Searching for X-ray luminous ‘normal’ galaxies in 2dFGRS

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Abstract. We cross-correlated the Chandra XASSIST and XMM-Newton Serendipitous Source Catalogues with the 2 degree Field Galaxy Redshift Survey (2dFGRS) database. Our aim was to identify the most X-ray luminous ($L_X > 10^{42}$ erg s$^{-1}$) examples of galaxies in the local Universe whose X-ray emission is dominated by stellar processes rather than AGN activity ('normal' galaxies) as well as to test the empirical criterion $\log(f_X/f_O) < -2$ for separating AGN from NGs. With XMM-Newton (Chandra) we covered an area of $\sim 8.2$ ($\sim 5.8$) deg$^2$ down to a flux limit of $\sim 10^{-15}$ ($\sim 1.6 \times 10^{-15}$) erg cm$^{-2}$ s$^{-1}$ and found 18 (20) 2dFGRS galaxies. Using emission-line intensity ratios, we classified 6 2dFGRS spectra as star-forming, H II nuclei, and 2 spectra as possible H II nuclei. The rest of the objects are absorption-line galaxies and AGN, including 3 possible LINERs. No luminous ‘normal’ galaxies have been found but out of 19 ‘normal’ galaxies in this sample 5 H II and 3 absorption-line galaxies have $\log(f_X/f_O) > -2$. We performed a similar search in two nearby-galaxy samples from the literature. All 44 galaxies in the Zezas (2001) sample have $\log(f_X/f_O) < -2$ and $L_X < 10^{42}$ erg s$^{-1}$. In the Fabbiano et al. (1992) sample, out of a total of 170 ‘normal’ galaxies, we found 16 galaxies with $\log(f_X/f_O) > -2$, the majority of which are massive ellipticals. Three of these have $L_X > 10^{42}$ erg s$^{-1}$.

Key words. X-rays: galaxies; Galaxies:starburst; Galaxies:active

1. Introduction

Galaxies hosting an active galactic nucleus (AGN) have long been known to be sources of copious amounts of X-ray emission. On the other hand, galaxies which are ‘normal’ (NGs), in the sense that they are not AGN dominated, have also been studied in detail. The source of X-ray emission in these systems is diffuse hot gas and/or X-ray binary stars. In the most massive early-type galaxies the X-ray emission is dominated by the hot interstellar medium with temperatures $kT \sim 1$ keV. A smaller fraction of the observed X-ray luminosity is due to low mass X-ray binaries associated with the older stellar population. In late-type galaxies, the X-ray emission originates in hot gas with temperature $kT \sim 1$ keV, which is heated by supernova remnants, as well as in a mixture of low and high-mass X-ray binaries (see Fabbiano, 1989, for a review). The diffuse hot gas contributes significantly in the soft X-ray band ($< 2$ keV) while the X-ray binary systems are responsible for the bulk of the emission at harder energies (e.g. Stevens et al., 2003). The integrated X-ray emission of ‘normal’ galaxies is believed to be a good indicator of the star-formation activity in these systems (e.g. Gilliland et al. 2004), at least if the star formation rate is not too low.

The X-ray luminosity of NGs is usually weak, $\lesssim 10^{42}$ erg s$^{-1}$, i.e. a few orders of magnitude below that of powerful AGN (Moran et al. 1999; Zezas et al. 1998). As a result, observed X-ray fluxes are faint and, until recently, only the very local systems (< 100 Mpc) were accessible to X-ray missions. With the new generation of X-ray missions, Chandra and XMM-Newton, the situation has changed dramatically. The Chandra Deep Fields North and South (CDF-N, CDF-S; Alexander et al. 2003; Giacconi et al. 2002) have reached fluxes $f(0.5 - 2.0$ keV) $\sim 10^{-17}$ erg cm$^{-2}$ s$^{-1}$, thus providing the first ever X-ray selected sample of NGs at cosmologically interesting redshifts. Using the 2Ms CDF-North Hornschemeier et al. (2003) provided a sample of 43 NG candidates for which optical spectroscopic observations are available. These galaxies have X-ray–to–optical flux ratios $\log(f_X/f_O) \lesssim -2$, which these authors use as an empirical boundary, separating quiescent NGs from AGN. Norman et al. (2004) extended this study and identified over 100 NG candidates in the combined CDF-N and CDF-S, although op-
tical spectroscopic data are available only for a fraction of these objects. However, these authors have included NGs with \( \log(f_X/f_O) > -2 \). On the other hand, Georgakis et al. (2003) and Georgakis et al. (2004) have identified NGs with \( \log(f_X/f_O) \approx -2 \). Within the framework of the ‘Needles in the Haystack Survey’ (NHS) and Georgantopoulos et al. (2005) combined XMM-Newton data with the Sloan Digital Sky Survey and used several selection criteria, including \( \log(f_X/f_O) < -2 \), to identify 28 NG candidates. By combining this sample with 18 at \( z < 0.2 \) galaxies from the CDFs these authors constructed the first local X-ray luminosity function of NGs. However, this result depends crucially on the completeness of NG samples, which, in turn, may be biasing to quiescent systems and selecting against X-ray luminous (with X-ray luminosities \( L_X > 10^{42} \text{erg s}^{-1} \)) starbursts and massive ellipticals, which are likely to show \( -2 < \log(f_X/f_O) < -1 \) (Alexander et al. 2003). Indeed, the local luminosity function of Georgantopoulos et al. (2005) agrees well with that of Norman et al. (2004) at the faint end but disagrees at the bright end. If bright galaxies are missed due to the \( \log(f_X/f_O) < -2 \) criterion, this might explain the discrepancy. Alternatively, the Norman et al. (2004) may suffer from AGN contamination.

It is thus imperative to understand the significance of this bias and to resolve the controversy in order to constrain the local luminosity function, which also provides a local ‘anchor point’ for investigating luminosity function evolution.

In the work described in this paper we searched for luminous NGs by performing a cross-correlation between, on the one hand, two large X-ray catalogues, and, on the other hand, the 2 degree field galaxy redshift survey (2dFGRS). Our aim was twofold:

1. to search for X-ray luminous \( (L_X > 10^{42} \text{erg s}^{-1}) \), especially star-forming galaxies, and
2. to test the empirical criterion \( \log(f_X/f_O) < -2 \) for separating NGs from AGN so as to address the discrepancy described above.

Throughout this paper we use a Hubble parameter \( H_0 = 72 \text{ km s}^{-1}\text{Mpc}^{-1} \), matter density \( \Omega_M = 0.3 \) and a cosmological constant \( \Omega_X = 0.7 \).

2. Data

2.1. 2dFGRS data

The 2dFGRS is a joint UK-Australian project, which obtained spectra for 245,591 objects brighter than a nominal extinction-corrected magnitude limit of \( b_J = 19.45 \) over an area of \( \approx 1500 \text{ deg}^2 \). This survey is fairly uniform with a known incompleteness at the bright end \( (b_J \approx 16, \text{Norberg et al. 2002}) \). Reliable redshifts were obtained with the aim of providing a detailed three-dimensional picture of galaxy population and large scale structure in the local Universe (Colless et al. 2003 2001). We used heliocentric corrected redshift values given in the FITS headers of the 2dFGRS spectra. The galaxies are selected from the extended APM Galaxy Survey in three regions: a strip near the north galactic pole, a strip near the south galactic pole and random fields around this.

For our purposes the 2dFGRS presents the advantage that its depth allows detection of galaxies up to \( \log(f_X/f_O) \lesssim -1 \) for \( f_X \approx \text{few} \times 10^{-14} \) (see Fig. 2).

2.2. XMM-Newton observations

We used XMM-Newton archival observations from the XMM-Newton Serendipitous Source Catalogue, Version 1.1.0, (1XMM), whose fields overlap with those from the final data release of the 2dFGRS. The catalogue contains more than 50,000 single sources in a total of 585 fields. Specifically, we have cross-correlated the celestial coordinates (right ascension and declination, J2000) of sources in the two data sets in order to detect optical and X-ray counterparts. The cross-correlation was performed independently for each of the three CCDs of the EPIC camera because in some cases a source may not have been recorded in all three CCDs. The X-ray band was restricted to \( 0.5 - 2.0 \text{ keV} \) as galaxies are preferentially soft X-ray emitters (e.g. Levenson et al. 2001). We set the detection likelihood parameter to \( \gtrsim 7 \) and the matching radius to \( 6'' \). This corresponds to \( \approx 3\sigma \) in terms of on-axis XMM/EPIC positional uncertainty. Off-axis sources suffer from vignetting and such sources will have increased positional uncertainty. This is further increased for sources whose X-ray emission is dominated by an off-nuclear component.

We obtained 18 sources which have been detected both by 2dFGRS and by XMM/EPIC. The sources are detected in 42 XMM-Newton fields. The area covered for this sample is \( \approx 8.2\text{deg}^2 \) to a flux limit of \( \approx 10^{-15} \text{ erg cm}^{-2} \text{ s}^{-1} \). The largest separation between an X-ray and an optical position in this sample is \( 5.1'' \). All X-ray/optical counterparts were checked visually. For all sources we estimate the probability of detecting an optical counterpart by chance to be less than 1% for all sources. These 18 X-ray/optical pairs form our XMM-Newton–2dFGRS correlation sample.

We calculated X-ray fluxes, \( f_X \), after taking into account the column density of Galactic neutral hydrogen, \( N_H \), along the line of sight to each observed source. Further, we calculated the X-ray luminosity, \( L_X \), by using source redshifts, \( z \), and X-ray fluxes, assuming power law spectra with a photon index \( \Gamma = 1.8 \).

We obtained hardness ratio values, HR, from the 1XMM catalogue, using unvignetted count rates in the energy bands 0.5-2.0 keV (S) and 2.0-4.5 keV (H), so that

\[
HR \equiv \frac{H - S}{H + S}.
\]

Details of our XMM-Newton–2dFGRS correlation sample are given in Table 4.
2.3. Chandra observations

We used Chandra archival observations from the Chandra X-ray catalog and the Chandra X-ray catalog to compare the results with the Chandra X-ray results. Table 2 shows the Chandra observations and the XMM-Newton observations. The Chandra observations were used to compare the results with the XMM-Newton observations. The results were obtained using the Chandra X-ray catalog and the Chandra X-ray catalog. The Chandra observations were used to compare the results with the XMM-Newton observations.

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3. Classification of sources

In what follows we refer to the XMM-Newton and Chandra correlation samples together as ‘the 2dFGRS correlation sample’. We now describe our approach for identifying NGs in this sample.

For optical spectra it has been shown that empirical emission-line intensity ratios may be used as a diagnostic of AGN activity (BPT diagrams, Baldwin et al., 1981). We adopted the classification scheme of Ho et al. (1997), which is based on the diagnostic diagrams proposed by Veilleux & Osterbrock (1987). Ho et al. (1997) used the line ratios [O III] 5007/Hβ, [O I] 6300/Hα, [N II] 6583/Hα and [S II] 6716, 6731/Hα, which are least sensitive to dust reddening and flux calibration because the wavelength separation between members of each line pair is small. Additionally, since the ratios involve a line of only one element and an H I Balmer line, they are less abundance-sensitive. We used this as our primary method of classification. Unfortunately, absolute flux calibration for 2dFGRS fibres, which can differ substantially in their throughput, cannot be done reliably. For this reason we were unable to perform subtraction of stellar templates which depends crucially on the shape of the galaxy spectrum. As a result, we only classified galaxies as ‘normal’, or otherwise, when all four of the line-intensity ratios unambiguously suggested this. If only some lines were observable, the classification is only tentative. This is denoted by a question mark after the type entry in the sample tables. Finally, some spectra were tentatively classified as LINERS, according to the classification criteria of Ho et al. (1997).

In the case of sources 1, 2, 4 and 6 from the Chandra-2dFGRS correlation sample the above method failed. Using the tool PIMMS1, we carried out tests to estimate the hydrogen column density needed to obtain the observed hardness ratio, assuming the source flux and redshift, as well as a power law spectrum with photon index around $\Gamma = 1.8$. Our tests showed that for all sources $N_\text{H} > 10^{22}$, suggesting obscured AGN as indicated in Table 2. However better optical observations are needed to clarify the situation further, for the following reasons. For source 1 the spectrum is of poor quality, whilst the Hα line is not covered. For source 2, the Hα and [N II] lines appear suppressed but it is unclear whether this has a physical origin or is a data reduction artefact. For source 4, there is a hint of a broad Hα line, which only partially falls within the 2dFGRS spectrum. In the case of source 6, the Hα line appears absorbed and the [N II] line falls outside the spectrum.

The emission-line ratio method also failed for sources 17 and 19. However, as the optical spectra of these sources show very broad Hα or Hβ emission lines (> 1000 km s$^{-1}$), the sources were also classified as AGN, and this is indicated in Table 2.

Further, in order to separate NGs from AGN, it is often assumed that for NGs, the X-ray–to–optical flux ratio obeys log($f_X/f_O$) $< -2$, i.e. is two orders of magnitude lower than for typical AGN. The X-ray luminosity is similarly assumed to obey $L_X \lesssim 10^{42}$ erg s$^{-1}$ (Fabbiano, 1989).

For the 2dFGRS correlation sample we estimated log($f_X/f_O$) from the relation

$$\log \frac{f_X}{f_O} = \log f_X (0.3 - 3.5\text{keV}) + 0.4V + 5.37$$

(2)

(Stocke et al., 1991). The X-ray flux for this relation was calculated from the 0.2–8.0 keV (0.5–2.0 keV) flux of our XASSIST (1XMM) dataset, assuming a power law index $\Gamma = 1.8$. The V magnitude was calculated from the $b_j$ magnitude listed in the 2dFGRS database and used to select the objects optically. The conversion was performed using the relations

$$b_j = B - 0.28(B - V)$$

(3)

which holds for the 2dFGRS galaxies and

$$B - V = 0.53$$

(4)

(Fukugita et al., 1995, Table 3a). This is the average $B-V$ value for nearby galaxies with types in the range Sab, Sbc, Scd and Irr.

We stress that we did not use either $L_X$ or log($f_X/f_O$) to classify sources. On the contrary, as explained above, where possible we first classified sources as NGs or AGN using optical criteria. Subsequently, we used $L_X$ to look for luminous NGs and checked whether the classification agreed with the empirical AGN/NG break at log($f_X/f_O$) $\sim -2$.

4. Results and discussion

Results for the 2dFGRS correlation sample are summarised in Tables 1 and 2. We found six NGs, which fall under the category of H II nuclei, and two tentative H II nuclei. Five galaxies are classified as AGN, and three as tentative AGN. There are eleven absorption line, presumably elliptical, galaxies, for which the $L_X$, log($f_X/f_O$) and HR values, considered together, suggest that these are also not AGN-dominated. A further three sources are tentatively classified as LINERS. For the rest of the galaxies there is not enough information to make even a tentative classification. As can be seen in Tables 1 and 2 all ‘non-A’ NGs have log $L_X < 42$. In that sense, no luminous star-forming galaxies have been found. However, four of the H II nuclei,
Table 3. NGs with log($f_X/f_{\odot}$) > −2. Groups of rows separated by horizontal lines correspond to the sample indicated in the first column. 2dFGRS stands for the combined correlation samples 2dFGRS–XMM-Newton and 2dFGRS–Chandra. Each row corresponds to the NG type indicated in the second column. Each of the last three columns gives the fraction of NGs with log($f_X/f_{\odot}$) > −2 in the log $L_X$ region indicated at the top of the column. Note that the second of these columns includes NGs from the log $L_X$ < 42 column which also have log $L_X$ > 41. Thus the numerator gives the number of NGs of a given type in a given sample and a given log $L_X$ range, and the denominator the total number of NGs in the same sample and log $L_X$ range. Galaxies for which only upper limit information is available have not been taken into account. Empty entries indicate that no NGs of this type have been found. Galaxy labels are as in tables 2 and 1. Additionally, sb stands for starburst and E for elliptical.

| Sample       | NG type | log $L_X$ < 42 | 41 < log $L_X$ < 42 | log $L_X$ ≥ 42 |
|--------------|---------|----------------|---------------------|---------------|
| 2dFGRS       | H ii    | 4/18           |                     |               |
|              | H ii?   | 1/18           |                     |               |
|              | A       | 2/18           | 2/2                 | 1/1           |
| Zezas (2001) | any     | 0              | 0                   | 0             |
| Fabbiano et al. (1992) | sb | 2/167         | 1/26                |               |
|              | E       | 11/167         | 11/26               | 3/3           |

![Fig. 1](image.png)

**Fig. 1.** Plot of log($f_X/f_{\odot}$) versus log $L_X$. Plotted here are values calculated from our XMM-Newton and Chandra data, as well as from the literature (see legend in the plot). For all samples only galaxies which are classified as H ii or absorption-line are plotted. All luminosities are for the same energy band (0.5 – 2.0 keV). The two dashed lines demarcate the regions of log($f_X/f_{\odot}$)–$L_X$ space which may be inhabited mainly either by NGs (log $L_X$ < 42, log($f_X/f_{\odot}$) < −2) or by AGN. The dash-dotted line indicates an estimate for log($f_X/f_{\odot}$) from low mass X-ray binaries in a 10$^{11}$ $M_\odot$ galaxy (see text).

A plot of log($f_X/f_{\odot}$) versus $L_X$ is shown in Fig. 1. Apart from our XMM-Newton and Chandra results, for comparison and completeness purposes we have plotted data from the following sources:

1. The nearby star-forming galaxy sample compiled by Zezas (2001). This comprises 44 galaxies detected by ROSAT PSPC, spanning the luminosity range $L_X(0.1 – 2.4$ keV) $\approx 4 \times 10^{37} – 3 \times 10^{41}$ erg s$^{-1}$. Galaxies in this sample have been classified on the basis of high quality nuclear spectra from Ho et al. (1997).

one of the tentative H ii nuclei, as well as three absorption-line galaxies have log($f_X/f_{\odot}$) > −2 (Table 3), i.e., overall, ~ 40% of NGs found appear to have log($f_X/f_{\odot}$) > −2.
2. The nearby galaxy sample of Fabbiano et al. [1992].

The galaxies have been observed with the Einstein observatory and comprise all morphological types. Galaxies flagged as AGN hosts in the original sample have been excluded. We have also carried out a further literature search to exclude more AGN from the final plotted sample. Galaxies for which only upper limit \( f_X \) and \( L_X \) information is available are plotted with downward-pointing arrows. We used the \( L_X \) values from Fabbiano et al. [1992], after scaling for \( H_0 = 72 \) km s\(^{-1}\) Mpc\(^{-1}\). The log(\( f_X/f_O \)) values plotted were computed as explained in Section 3 using the 0.2–4.0 keV flux and \( B \) magnitude information from Fabbiano et al. [1992], and \( B - V = 0.655 \). The latter is the average \( B - V \) value for nearby galaxies of all morphological types (Fukugita et al. 1993 Table 3a).

There is a clear correlation between the quantities plotted in the figure. From the relation \( L_X \sim L_B^{0.8} \) (Fabbiano et al. 1992) we would indeed expect a correlation of the form, roughly, \( \log(f_X/f_O) \sim 0.5 \log L_X \) as is the case in this plot.

The observed correlation shows that log(\( f_X/f_O \)) reaches values significantly higher than \(-2\) as \( L_X \) becomes higher than \( \log L_X \approx 41 \). Thus, any survey for NGs which uses a log(\( f_X/f_O \)) < \(-2\) cut is likely to suffer from incompleteness at the brightest luminosities. Although none of our samples can be said to be statistically complete, we may assume that galaxies from different populations are randomly selected. To assess the incompleteness we give in Table 4 the fraction of NGs in three \( L_X \) regions per NG type and sample. Only NGs with log(\( f_X/f_O \)) > \(-2\) are included. Galaxies for which only upper limit values are available are not used.

From Fig. 1 and Table 4 it is clear that all galaxies in the sample of Zezas [2001] have both \( \log L_X < 42 \) and log(\( f_X/f_O \)) < \(-2\). However, in the sample of Fabbiano et al. [1992] there is a number of galaxies for which log(\( f_X/f_O \)) > \(-2\).

Specifically, as can be seen from Table 4 there are 13 galaxies from this sample, for which log(\( f_X/f_O \)) > \(-2\) and \( \log L_X < 42 \). All but one of these galaxies have \( 41 < \log L_X < 42 \). About 15% are starbursts (2/13) and the rest massive ellipticals, brightest in a group (BGGs) or cluster (BCGs). In the \( \log L_X > 42 \) region, there are 3 galaxies with log(\( f_X/f_O \)) > \(-2\). Two of these are massive elliptical BGGs and the third is a CD BCG.

It is instructive to investigate how many galaxies with \( \log L_X > 42 \) we should expect to detect, given our survey’s flux limit and area covered. We used our flux limits and log(\( L_X \)) > 42 to integrate the local X-ray luminosity function of NGs (Georgantopoulos et al. 2003). We found that we would expect to see \( \lesssim 1 \) galaxy with each telescope. In the 2dFGRS correlation sample there is a single absorption line galaxy at \( \log L_X = 42 \), which is a good NG candidate. There is thus good order of magnitude agreement between our simple estimate and actual results.

It is also useful to compare observed values of log(\( f_X/f_O \)) to the numbers expected due to low mass X-ray binaries (LXRBs), whose combined luminosity has been shown to scale with the stellar mass of the host galaxy (Gilfanov 2004). We estimated the value of log(\( f_X/f_O \)) expected for a \( 10^{11} M_\odot \) galaxy, using the \( L_X\langle \text{LXRB}\rangle - M_\ast \) and \( M_\ast/L_K(B-V) \) correlations from Gilfanov [2004] (Figure 14 and Equation 2, respectively). We used the average value of \( B-V \) for all galaxies in our paper, and the average value of \( V-K \) for all galaxy types from Mannucci et al. (2001). We obtained the value log(\( f_X/f_O \))\langle \text{LXRB} \rangle = -3.8, shown by the dot-dashed line in Figure 1. The bulk of the points in this plot fall above this line, suggesting that this value is a good estimate for a lower log(\( f_X/f_O \)) estimate.

Our sample is by no means complete. In Figure 2 we plot \( b_j \) magnitude against 0.5–2.0 keV flux for all galaxies in the 2dFGRS correlation sample. The solid oblique lines show \( f_X - b_j \) loci for different values of log(\( f_X/f_O \)). Our galaxies are split in approximately equal numbers among the regions demarcated by the constant log(\( f_X/f_O \)) lines. The dashed horizontal line shows the 2dFGRS magnitude limit at \( b_j = 19.45 \). The dashed-dotted vertical line shows the approximate flux limit of our correlation sample. It is clear that, to this limit, our survey misses galaxies in the region \( -2 < \log(f_X/f_O) < -1 \), where luminous NGs are likely to be found. Such galaxies would not be missed only at a higher flux limit, \( \sim 2 \times 10^{-14} \) erg cm\(^{-2}\) s\(^{-1}\). Furthermore, for galaxies brighter

![Fig. 2. Plot of \( b_j \) magnitude versus logarithmic X-ray flux for all galaxies in Tables 1 and 2. The region to the right of the line log(\( f_X/f_O \)) = −1 is expected to be occupied mainly by AGN. NGs are expected to be found mainly in the region to the left of the line log(\( f_X/f_O \)) = −2.](image-url)
than $b_j \sim 16$, saturation effects affect the completeness of $2dFGRS$ \cite{Norberg2002}. The $2dFGRS$ sample also suffers from increasing incompleteness as log $L_X$ increases. Table 3 shows that the fraction of NGs with log$(f_X/f_o) > -2$ rises from $\sim 8\%$ (13 out of 167 galaxies) below log $L_X = 42$ to 100$\%$ above log $L_X = 42$ (3 out of 3 galaxies). For log $L_X < 42$ the majority of NGs with log$(f_X/f_o) > -2$ are massive ellipticals and for log $L_X \geq 42$ all are of this type. Although the $2dFGRS$ correlation sample has fewer galaxies, it is clear that, at least at the highest luminosities, there is a similar pattern, with absorption line galaxies making up the bulk of NGs with log$(f_X/f_o) > -2$. We note, however, that, considering all $L_X$ regions together, the fraction of NGs with log$(f_X/f_o) > -2$ in the $2dFGRS$ correlation sample is much higher than in the \cite{Fabbiano1992} sample ($\sim 40\%$ versus $\sim 9\%$). This may suggest that the $2dFGRS$ correlation sample may suffer from residual AGN contamination. Furthermore, as mentioned in Section 4 this sample suffers from incompleteness at bright optical magnitudes.

Considering all samples, a picture is thus emerging in which the log$(f_X/f_o) < -2$ criterion selects against the brightest ellipticals, but is not inadequate for other morphological types. However, the ellipticals in question, although ‘normal’ in the sense that they do not host an AGN, belong to a distinct sub-class with respect to star-forming galaxies, as well as other ellipticals: these galaxies are found in the centres of X-ray bright groups or clusters. Such systems are affected significantly by their environment. For instance, they are, on average, considerably more luminous than normal ellipticals. Furthermore, group dominant galaxies have been shown to have temperature profiles indicative of central cooling \cite{Helsdon2000}, leading to the suggestion that their halos are actually the product of cooling flows associated with the surrounding group.

The significance of the findings from the $2dFGRS$ correlation samples is unclear, given the uncertainty in morphological type and diagnostic emission line ratios. Furthermore, classification of $2dFGRS$ galaxies which remain unclassified in this work would make the current picture more clear. However, flux calibrated spectra of higher signal-to-noise ratio over the full wavelength range, covering all diagnostic emission lines, are necessary for this to be achieved.

From a different perspective, we note that we found no confirmed AGN with log$(f_X/f_o) < -2$. Regardless of any completeness problems, this shows that the NHS surveys \cite{Georgakakis2004}, \cite{Georgantopoulos2003} are at least not significantly contaminated by AGN.

5. Summary

We compiled a sample of galaxies observed with XMM-Newton and Chandra for which there are optical spectral observations in the $2dFGRS$. We looked for X-ray luminous ($L_X > 10^{42}$ erg s$^{-1}$) NGs and assessed the empirical criterion log$(f_X/f_o) < -2$ for separating NGs from AGN. Our main results are:

1. No luminous NGs were found.
2. Five H II galaxies and three absorption-line galaxies have log$(f_X/f_o) > -2$.

We also carried out the same type of search in two samples from the literature. In the \cite{Zezas2003} sample all galaxies have log $L_X < 42$ and log$(f_X/f_o) < -2$. In the \cite{Fabbiano1992} sample, there are two starbursts and fourteen ellipticals with log$(f_X/f_o) > -2$. This translates to an incompleteness of $\sim 8\%$ (100$\%$) for log $L_X < 42$ (log $L_X \geq 42$).

Considering all samples, we thus find that the log$(f_X/f_o) < -2$ criterion seems to select primarily against the brightest, massive ellipticals (BCGs and BGGs).

Further, we also find that the great majority of our galaxies have log$(f_X/f_o) > -3.8$ which represents an estimate for the contribution of LXRBs to the X-ray luminosity of galaxies.

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