A New Sample of "Normal" X-ray Emitting Galaxies



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X-ray emission from "normal" galaxies

- Working definition: galaxy X-ray emission not dominated by AGN
 - ie powered by:
 - Σ (galactic population: XRB, SNR, active stars, ISM ...)
 - star-forming phenomena: starburst wind + XRB/SNR ...
 - hot gas halo: "mini cluster" massive ellipticals
 - wide variety of phenomena
- X-ray emitting normal galaxies typically have
 - low luminosity $L_{\chi} \le 10^{42} \text{ erg s}^{-1}$
 - low surface density N ~ 1 deg⁻² at $f_X = 10^{-14}$ erg cm⁻² s⁻¹









X-ray emission from "normal" galaxies

- Previous studies: Einstein/EXOSAT/ROSAT
 - detailed studies of nearby galaxies (D<100 Mpc), typically optical selected
- XMM & Chandra sensitivity: detect normal galaxy X-ray emission to larger distances
 - z ~ 0.1 0.3 (typical XMM/Chandra observations)
 - eg Georgantopoulos 05: 28 galaxies; Kim 06 (ChaMP): 36/136 galaxies
 - z ~1 (deep Chandra observations)
 - Hornschemeier 03: 43 galaxies; Norman 04: ~100 galaxies; Ptak 07: 86 galaxies
 - deep surveys show galaxies make significant contribution to CXRB and number counts
 - provide new channel for constraining star formation history





X-ray emission from "normal" galaxies

- This project
 - use large sky coverage of 2XMM serendipitous
 X-ray catalogue: 350 sq.deg.
 - much larger sample possible: 450 galaxies
 - improved measurement of X-ray galaxy source counts and XLF at low redshift (*not yet complete*)
 - link to deep surveys
 - critical examination of selection methods & assumptions
 - separation of normal galaxies from AGN not simple
 - are deep field results correct?
 - key by-product: new samples of low luminosity AGN
 - LLAGN not well understood or characterised



2XMM: largest X-ray catalogue ever:

- ~200,000 sources
- $f_{\chi} \approx 10^{-15} 10^{-14} \text{ cgs}$
- A ≈ 350 sq.deg.





2XMM-DR6 sample

- 2XMM catalogue + SDSS DR6
 - 30% of 2XMM sources lie in SDSS DR6 region
 - Positional cross-match ⇒ ~27000 secure "photometric" SDSS matches
 - chance match rate ~few percent
- Overall ID fraction >50%, but strongly dependent on f_x
- >1500 matches have SDSS spectra (5.6%)
 - ~40% galaxies (ALG/NELG)
 - ~60% BL AGN
 - few percent stars







X-ray galaxy sample

- Select subsample from 2XMM-DR6 matches (483 XMM obs)
 - SDSS spectrum
 - NELG or ALG class: exclude BLAGN
 - galaxy morphology
 - $f_x/f_{opt} < -1$ (and $L_X < 10^{43}$)
 - include both galaxies & LLAGN examine distributions
 - sample not complete for $f_x < 2 \times 10^{-14}$ due to SDSS spectroscopic limit
 - exclude ext. X-ray sources & poor quality
 - ➡ 454 galaxies







Sample classification

- Classification methods
 - optical spectrum, morphology
 - line ratios, SED
 - X-ray spectrum, variability ...
- Primary classification using line ratios (BPT diagram)
 - distinguishes AGN- and HIIdriven emission processes
- Results using optical line ratios
 - 231 absorption line galaxies
 - almost all have emission lines, but too weak to classify reliably
 - dominated by early-types
 - 223 emission line galaxies
 - AGN & HII & composite





Sample properties

- Median z~0.08
- $L_{\rm X} \sim 10^{39}$ 3 x 10⁴² erg s⁻¹
- AGN predominantly have
 - $f_x/f_{opt} > -1$
 - $L_{\chi} > 10^{41} \text{ erg s}^{-1}$
- other types have ~flat distribution with f_x/f_{opt} and L_x
- note HII galaxies with $L_{\chi} < 10^{41}$ but high f_{χ}/f_{opt} : low mass galaxies

XMM-Newton









apparent correlation of f_x/f_{opt} with L_x due to selection effects

Is classification correct?

 X-ray hardness ratios indicate overall X-ray spectral shape: but HR errors

large



- Use binned & smoothed HR density plots to show main features
- Plots for whole sample show 2 maxima:
 - hard PL: typical of AGN & XRB
 - soft thermal: hot gas with $kT \sim keV$
 - & little evidence for absorbed spectra
 - average X-ray spectrum well correlated with fx/fopt & Lx



$L_{\rm X} < 10^{41}$







Is classification correct? X-ray HR results

Absorption line galaxies $\checkmark\checkmark$

- ALG dominated by soft emission at all L_x: consistent with soft thermal emission from hot gas halos of ellipticals
- AGN contamination low

AGN 🗸

- AGN dominated by hard emission at high L_{χ}
- less clear picture at low L_x
- weak evidence for absorbed sources

HII galaxies ? \checkmark

- Low L_x: two maxima consistent with hot gas and hard PL:
 - SB wind & XRB
- High L_X: unclear
 - several emission processes?
 - AGN contamination?

Composite galaxies \checkmark

- Low L_X: consistent with hot gas
 SB wind
- High L_x: ~consistent with hard PL
 AGN
- suggests 50:50 AGN/HII split



LLAGN

- LLAGN in sample have
 - narrow emission lines
 - typically hard X-ray spectra (exceptions at lower luminosity?)
- Nature
 - Seyfert 2?
 - expect significant X-ray absorption
 - NLS1?
 - possibly some interlopers with FWHM < 1000 km s⁻¹
 - Compton-thick AGN?
 - several candidates (next slide)
 - AGN with very weak broad lines?
 - XBONG











AGN: correlation of L_X & L_[OIII]





AGN: correlation of L_x & L_[OIII]



 $L_{\rm [OIII]}$ assumed to indicate $L_{\rm AGN}$ CT-AGN with $L_{\rm X}$ significantly belov correlation



Summary

- valuable new large sample of non-active & low-luminosity active galaxies from 2XMM-SDSS DR6 correlation
- robust classification difficult!
 - f_x/f_{opt} & X-ray HR selection minimise AGN contamination
 - but also rejects significant fraction of normal galaxies
 - several HII galaxies at low L_{χ} but high f_{χ}/f_{opt} : low-mass galaxies
 - probably AGN contamination of HII galaxies & ALG at higher L_{χ}
- Final tally:
 - normal galaxies ~70%↓ (ALG 50%, HII 20%); AGN ~30%↑
- Coming next: log N-log S and XLF
- LLAGN: do we understand why lines are narrow? Not all Sy2 ...



end

