Normal Galaxies in a Very Wide XMM Survey

A. Ptak (Johns Hopkins University)

X-ray Emission Mechanisms in Starbursts

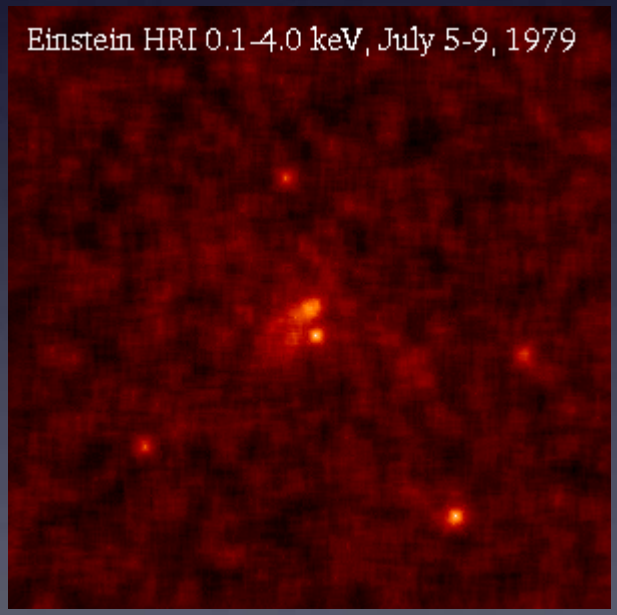
Point Sources

- Hot Stars (mostly massive OB, WR stars; L_X <~ 10^{33} ergs s^{-1})
- Young supernovae (L_X <~ 10^{39} ergs s^{-1}; more typically L_X <~ 10^{36} ergs s^{-1}, e.g., Cas-A)
- Low-mass and High-mass X-ray Binaries/BHC (L_X <~ 10^{39} ergs s^{-1})
- ULXs (Ultraluminous X-ray sources; L_X = $10^{39\text{-}41}$ ergs s^{-1})
- LLAGN (L_X > 10^{39} ergs s^{-1})

Diffuse Flux

- Hot ISM (L_X <~ 10^{41} ergs s^{-1})
- Superwinds (L_X <~ 10^{42} ergs s^{-1})
- IC scattering of IR and CMB

See Persic & Rephaeli (2002)

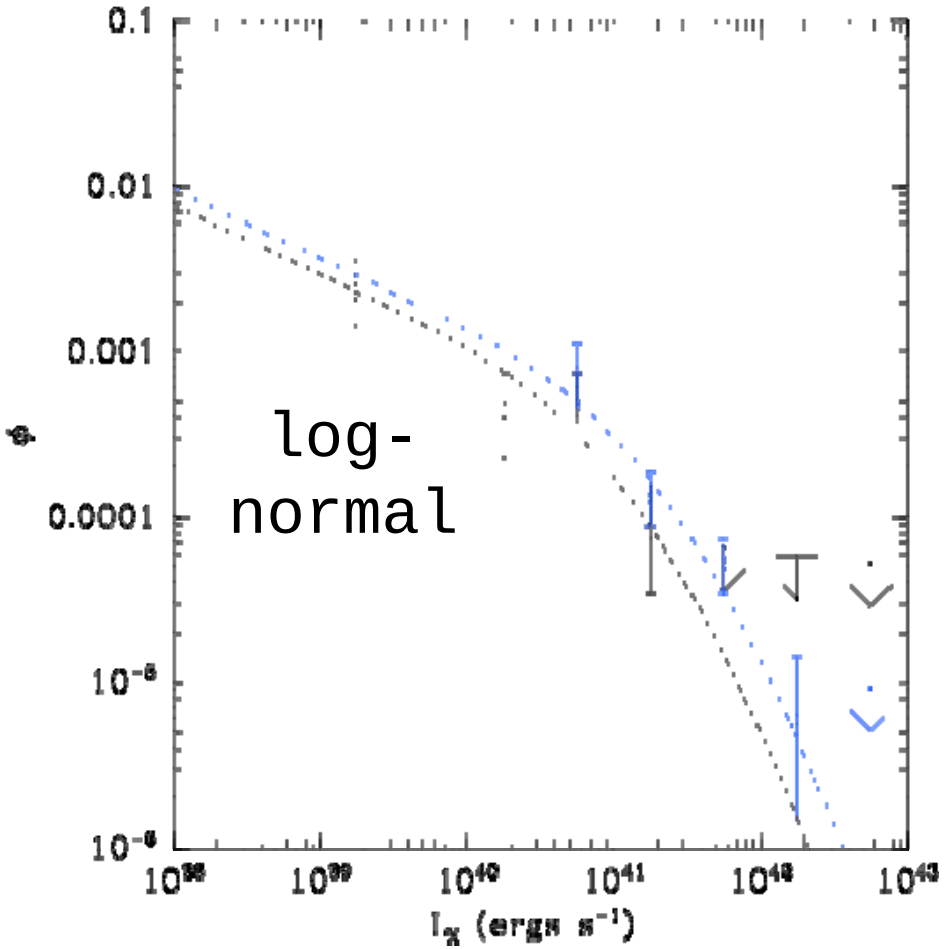


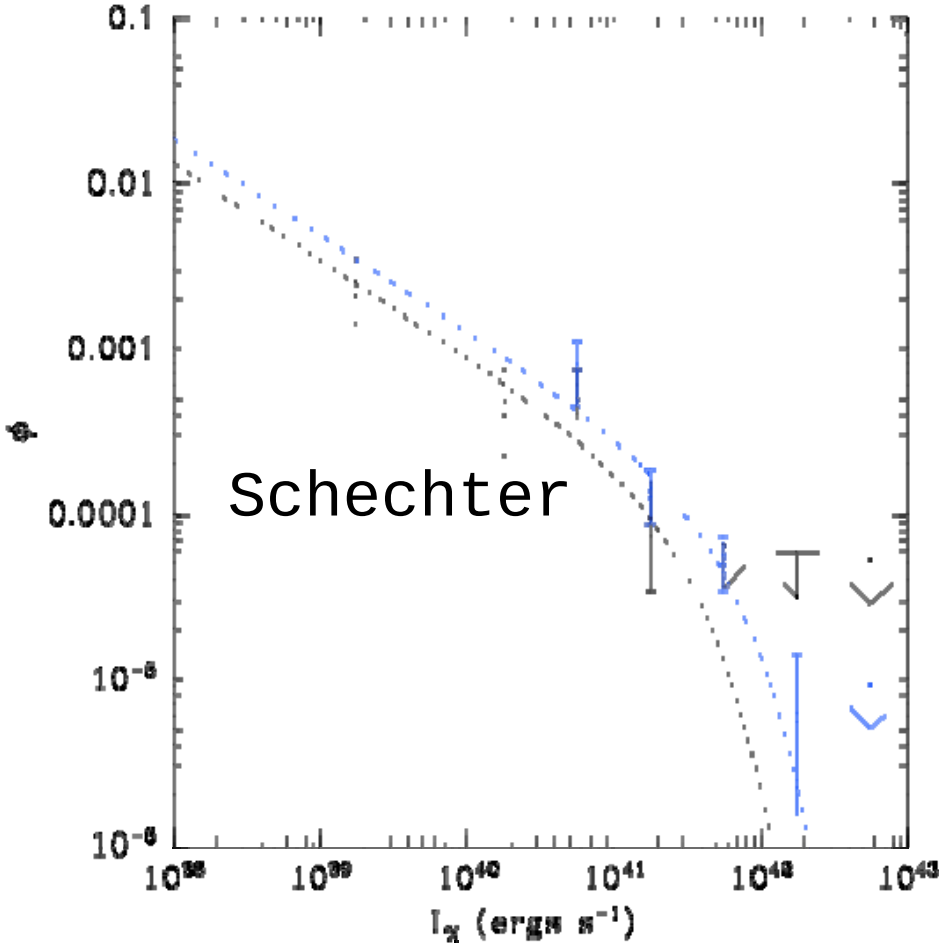
Normal/Starburst Galaxy Goals of a very Wide Survey

- Derive unbiased local XLF
- Determine statistical properties of X-ray emission of nearby galaxies
  - Select by spectral type, SFR, stellar mass, environment
  - For sources with > 50 counts, crude spectral analysis
    - How does F(0.5-2.0)/F(2-10) depend on galaxy type, SFR, etc.?
      - Relative importance of hot ISM and binaries
    - Is heating of ISM sufficient to drive outflows?
      - Enrich IGM
      - Drive evolution of low-mass galaxies
  - Results can be used to improve priors for (Bayesian) classification of sources (Norman et al. 2004, Ptak et al. 2007)
- Potentially detect tidal captures

Fitting for Pure Luminosity Evolution

Fit low and high-z XLFs simultaneously, only allowing logL* to vary between XLFs

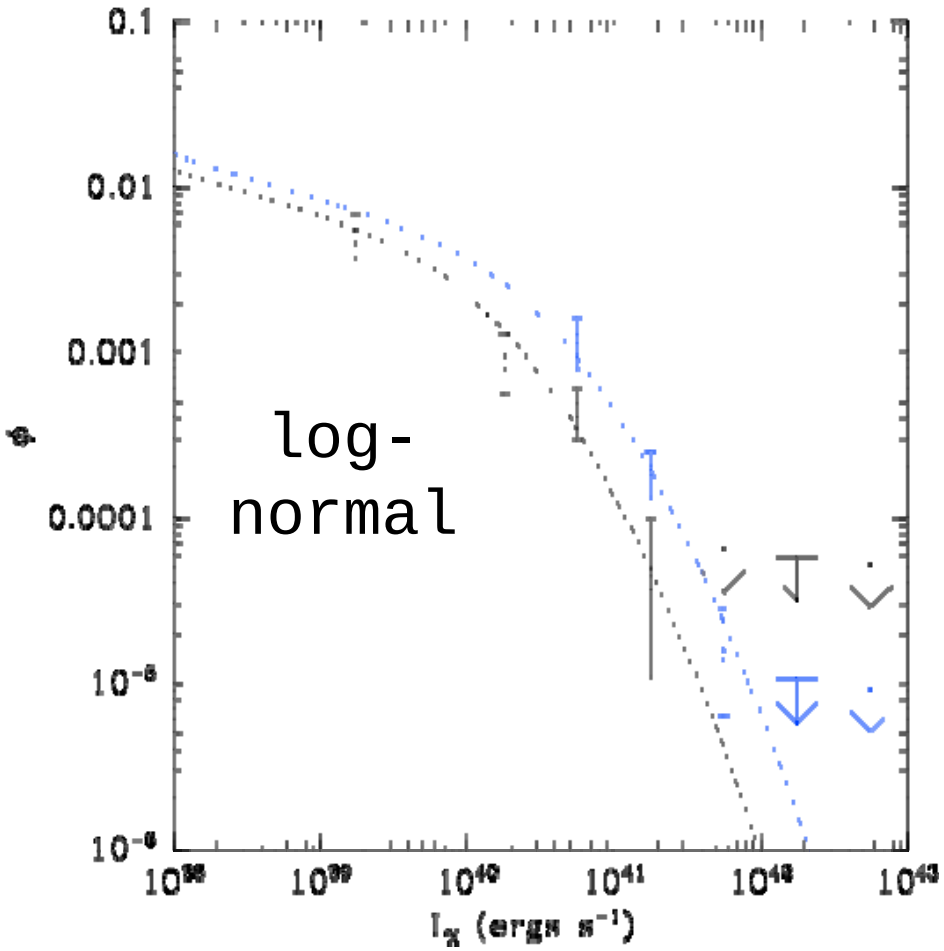


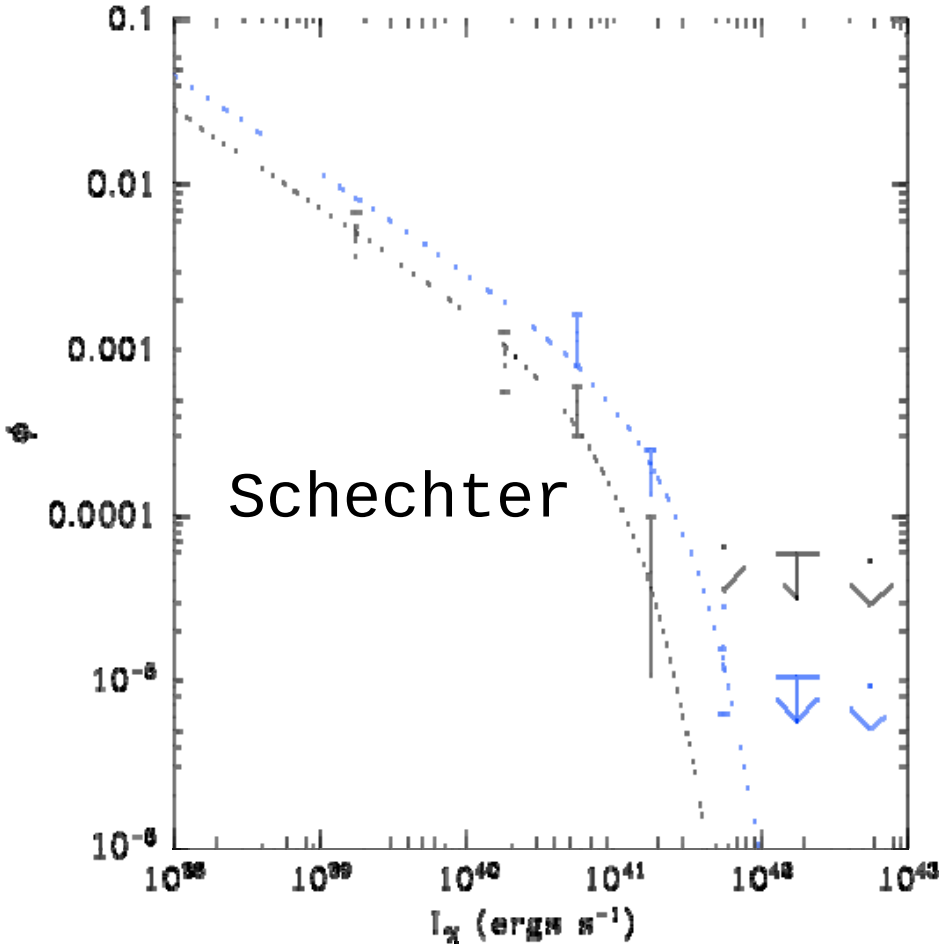


Early-type galaxies

Fitting for Pure Luminosity Evolution

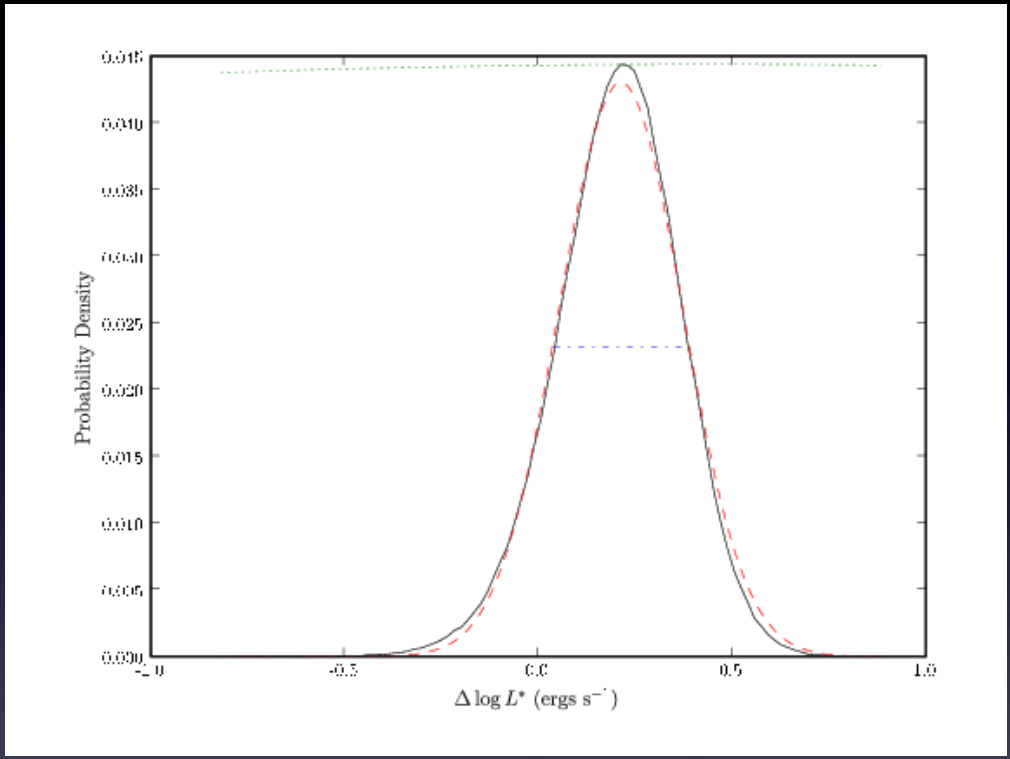
Fit low and high-z XLFs simultaneously, only allowing logL* to vary between XLFs

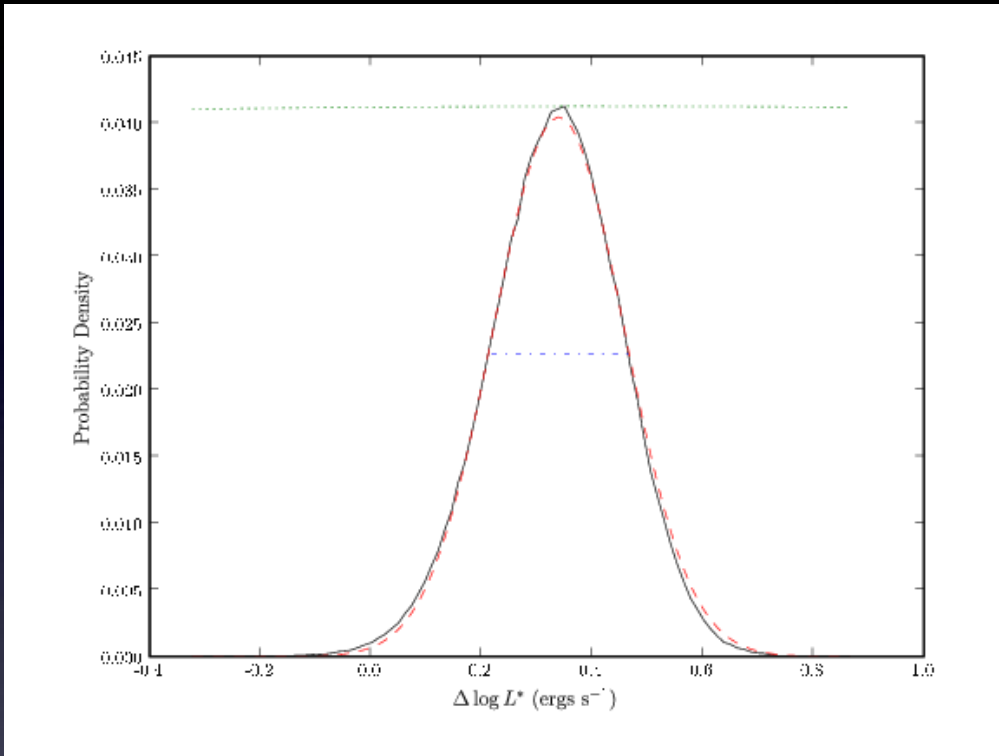




Late-type galaxies

Posterior for $\Delta logL^*$





Early-type Galaxies

$\Delta logL^* = 0.23$ (0.07-0.38)

$p = 1.57$ (0.54-2.66)

Late-type Galaxies

$\Delta logL^* = 0.34$ (0.23-0.46)

$p = 2.33$ (1.51-3.08)

$logL^* \sim (1+z)^p$

Ptak et al. (2007)

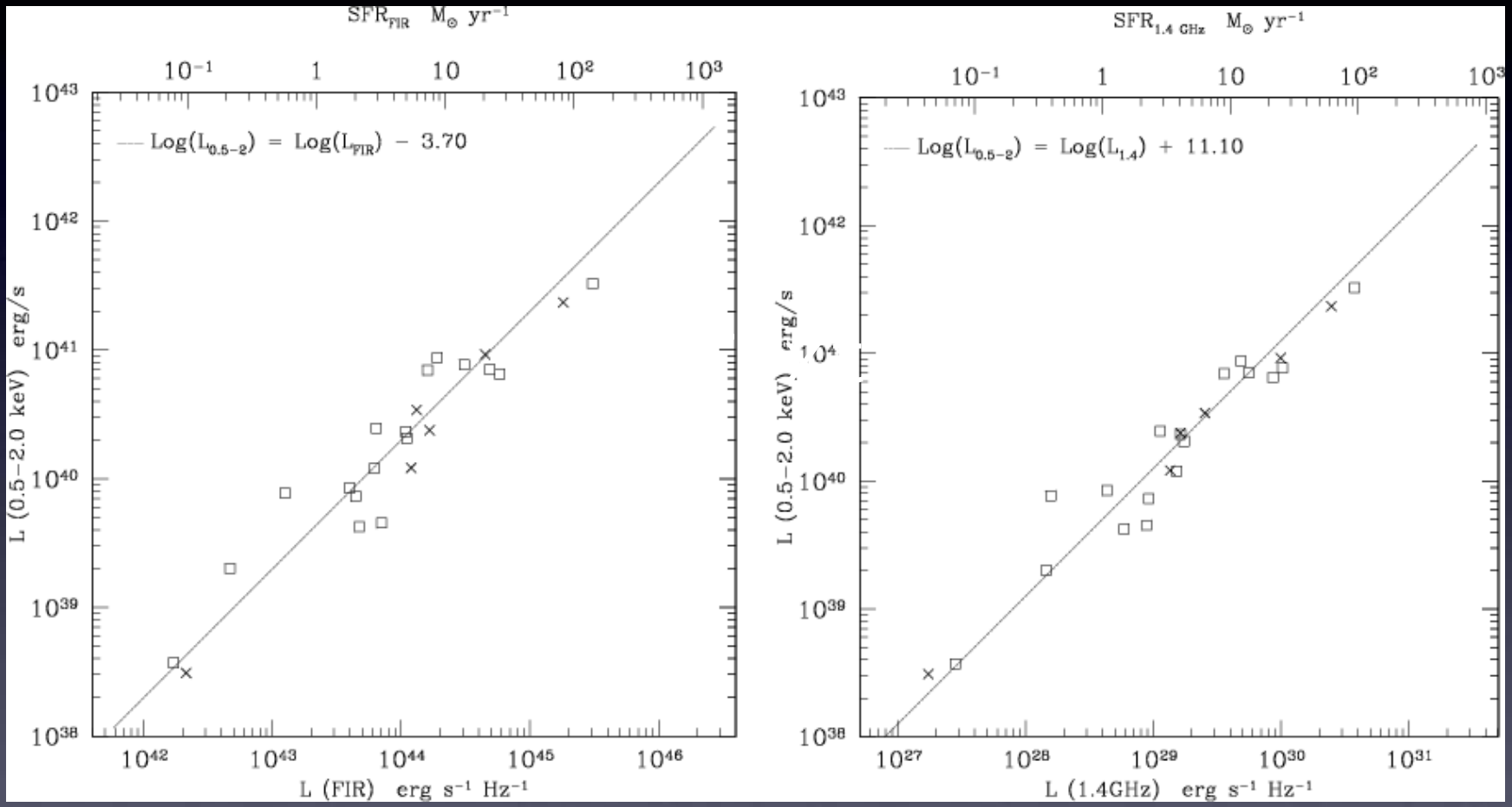
X-ray/SFR and X-ray/M

- X-rays have been known to be correlated with both star-formation rate and galaxy mass since 1980s
  - SN, SN-heated gas, High-mass X-ray binaries (HMXRB), black-hole candidates (BHC), ultra-luminous X-ray sources (ULXs) correlated with SFR
  - Low-mass x-ray binaries (LMXRB) correlated with galaxy mass

Total X-ray Flux / SFR Correlation

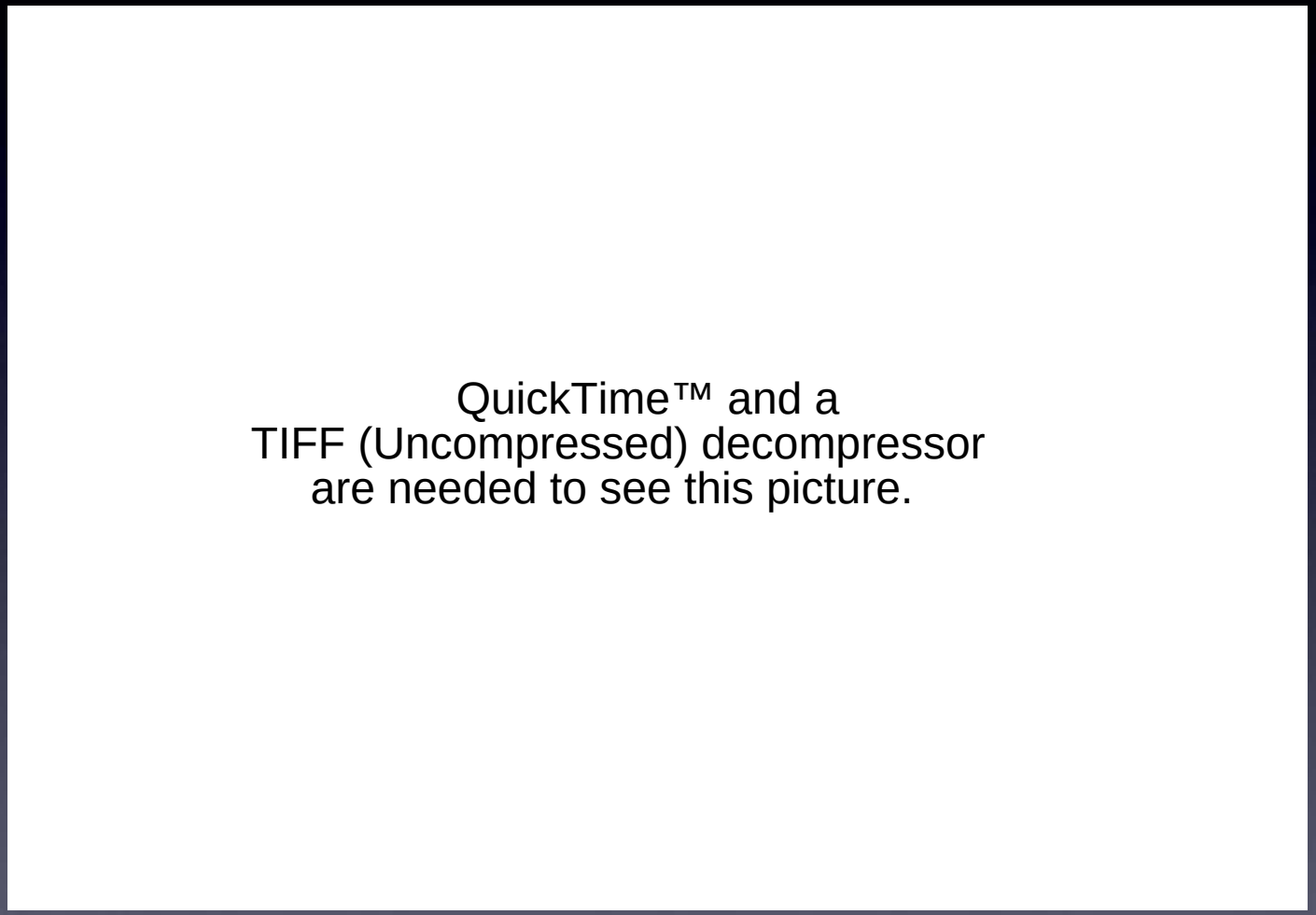
- Ranalli et al. (2003)
  - Correlated 0.5-2.0 keV and 2-10 keV X-ray lum. vs. both radio (1.4 Ghz) and FIR lum.
  - SFR = 2.2 x 10^{-40} $L_{0.5\text{-}2.0\ keV}$
  - SFR = 2.0 x 10^{-40} $L_{2\text{-}10\ keV}$
- Persic et al. (2004): SFR = 10^{-39} $L_{2\text{-}10\ keV,\ HMXRB}$
- Grimm et al. (2003), Gilfanov et al. (2004)
  - $L_{2\text{-}10keV,HMXRB}$/SFR relation is non-linear below SFR ~ 1
  - Implies universal HMXRB XLF and cut-off exist
- Colbert et al. (2004): L_{XP} = 1.3 x 10^{29} (Mass) + 0.7 x 10^{39} (SFR)

X-rays vs. FIR and Radio



From Ranalli et al. (2003)

Lehmer et al. (2008)

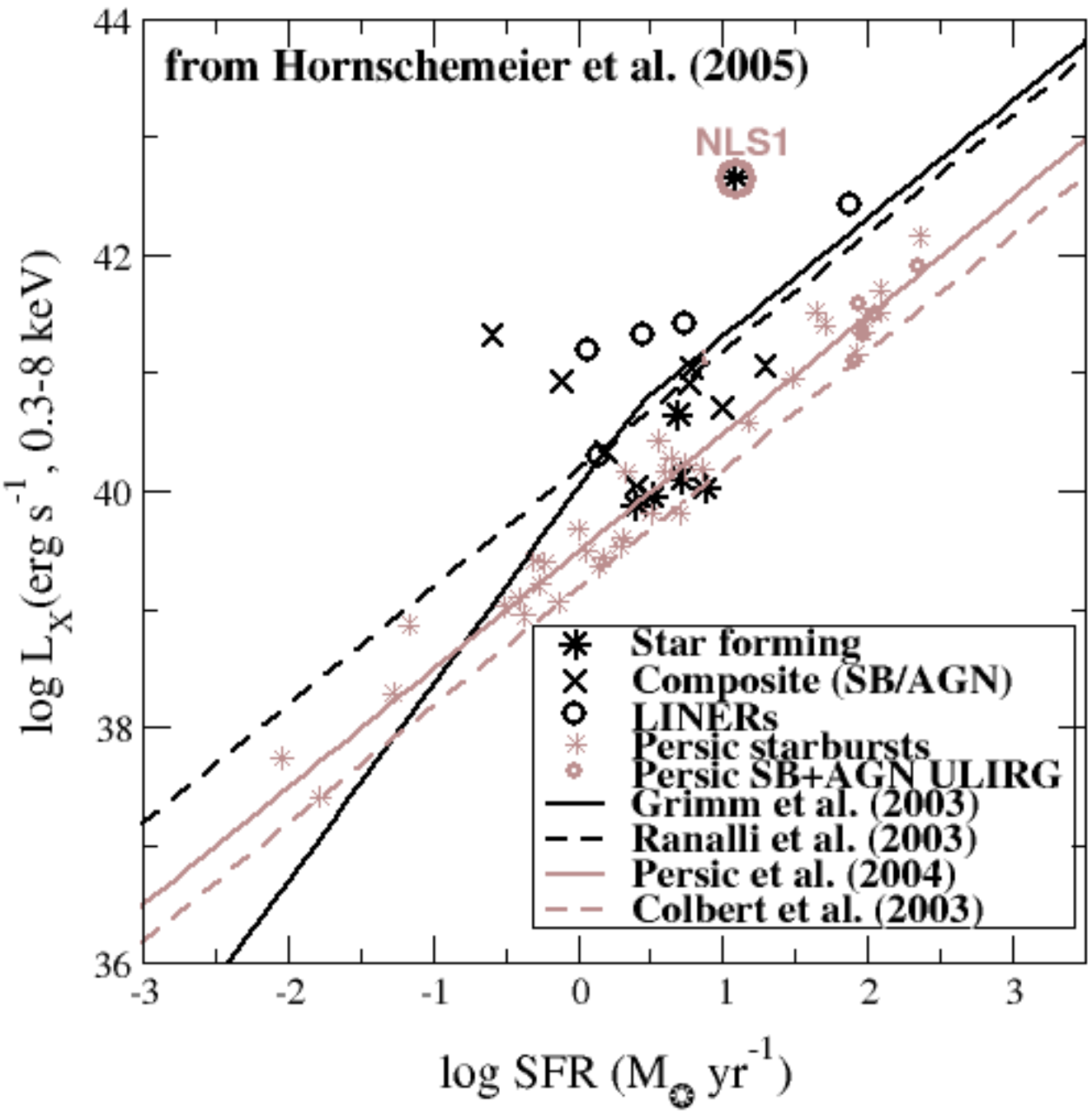


Serendipitous Source Surveys

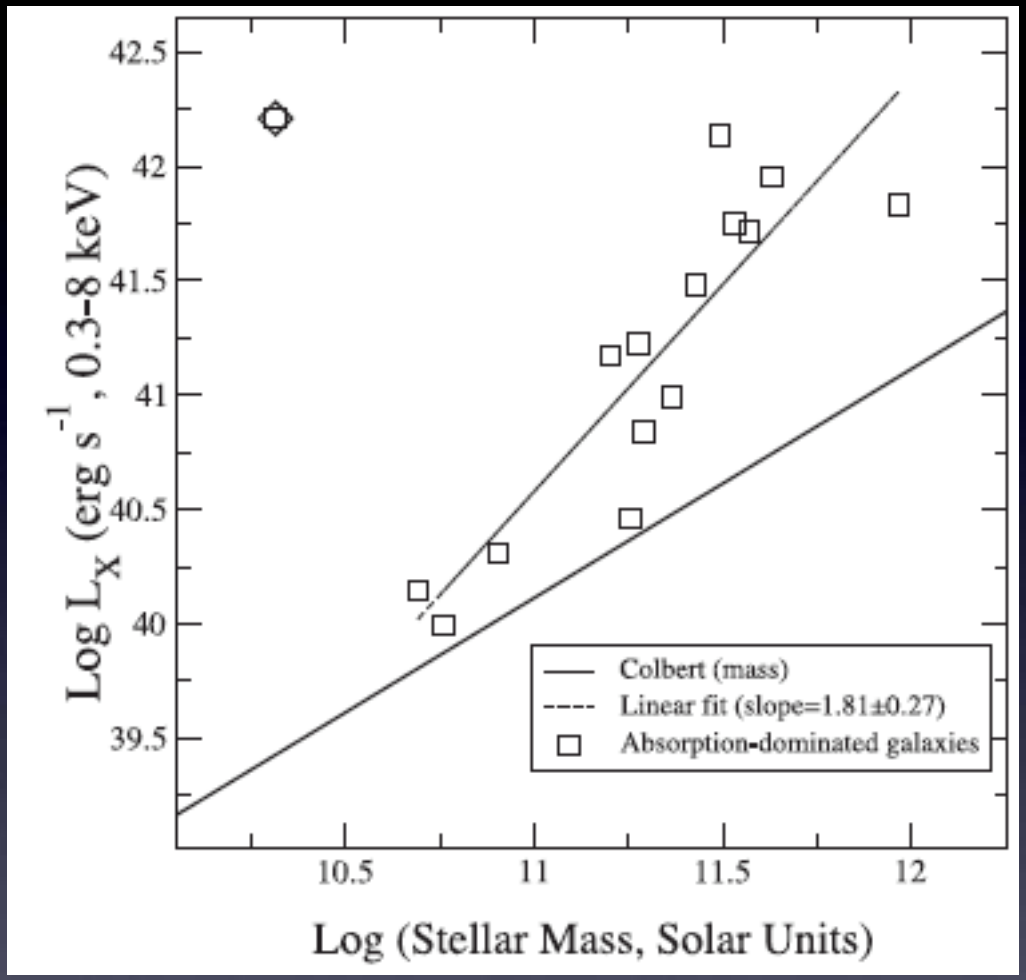
- Serendipitous source surveys of galaxies tend to result in weak detections and small sample sizes due to limited overlap
  - Hornschemeier et al. (2005) correlated Chandra archive with SDSS galaxy catalog of Brinchmann et al. (2004)
  - 2XMM catalog - SDSS match (Georgakakis 2008, Watson et al 2008)
  - Correlation of full Chandra and XMM-Newton archive with RC3, etc. catalog may be promising
  - Swift UVOT + XRT survey (S. Immler)

6/24 emission-line galaxies detected were star-forming, but occupy a relatively narrow SFR range

Results consistent with lower X-ray/SFR ratio

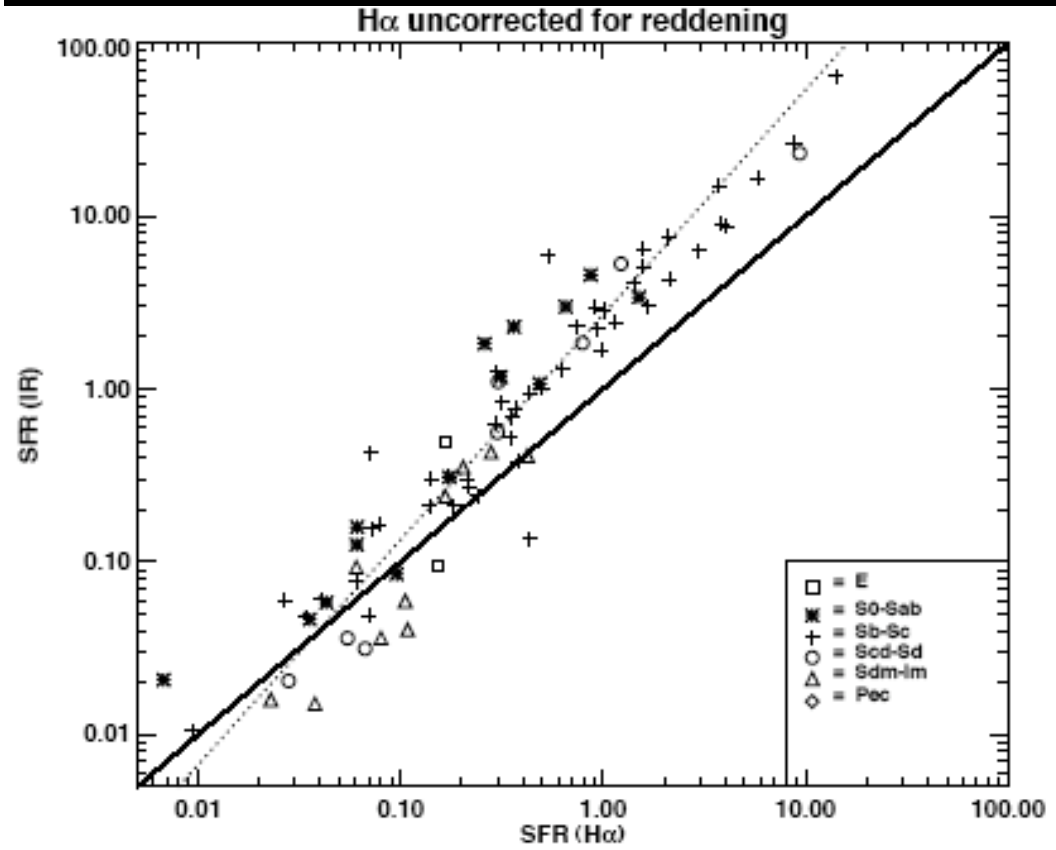


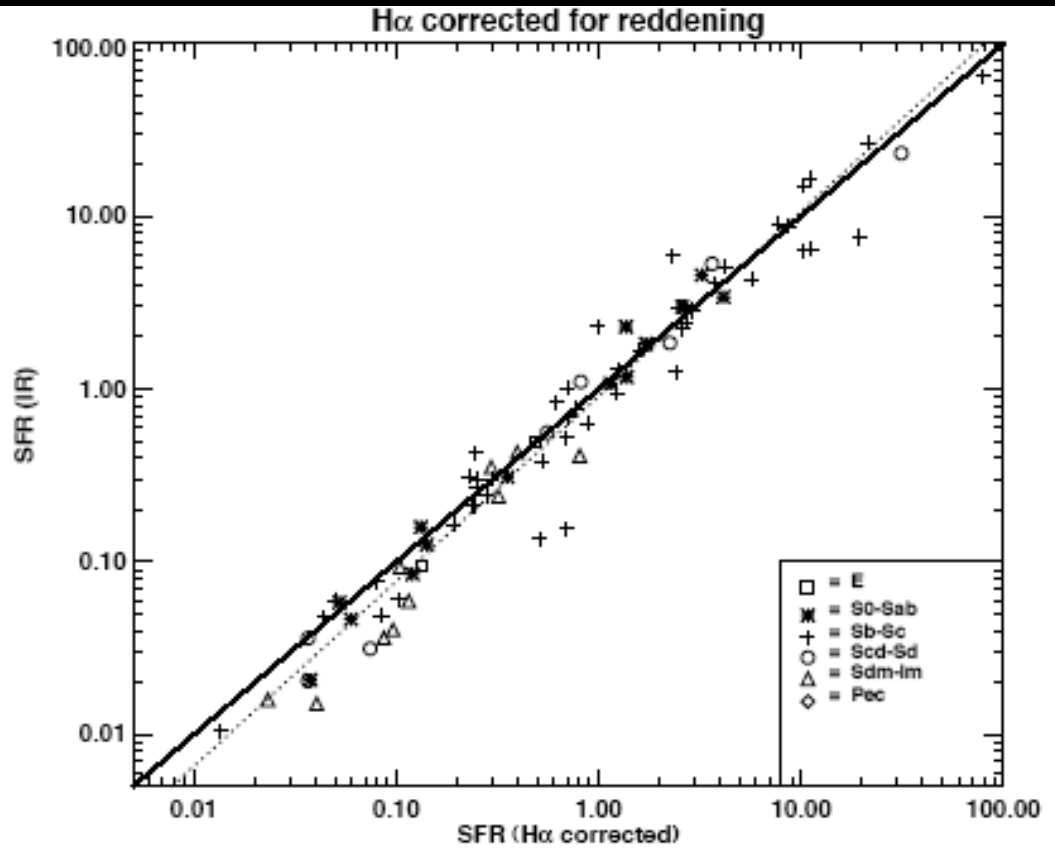
Absorption line galaxies from Hornschemeier et al. (2005)



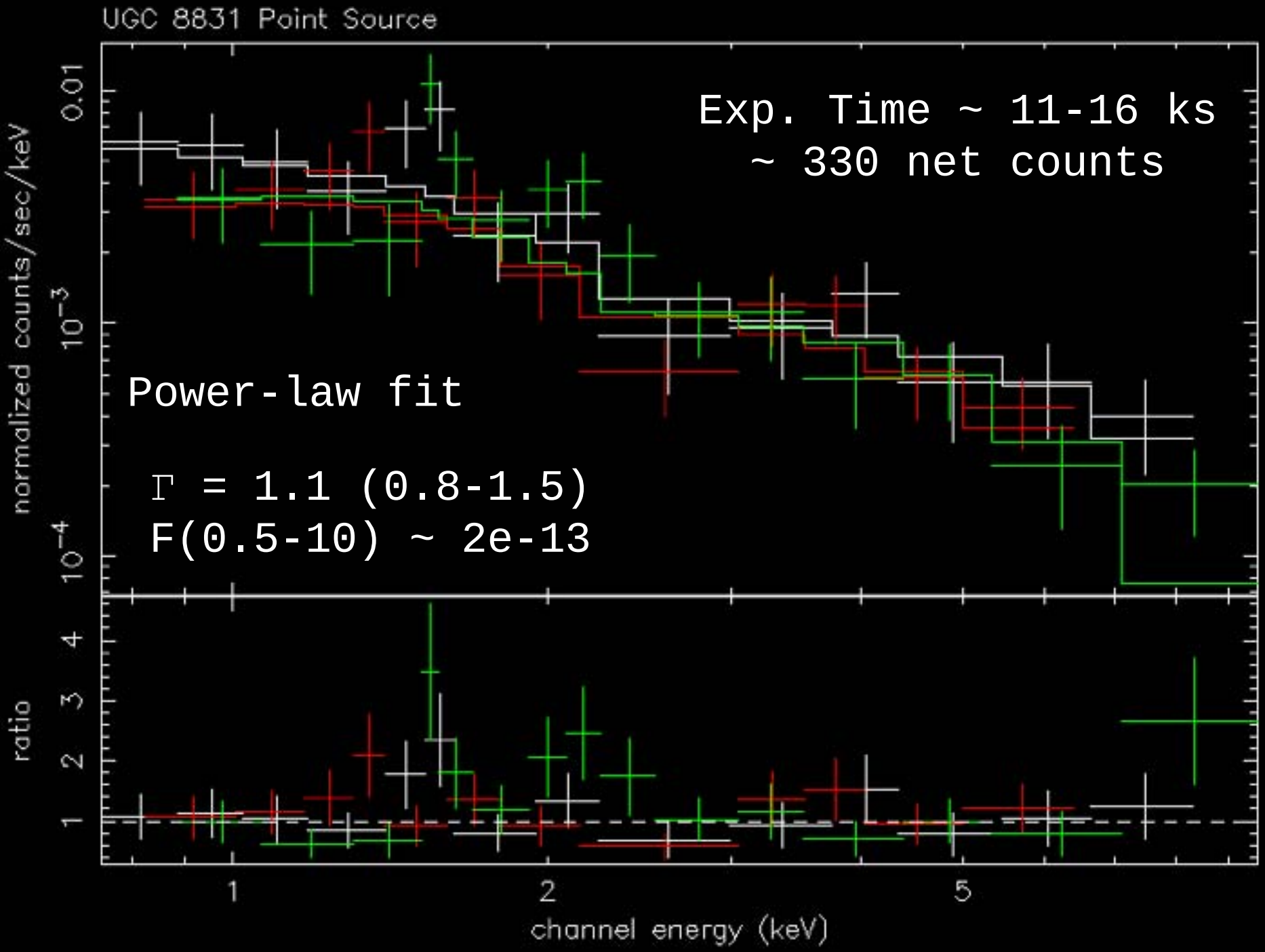
Pointed Observations

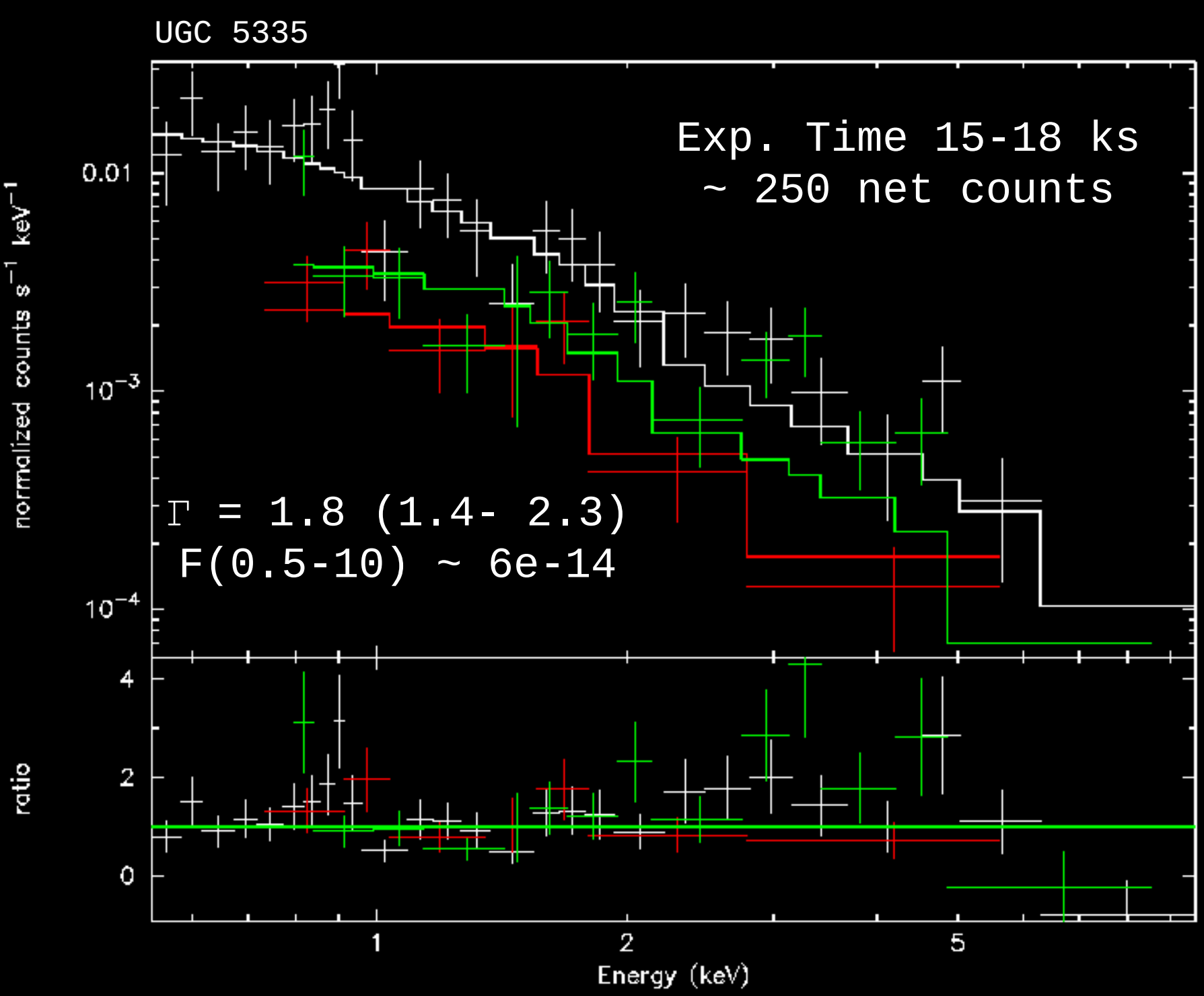
- Remove bias by selecting galaxies to be observed from galaxy catalogs rather than X-ray flux
- SINGS: Approved Chandra large program (PI L. Jenkins)
- Nearby Field Galaxy Survey: well-determined SFR via integral-field spectroscopy
  - Observed 6 targets w/ XMM
- Very slow way to build a sample, but gets larger number of sources with sufficient counts for spectral analysis





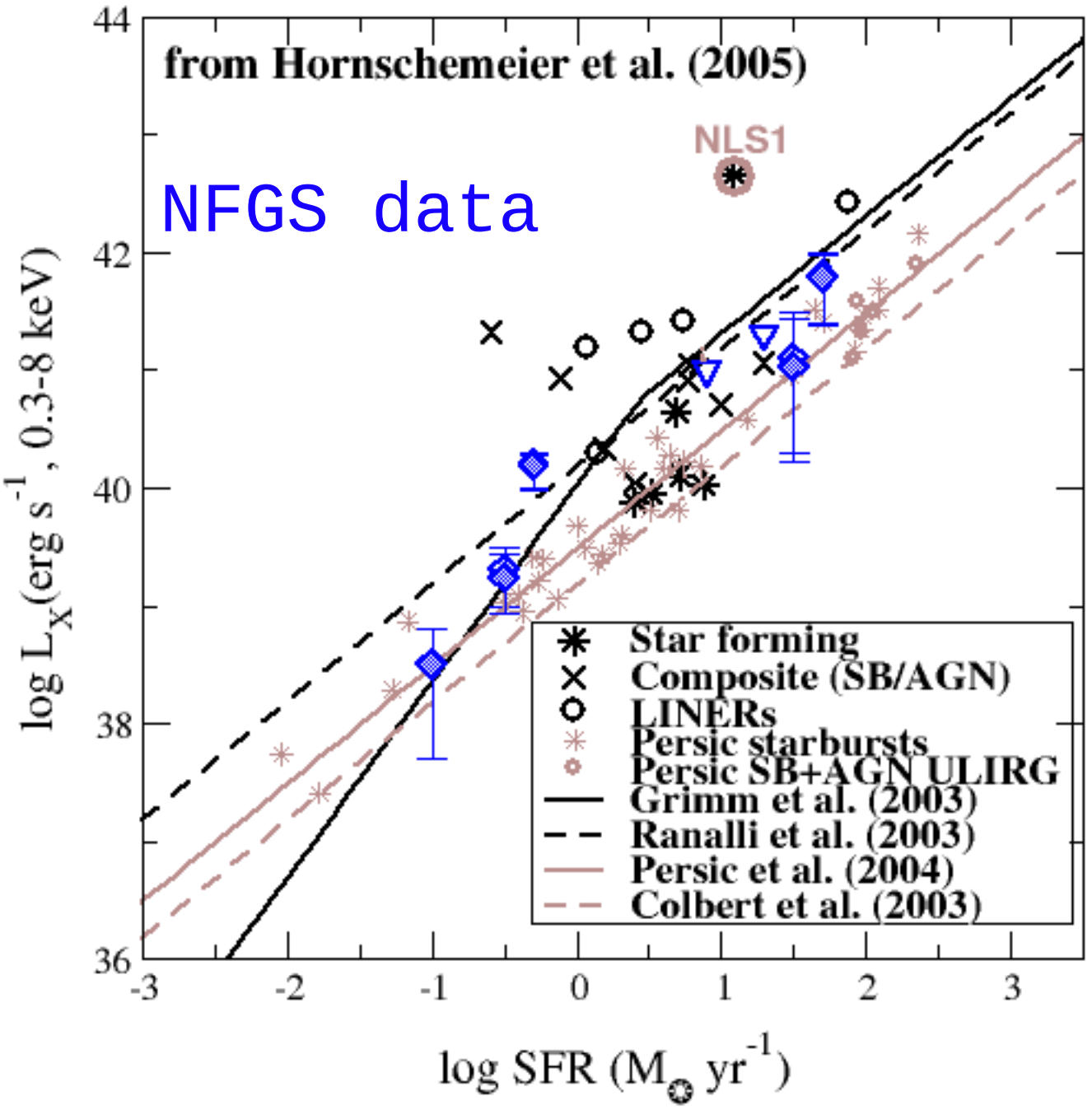
From Kewley et al. (2002)

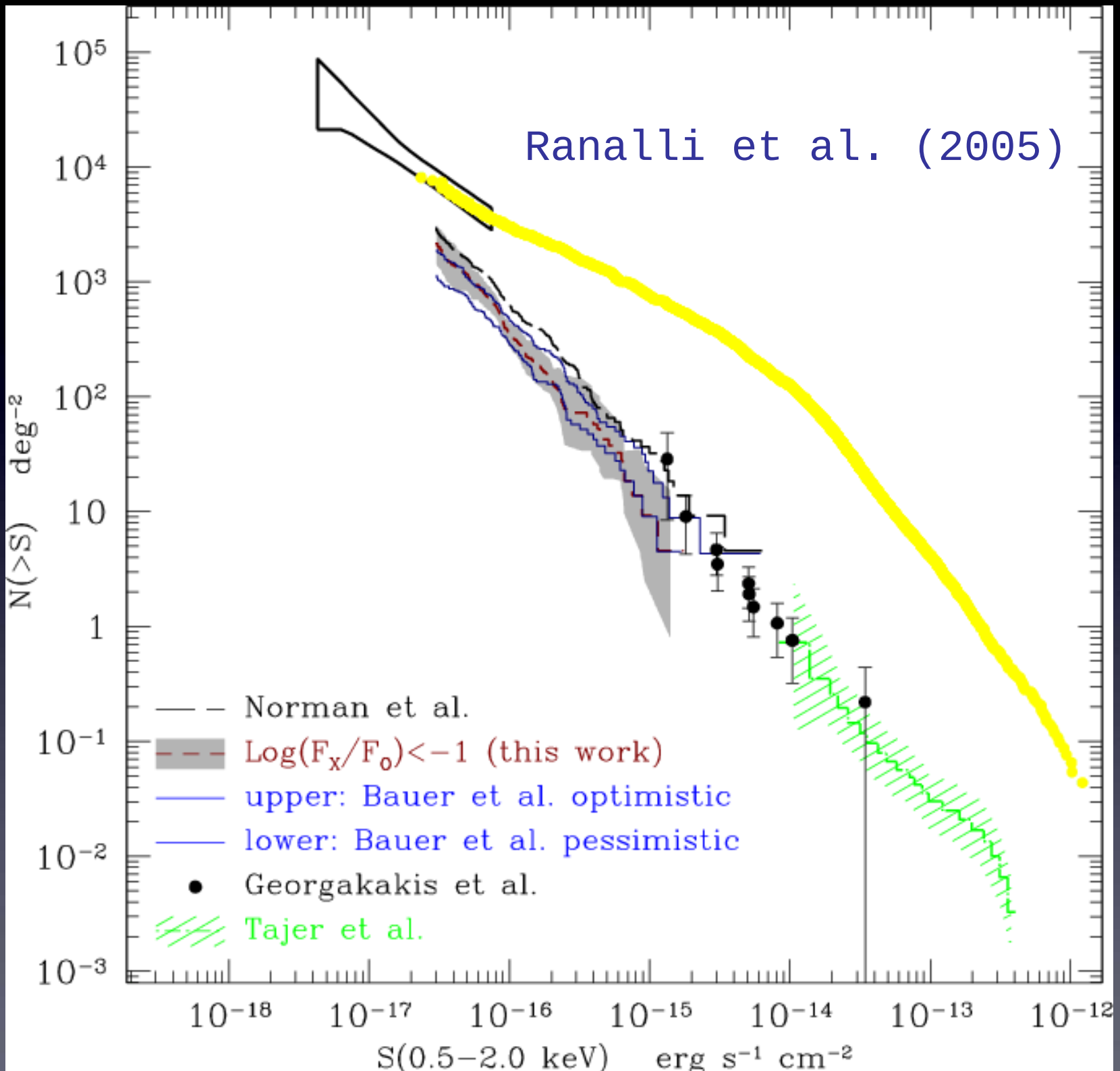

UGC 8831 Point Source
Exp. Time ~ 11-16 ks
~ 330 net counts
Power-law fit
Γ = 1.1 (0.8-1.5)
F(0.5-10) ~ 2e-13
normalized counts/sec/keV
0.01
10^{-3}
10^{-4}
ratio
1
2
3
4
1
2
5
channel energy (keV)


UGC 5335
Exp. Time 15-18 ks
~ 250 net counts
Γ = 1.8 (1.4- 2.3)
F(0.5-10) ~ 6e-14
normalized counts s^{-1} keV^{-1}
0.01
10^{-3}
10^{-4}
ratio
4
2
0
1
2
5
Energy (keV)

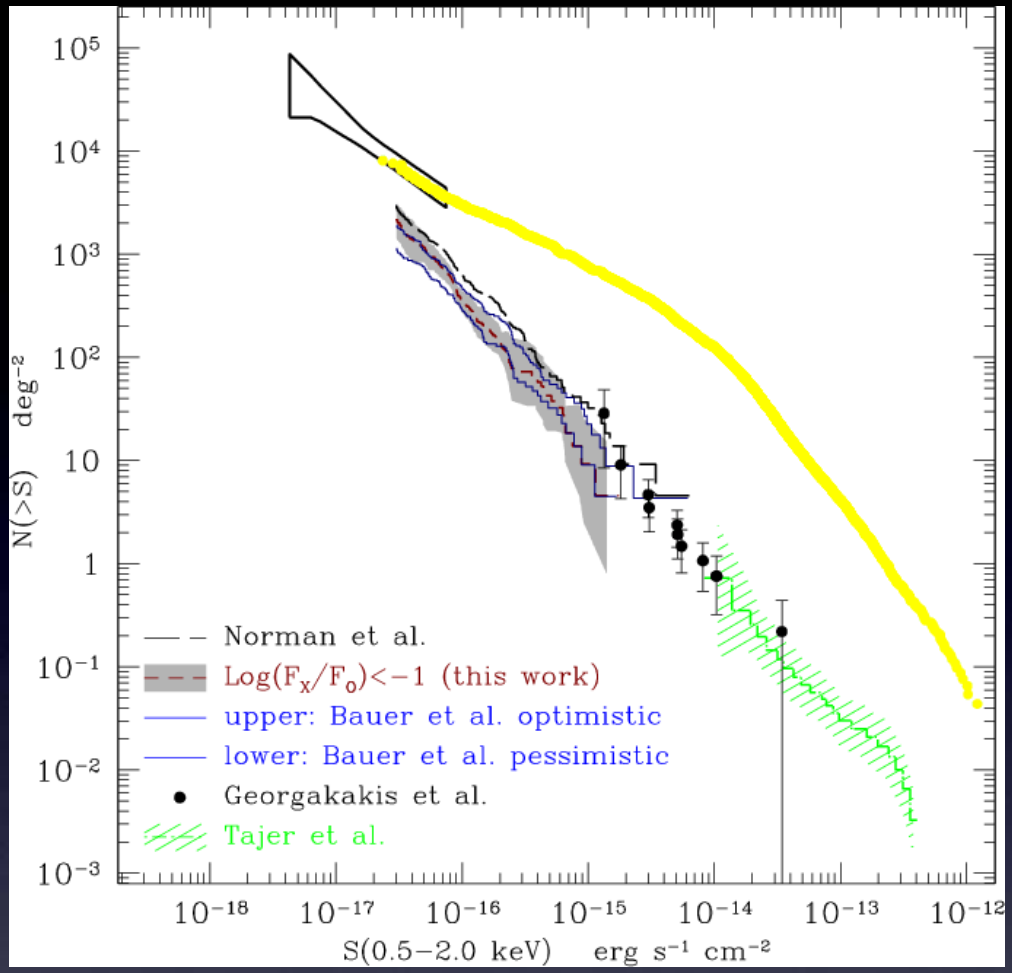
Tentative evidence for higher X-ray/SFR norm.at SFR > 1, break below SFR = 1

Note:
Lehmer et al. (2008) found constant X-ray/SFR ~ from stacking in CDF fields, at level consistent with lower X-ray/SFR norm.




Ranalli et al. (2005)
N(>S) deg⁻²
S(0.5−2.0 keV) erg s⁻¹ cm⁻²
Norman et al.
Log(F_X/F_O)<−1 (this work)
upper: Bauer et al. optimistic
lower: Bauer et al. pessimistic
Georgakakis et al.
Tajer et al.

Flux	N (deg^{-2})	Photons/ 10 ks
1e-15	~ 10-30	~ 7
2e-15	~ 3-10	~ 15
5e-15	~ 1-3	~ 35
1e-14	~ 0.3-1	~ 70
5e-14	~ 0.04-0.1	~ 350



Expected Number Counts:

Flux	N(50)	N(200)
1e-15	250-1500	
2e-15	150-500	300-1000
5e-15	50-150	200-600
1e-14	15-50	60-200
5e-14	2-5	8-20

< 50 photons
50-100 photons
100-500 photons
> 500 photons

With either survey strategy stacking will give mean spectra for galaxies in a given subset

N(50) = 50 deg^2 survey, 40 ks exp.
N(200) = 200 deg^2 survey, 10 ks exp.

Ancillary Data

- $F_X/F_{opt} \sim 10^{-2}$, only need to get to R ~ 22 for faintest X-ray detect galaxies
- “Value-added” spectra from SDSS gives stellar mass, SFR
- UV from GALEX and OM to get unobscured SFR, improve phot-z
- Spitzer IR would improve SFR estimate, help segregate LLAGN

Field Selection

- Field selection will be dominated by AGN and cluster requirements, but good SFR (FIR, UV, and/or optical spectra) and stellar mass (NIR) indicators would be nice
- SWIRE fields
- Pan-Starrs Medium Deep Survey
  - 10 fields, 7 sq. deg. FOV
  - Expected to detect ~ 15 tidal captures/year

Wide Field X-ray Telescope

- ~ 5" psf across 1 degree FOV, 6X Chandra area
- Proposed for 2007 NASA Mission Concept study but not accepted
- Awarded internal funds for initial development
- Key participants include Colin Norman (PI), Riccardo Giacconi, Steve Murray, Steve Allen, Niel Brandt, Piero Rosati, Roberto Gilli, Stefano Borgani, Paolo Tozzi
- Would perform 3 dedicated surveys, analogous to Galex (wide, medium, deep)
  - > 10^5 normal/SB galaxies would be detected

Summary

- Constant exp. time x solid angle will result in roughly same no. of galaxy detections (~ 500-1000)
- Main science goals would include
  - Determining local XLF of galaxies
    - Baseline for evolution
    - Energy density of hot ISM + binaries

Summary

- Deeper exposures would result in more galaxies with enough counts for crude spectral analysis (roughly 100 for 50 deg^2 / 40 ks survey)
  - Allow for determination of flux in soft band (often dominated by hot gas) vs. hard band (dominated by binaries) as fn. of galaxy parameters
  - Improved flux estimates (by factor of ~ 2) when at least hardness is known
- Stacking will give mean spectra for tens of subsamples

Pan-Starrs MDS

Filter	Bandpass (nm)	5σ, 1 yr	5σ, 3 yr
g	405-550	26.68	27.27
r	552-689	26.34	26.93
i	691-815	27.34	27.93
z	815-915	25.67	26.26
y	967-1024	24.23	24.82

Pan-Starrs MDS Fields

XMM-LSS
CDFS
IFA/Lynx
COSMOS
Lockman
NGC 4258
VISTA
EliasN1
Vimos4-DXS-SSA
DEEP2