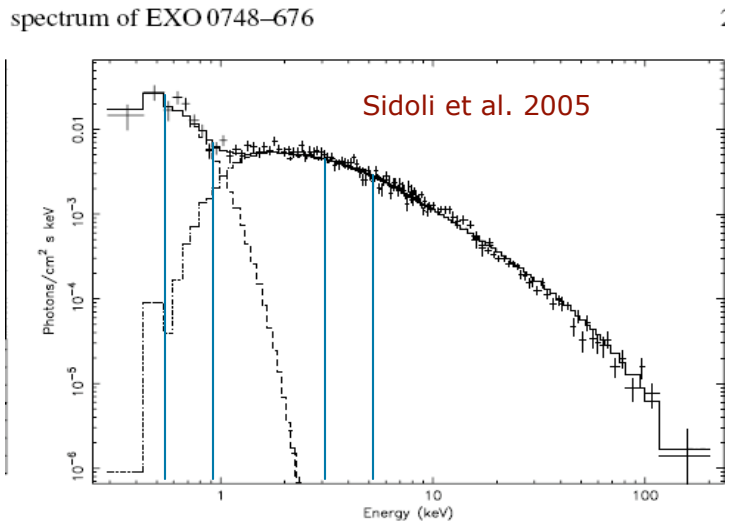
- Bandpass change factor not right due to soft excess?

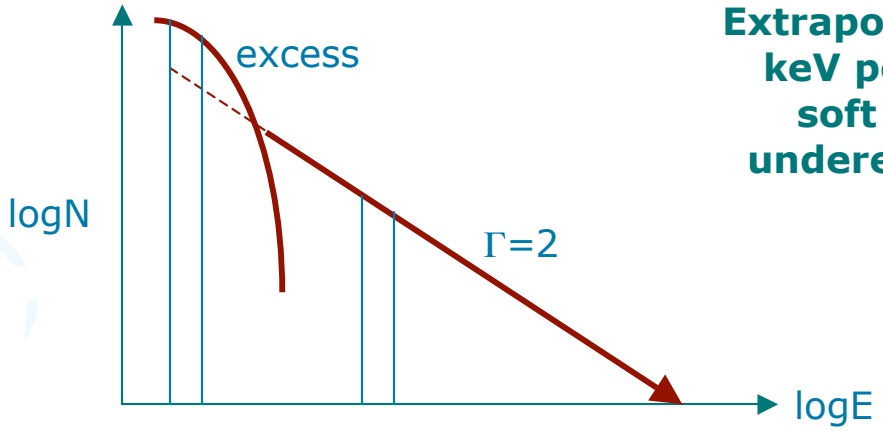
$$L_x = 4\pi d_L^2 f_x (1+z)^{\Gamma-2}$$

  $\Gamma = 2$ normally used Kim et al. `92, Ptak etal. `99

- But… LMXB spectra have soft excess?

# LMXB Spectrum: Soft Excess




**Extrapolation of 2-10 keV power law to soft band may underestimate flux**

# Normal/Starburst Galaxies vs. AGN

## Discriminators

- X-ray luminosity: Critical value ~ 3 x $10^{42}$ erg $s^{-1}$, AGNs more, galaxies less
- X-ray spectra: Critical hardness ratio ~ 0.8, AGNs harder, galaxies softer
- $f_x/f_{opt}$ ratio: Critical value ~ 0.1, AGNs more, galaxies less
- Optical spectroscopy: Broad/Hi-ionization AGN emission lines
- Radio properties

# logN-logS Diagnostics

- Bulk (85-95%) of X-ray background power from AGNs
- Only ~5-15% from galaxies:
  - Starbursts dominate in soft
  - Quiescents dominate in hard
- But in number density, star-forming galaxies will overtake AGNs at soft flux ~ $10^{-17}$ erg $cm^{-2}$ $s^{-1}$

# Summary

- Lx evolution qualitatively correct, details to be clarified:
  - Observational issues
  - More detailed theory
- XRB power dominated by AGNs, but number counts dominated by normal/starburst galaxies at faint fluxes
- X-ray correlations with other wavebands indicate diagnostic value of X-rays in probing star formation

# logN-logS Diagnostics . 1

**Soft Band**

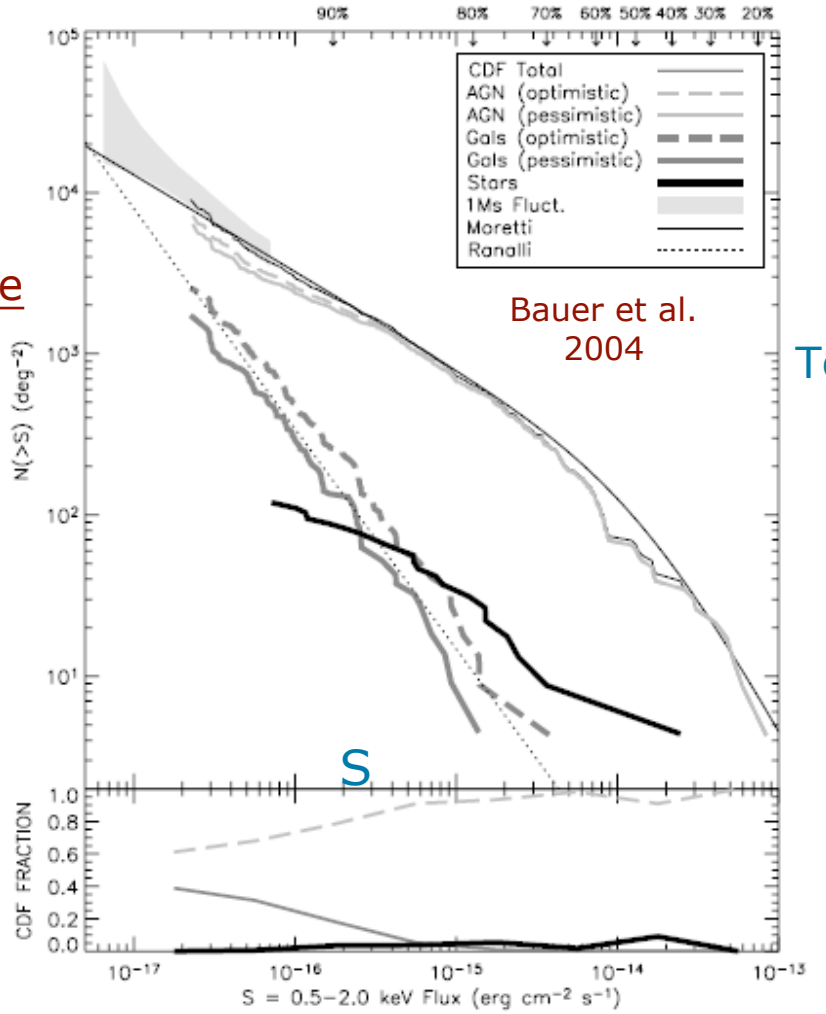
**0.5-2 keV**

Total Counts: Slope

~ 0.55

XRB Resolved Fraction

~ 89%  soft




Bauer et al. 2004

Galaxies: Slope

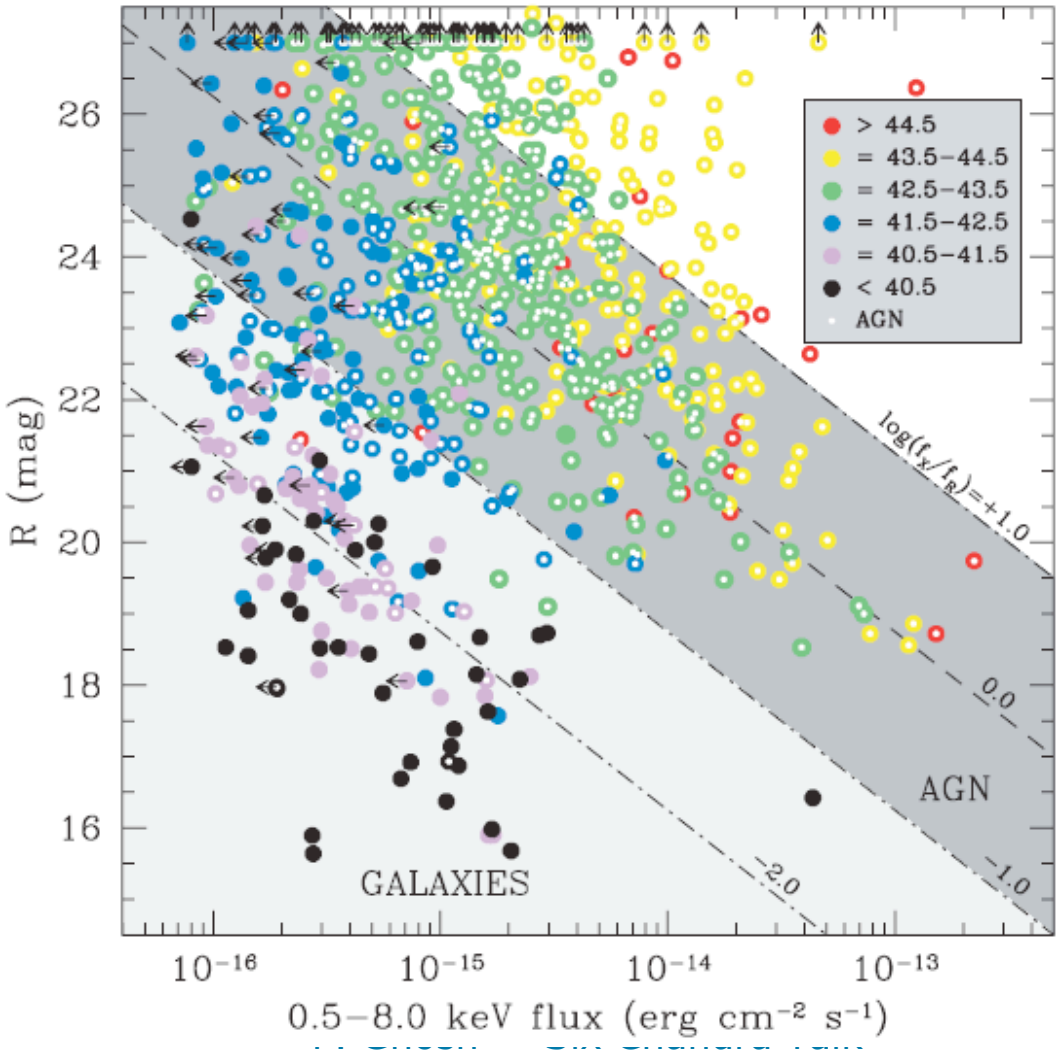
Total & Quiescent ~ 1.3

Starburst ~ 1.7

Elliptical ~ 1.1

# Normal/Starburst Galaxies vs. AGN

Bauer et al. 2004



# X-ray/Optical Correlations

## Optically Bright X-ray Faint (OBXF) galaxies

- OBXF : $\log(f_x/f_R) \sim -2$ or less
- "Distant analogs of `normal' galaxies in the local universe." Hornschemeier et al. 2003 $z \sim 0.1 \rightarrow 0.8$
- OBXF dominated by non-AGN: quiescent and starburst galaxies, some low-luminosity AGN
- $L_x$ > "normal" galaxies, soft X-ray spectra
- OBXF logN-logS slope ~ 1.7 very steep, as for starbursts: will dominate at low S
- Several off-nuclear ULXs

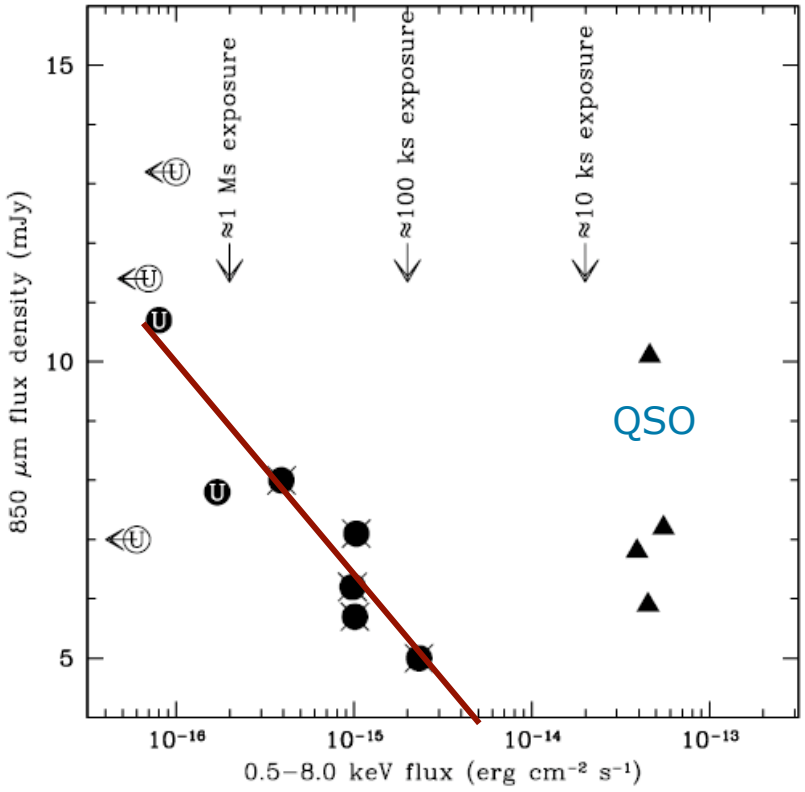
# X-ray/IR Correlations

- Tight correlation between X-ray and 15μm IR galaxy populations Alexander et al. 2002
- Luminous IR starburst galaxies: dust enshrouded star formation
- $\log(f_x/f_{IR}) \sim -1.5$ or less, non-AGN by all counts
- 15μm good indicator of star-formation rate ➡ X-rays also good indicator

# X-ray/Submm Correlations

- X-rays from 7 of 10 bright 850 μm SCUBA sources
- 5 of 7 are AGNs
- Anti-correlation between 850 μm and X-rays?
- AGNs contribute negligibly to submm emission
- Submm emission basically powered by star-formation, so can be used to probe star formation

Alexander et al. 2003



# X-ray/Radio Correlations

- Large overlap between X-ray and 1.4 GHz radio sources
- Excellent correlation between X-ray and radio luminosity, same at moderate z as in local universe
- X-rays good indicator of star formation, as radio emission is

Bauer et al. 2002