X-ray selected normal galaxies at low redshift

Antonis Georgakakis

National Observatory of Athens
Institute of Astronomy & Astrophysics

Outline

- Study of galaxies at X-ray wavelengths important
- State of the game + problems/issues
- Further progress requires wide area X-ray survey in the SDSS

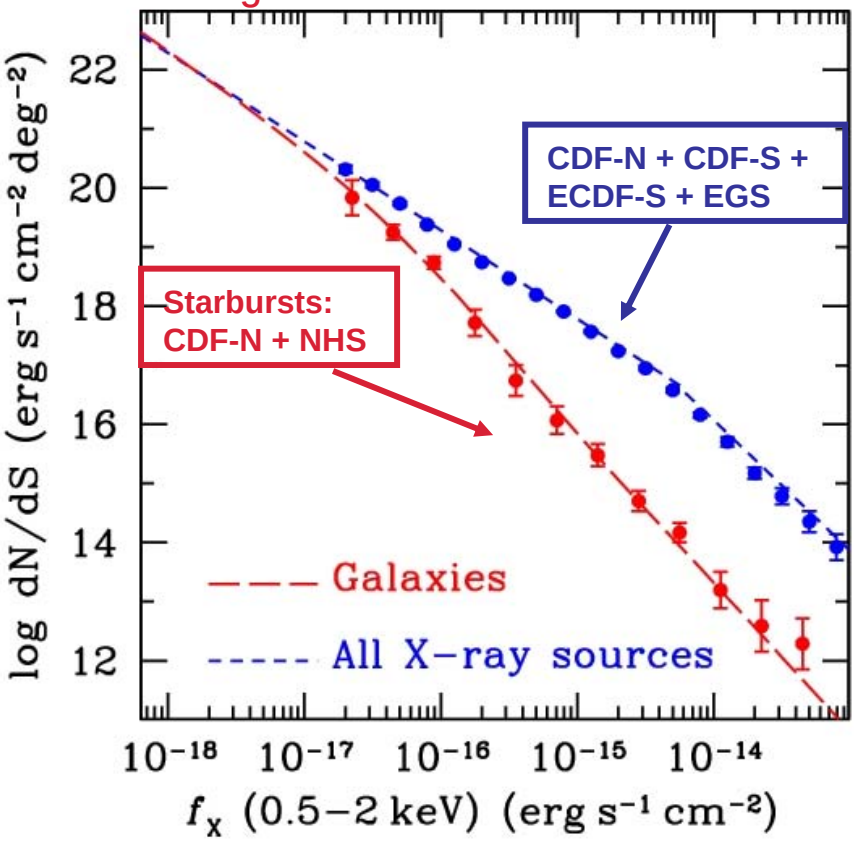
Galaxies at X-rays

- Dominant population in future X-ray surveys (e.g. XEUS)
- X-ray binaries and evolution
- Hot gas and metal enrichment

Why study galaxies

- Dominant population below the limit of current surveys (e.g. XEUS)
- At f_X~10^{-18}erg/s/cm^2
  - 30,000 galaxies/deg^2
  - Mean redshift <z>~1.5

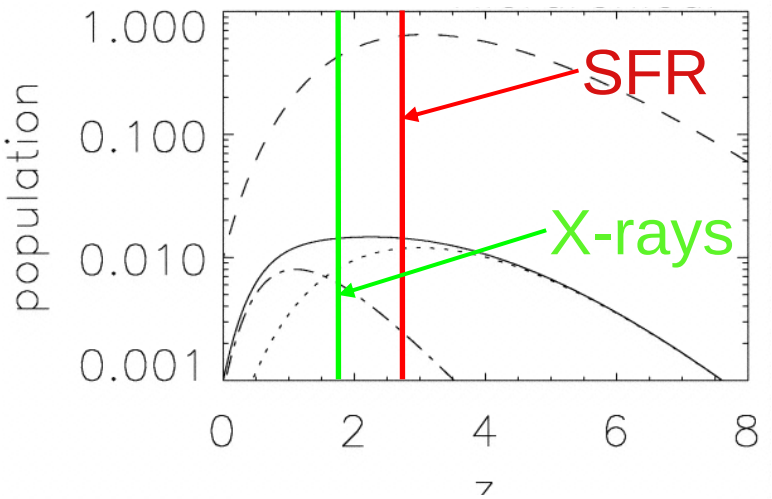
Georgakakis et al. 2008

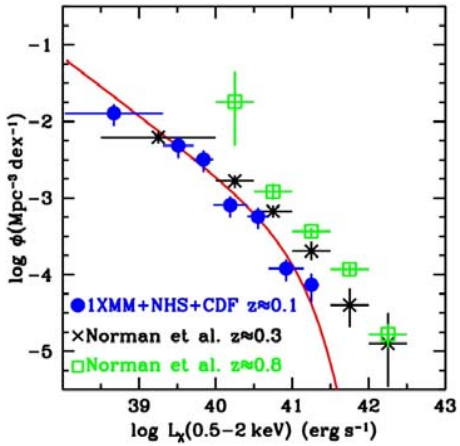


X-ray evolution of star-forming galaxies

- X-ray binaries:
  - low mass: long timescales
  - high mass: fast evolution
- X-ray evolution of starbursts different compared to other wavebands
  - time lag between the peaks of SF and X-ray luminosity
- Attempts to constrain galaxy XLF as a function of redshift
  - *Chandra* Deep Fields identify galaxies to *z*~1
  - *Chandra* & *XMM* wide-angle shallow surveys find galaxies at *z*~0.1

Ghosh & White 2001

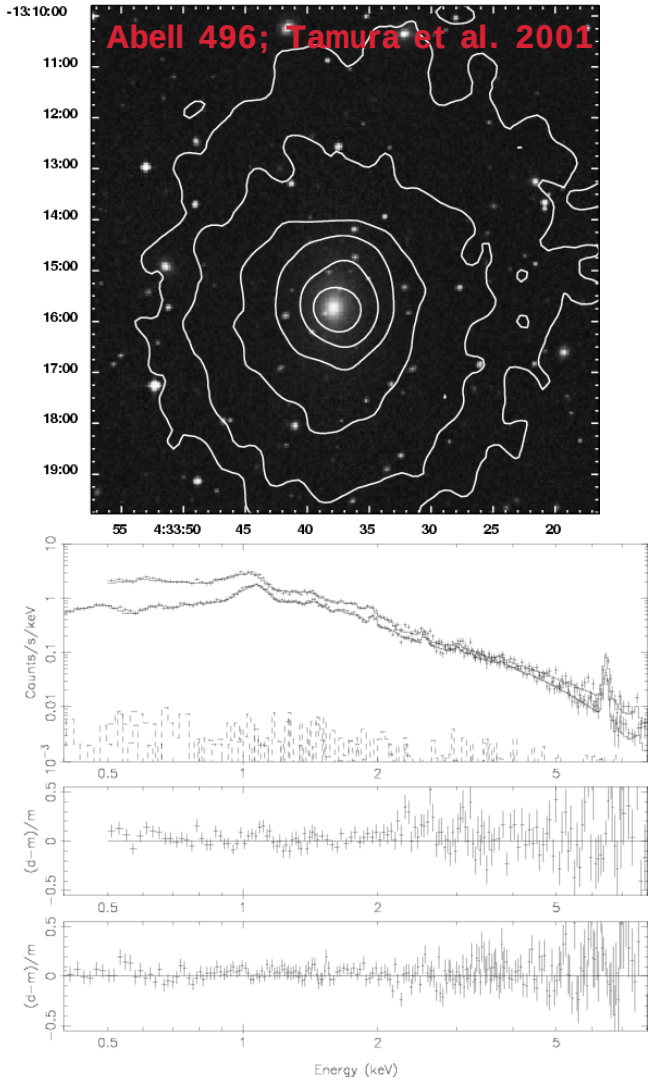




Norman et al. 2005;
Georgantopoulos et al. 2005;
Georgakakis et al. 2006

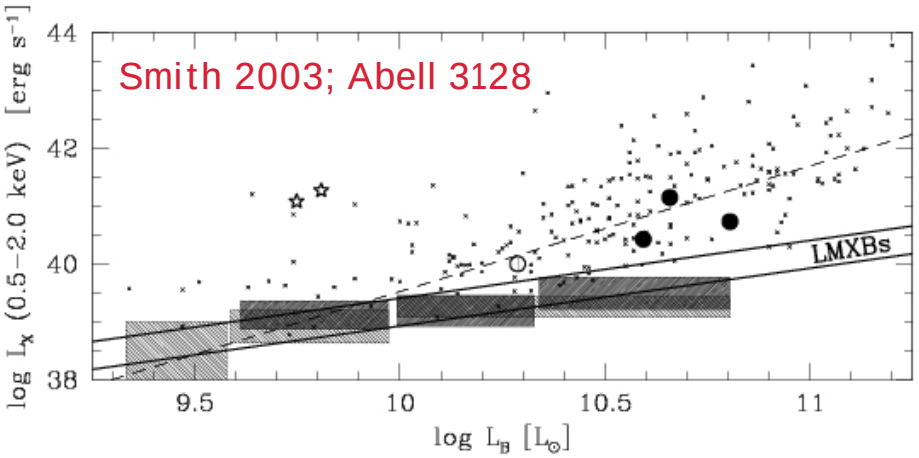
Metal enrichment

- Hot gas of clusters/groups rich in metals, i.e. not primordial
- Gas is processed in galaxies before transported to the inter-galactic medium:
  - SN explosions
  - Gas stripping
  - AGN jets
  - Galaxy interactions



Metal enrichment via gas stripping

- Early-type galaxies in clusters are X-ray faint for their L_B.
- X-ray emission dominated by binary stars
- Galaxy hot gas is stripped to the intergalactic medium
- We need to study of the X-ray properties of galaxies in a range of environments.



X-ray stacking of Abell 3128 cluster members (not individually detected)

Stacking signal consistent with low-mass X-ray binary expectation (no hot gas)

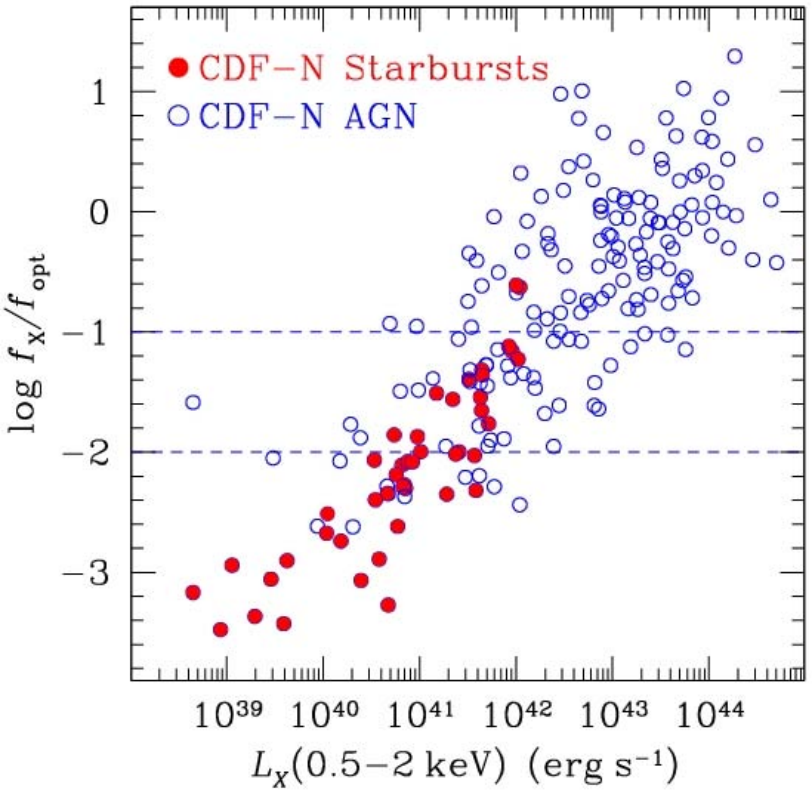
See also Hornschemeier et al. 2006

Problems

- Selection of galaxies
  - Contamination from AGN
  - Incompleteness
- Galaxy samples are still small (~100)
  - Luminosity function: uncertainties in the determination of the faint-end slope and L_*

Galaxy X-ray Luminosity Function: selection effects

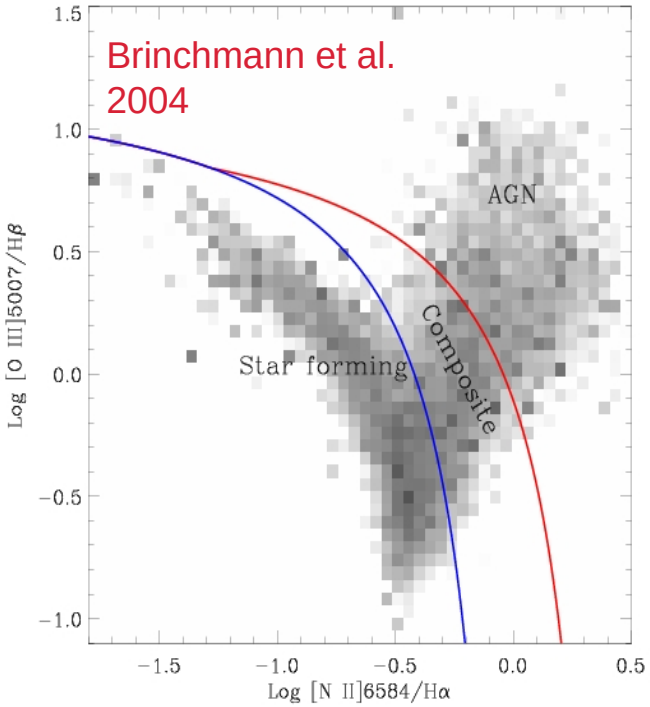
Georgakakis et al. 2007

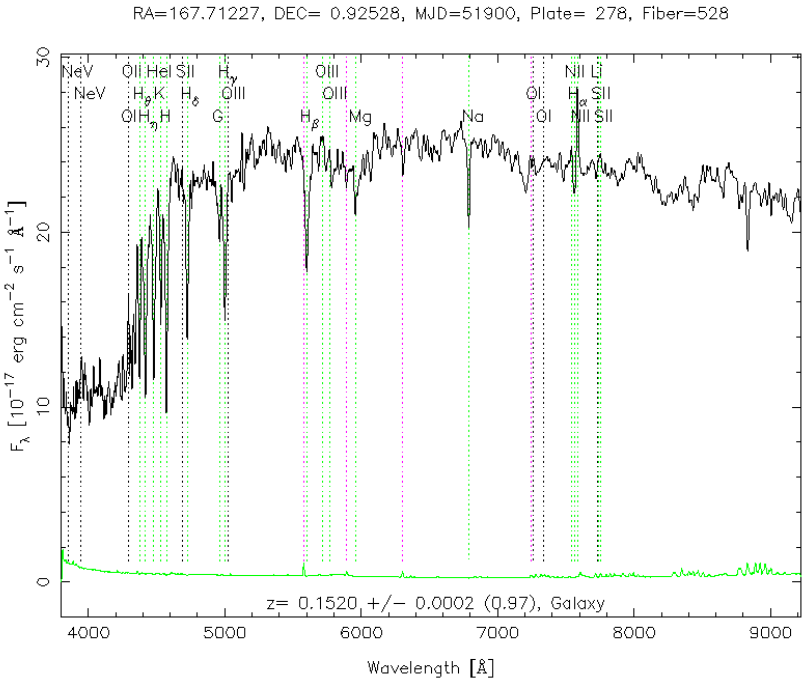


Galaxies are often selected to have $\log(f_X/f_{opt}) < -2$

incompleteness

Optical spectroscopy



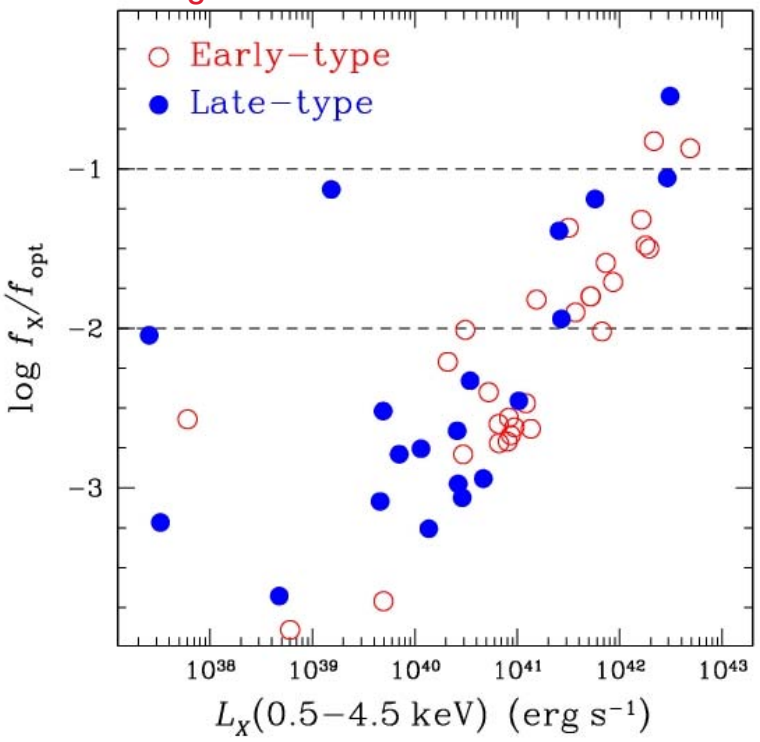


High quality optical spectra (e.g. SDSS):
Unbiased galaxy selection

X-rays + SDSS spectra

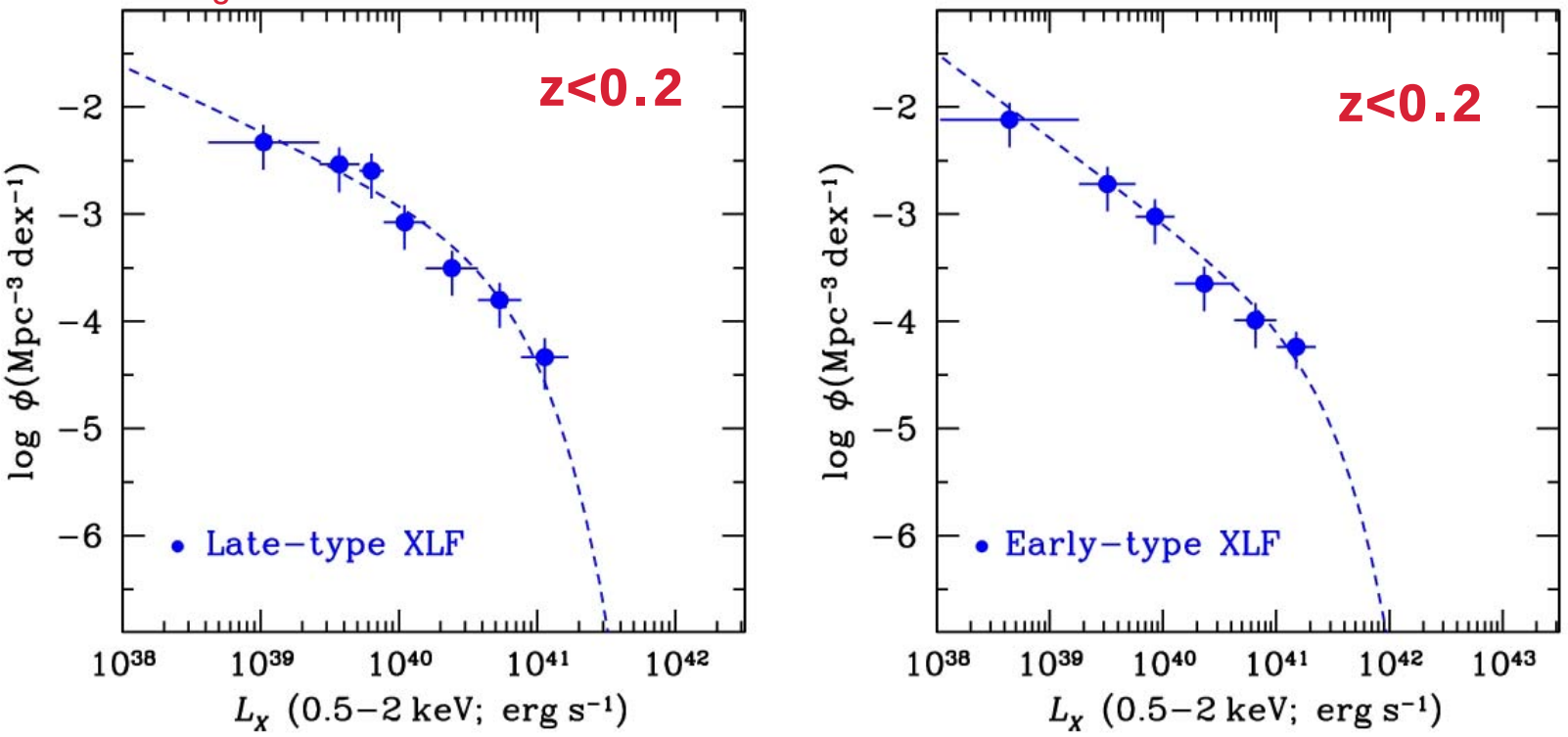
- Match 2XMM with the SDSS-DR4 spectroscopy
- Total of 48 galaxies
  - L_X ~10^{40}–10^{43}erg/s
  - 50% log(f_X/f_{opt})>–2

Georgakakis 2008



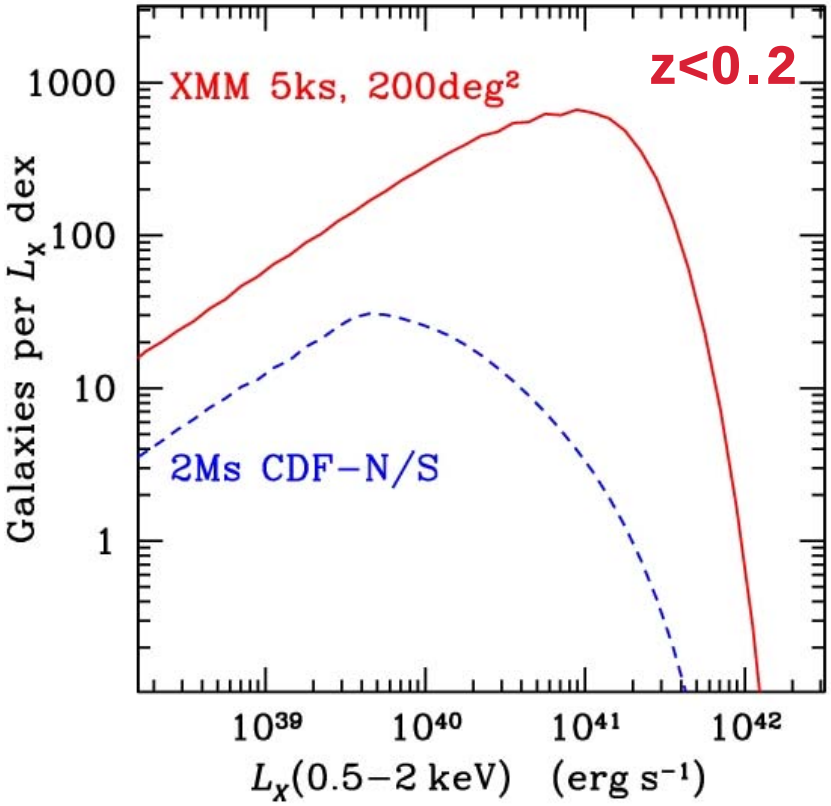
Galaxy X-ray Luminosity Function: small number statistics

Georgakakis et al. 2006



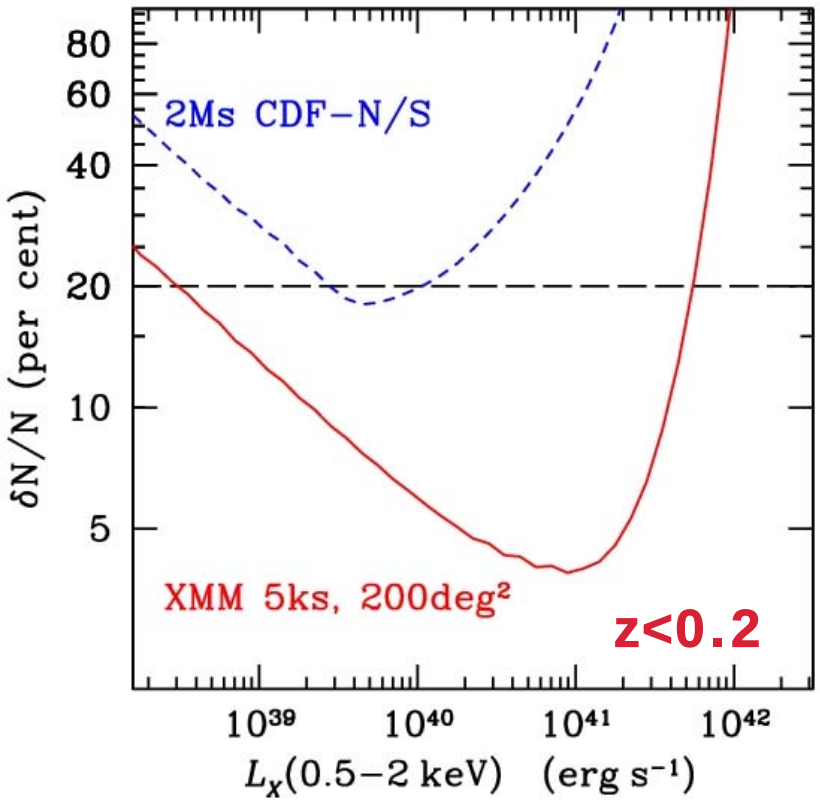
- Local X-ray Luminosity Function, $\langle z \rangle \sim 0.1$
- Data: Needles in Haystack Survey + 1XMM + Chandra Deep Fields (~15deg^2)

Wide-area & shallow X-ray survey in the SDSS



- Many z<0.2 galaxies over wide L_X–range
- Accurate XLF determination (e.g. faint-end slope, L_*)
- <20% uncertainty in individual L_X–bins

Wide-area & shallow X-ray survey in the SDSS

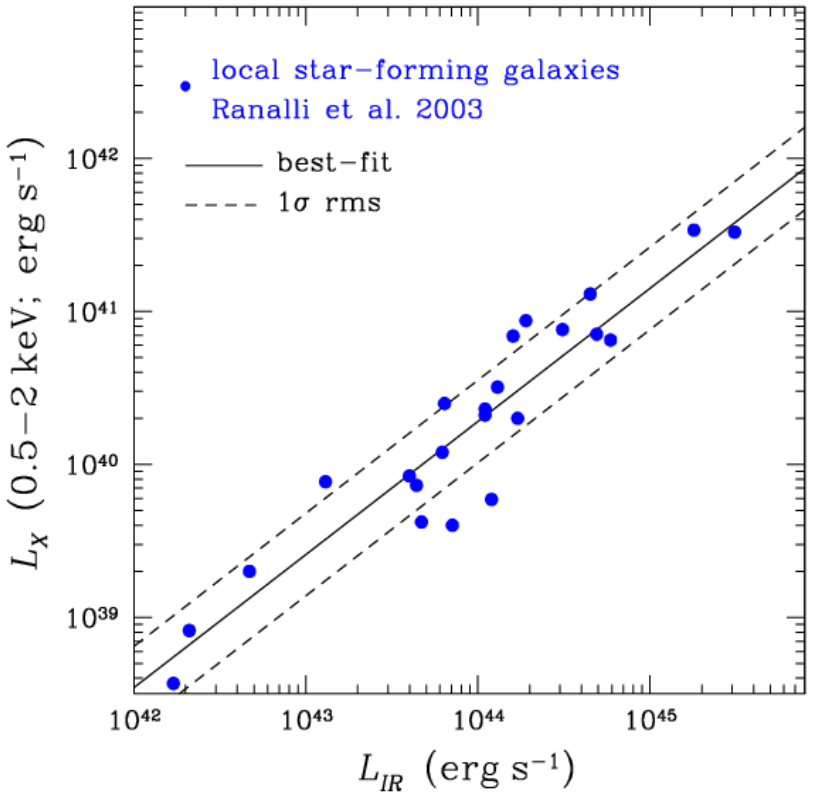


- Many z<0.2 galaxies over wide L_X–range
- Accurate XLF determination (e.g. faint-end slope, L_*)
- <20% uncertainty in individual L_X–bins

Calibrate infrared methods for selecting normal galaxies

- Mid/far-IR: alternative to optical spectroscopy for selecting galaxies
- Useful at high *z*, where high S/N spectra difficult
- IR selection methods not yet calibrated
  - contamination rate
  - incompleteness

Star-forming galaxies: Lx-Lir correlation

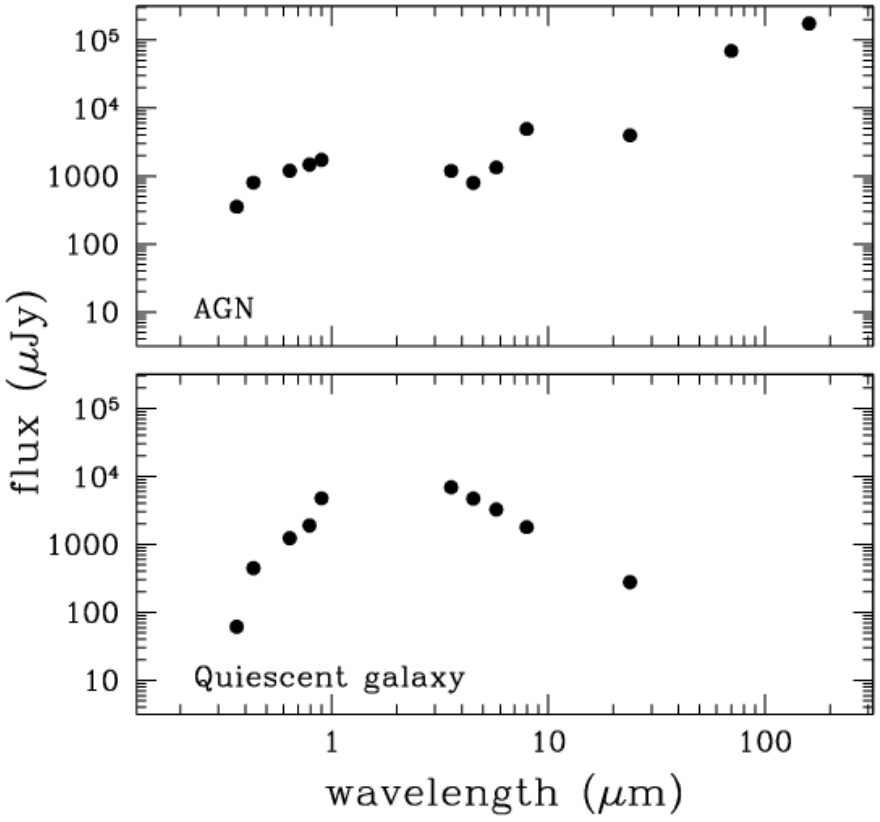


e.g. Georgakakis et al. 2008; Lehmer et al. 2008

Calibrate infrared methods for selecting normal galaxies

- Mid/far-IR: alternative to optical spectroscopy for selecting galaxies
- Useful at high *z*, where high S/N spectra difficult
- IR selection methods not yet calibrated
  - contamination rate
  - incompleteness

Quiescent galaxies: mid-IR SED shape



e.g. Georgakakis et al. 2008

Summary

- A wide-area (200deg^2) shallow (5ks) X-ray survey is needed for normal galaxy studies:
  - Unbiased & complete sample
- Important science:
  - X-ray luminosity function at z~0.1
    - evolution studies
    - interpretation of deeper surveys
  - Calibrate IR methods for selecting X-ray galaxies
    - Star-forming galaxies: L_X-L_{IR} correlation
    - Early-type galaxies: mid-IR SED