An XMM-Newton spectral survey of 12 micron selected galaxies. II. Implications for AGN selection and unification

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ABSTRACT

We present a multi-waveband analysis of a 126 galaxy sub-sample of the 12 micron galaxy sample (12MGS), for which we have carried out a detailed X-ray spectral analysis of in a previous paper. We determine the activity class of the galaxies by way of optical line ratio diagnostics and we characterise the optical classes by their X-ray, 12 $\mu$m and [O III] luminosities and by their X-ray spectral properties. Our most interesting results from this investigation are as follows: (i) Seyfert (Sy) 1s and Sy 2s show a significantly different X-ray luminosity distributions from each other (ii) Sy 2 galaxies with a detection of an HBLR show a significantly higher X-ray luminosity than those without a detection, supporting the findings of Tran (2003) (iii) Sy 1s also present a significantly different 12 $\mu$m luminosity distribution from both intermediate Sy types and Sy 2s (iv) the Seyfert 2 fraction decreases towards high X-ray luminosities (v) X-ray indications of AGN power agree well with the optical classifications (vi) There is X-ray evidence for the presence of an AGN in 17% of H II/AGN composite galaxies and 40% of LINERs (vii) we advocate the use of a 2-10 keV X-ray luminosity of $10^{41}$ erg s$^{-1}$ in the X-ray selection of AGN, rather than $10^{42}$ erg s$^{-1}$, which we find gives a contamination rate of only 3% from star-forming galaxies. (viii) from an analysis of the X-ray power-law index, $\Gamma$, we find that Sy 1s and Sy 2 have the same intrinsic distributions, implying that the central engines are the same, in support of AGN unification schemes (ix) We confirm previous work showing that the obscured fraction in AGN declines at high X-ray luminosity, but also find a decrease at low luminosity having peaked at $L_X \sim 10^{42}$ erg s$^{-1}$, suggesting that source luminosity has a large effect on the obscuring material, therefore also calling for a modification to unified schemes (x) We confirm previous work showing that the obscured fraction in AGN declines at high X-ray luminosity, but also find a decrease at low luminosity having peaked at $L_X \sim 10^{42}$ erg s$^{-1}$, suggesting that source luminosity has a large effect on the obscuring material, therefore also calling for a modification to unified schemes (xi) The average obscured and Compton thick fractions for this sample are 62 $\pm$ 5% and 20 $\pm$ 4% respectively, which are higher than hard X-ray and optically selected samples, therefore supporting mid-infrared (MIR) selection as a relatively unbiased method of selecting AGN (xii) we assess the use of the ‘T’ ratio ($F_X/F_{[OIII]}$) for selecting Compton thick candidates. We conclude here that this quantity can often be unreliable due uncertainties in the extinction corrections to the [O III] flux. These results have important impacts on AGN selection and unification and the results from the 12MGS are particularly useful as a local analogue to Spitzer/MIPS 24 $\mu$m samples selected at $z=1$, as observed 24 $\mu$m emission originates at rest-frame 12 $\mu$m in sources at this redshift.

Key words: galaxies: active - galaxies: Seyfert - X-rays: galaxies

1 INTRODUCTION

There are currently ongoing debates in astrophysics concerning many aspects of nuclear activity in galaxies. It has

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become widely accepted though, that most massive galaxies harbour a super-massive black hole in their nuclei \citep{Kormendy1988, Magorrian1998}, and that this component is central to the growth and evolution of the host galaxy itself \citep[e.g.][]{Ferrarese&Merritt2000,Gebhardt2000}. It is believed that accretion of matter onto these black holes is the energy source for what we know as active galactic nuclei (AGN). The term ‘active’ when applied to the nucleus of a galaxy is historically quite general and describes a nucleus which displays characteristics which cannot be attributed to normal stellar processes. This can be highly wavelength dependent and as such, the identification of AGN depends on the wavelength regime used. A prime example is NGC 6240, which was identified as an AGN from its X-ray luminosity, which exceeds any X-ray luminosity observed from pure star-forming galaxies \citep{Schulz1998}, but does not appear as an AGN in the optical. These types of AGN, which do not show themselves at all wavelengths, can be called ‘hidden’ AGN. AGN activity continues to be uncovered in previously thought of normal galaxies, such as with the use of MIR high excitation lines \citep[e.g.][]{Goulding&Alexander2009} or high spatial resolution X-ray imaging \citep[e.g.][]{Grier2010}. It is thus important to investigate the identification technique which selects AGN most completely.

AGN also appear in many different types, ranging from low ionisation nuclear emission-line regions (LINERs, \citealt{Heckman1980}) to quasars, and attempts have been made to unify these types into a single scheme. The most successful unification scheme explains the difference between the different Seyfert types by the orientation of the observer with respect to a circumnuclear structure of dust, now commonly believed to be a torus \citep{Antonucci1993,Urry&Padovani1995}. This scheme has held up well, owing to it simplicity, but has come under increasing pressure of late. For example, there is increasing evidence and supporting theoretical work to suggest that at low luminosity and/or accretion rate, AGN appear differently from their higher luminosity counterparts \citep[e.g.][]{Laor2003, Nicastro2003, Tran2003, Elitzur&Shlosman2006, Hopkins2009}. LINERs may also be accounted for in part by these low luminosity AGN models, but a concensus on the power generation mechanism in LINERs has not yet been achieved. Obscuration in AGN may also be dependent on luminosity, as has been found in several studies at high luminosity \citep[e.g.][]{Ueda2003}, but also suggested at low luminosity \citep{Akylas&Georgantopoulos2009, Zhang2009, Burlon2010}. This has important consequences for the current AGN unification paradigm, which attributes the sole difference between different AGN types to the orientation with respect to the observer.

To investigate the issues of AGN selection and unification, large, statistically complete galaxy samples are required. Most of these are based on flux limited surveys, for example the Revised Shapley-Ames Catalogue of Bright Galaxies (RSA, \citealt{RSA1979}) or the CfA sample \citep{Huchra&Burg1992}, both selected in the optical. Optical selection, however, is largely affected by extinction, presenting a bias against reddened sources. Galaxy samples selected at wavelengths less affected by extinction are thus optimal. Hard X-ray (>10 keV) surveys are ideal for avoiding biases against obscuration as at these wavelengths only the heaviest obscuration attenuates them. Current sensitivity at these wavelengths provided by the Swift/BAT and INTEGRAL surveys produces samples of sources down to $L_{\text{X}} \sim 10^{37}$ erg s$^{-1}$ \citep[e.g.][]{Tueller2008, Beckmann2009, Tueller2010, Cusumano2010}, and thus do not contain the lowest luminosity systems.

An alternative wavelength for AGN selection is the mid-IR, where the primary radiation of the AGN is re-emitted after having been reprocessed by hot dust. The extended IRAS 12 micron galaxy sample \citep[12MGS -][]{Rush1993, Spinoglio1993} is a sample of 893 MIR selected local galaxies which contains a high fraction of AGN (13% at the time of publication, RMS). The sample is taken from the IRAS Faint Source Catalogue, version 2 (FSC-2) and imposes a flux limit of 0.22 Jy, including only sources with a rising flux density from 12 to 60 microns (to exclude stars) and with a galactic latitude of $|b| \geq 25$ deg. Being selected in the mid-infrared (MIR) this sample is also relatively unbiased against absorption, low luminosity systems and ‘hidden AGN’. \cite{Spinoglio&Malkan1989} showed that a wide variety of AGN types emit a constant fraction of their bolometric luminosities at this wavelength, and furthermore shown to be true for star forming galaxies as well by \cite{Spinoglio1995}. The 12MGS should therefore also be representative of the true number of different active galaxy types in relation to each other and thus ideal for population statistics.

Empirically, 12 micron selection appears to be relatively unbiased with respect to extinction. However, it is expected theoretically that 12 $\mu$m emission is suppressed in heavily obscured AGN. In the radiation transfer models of \cite{Pier&Krolik1992}, the authors investigate the infrared emission of centrally illuminated smooth dust tori, thought to exist in AGN. A main conclusion of this is that these dust tori do not emit isotropically in the mid-IR, and that emission in the ‘face-on’ direction is greater than that in the ‘edge-on’ direction. This has important consequences for our work, as it would suggest that 12 $\mu$m selection is biased against these edge on systems. Alternatively, much support has been gained recently for a ‘clumpy’ torus in AGN, where the dust distribution is not smooth, but instead made up of individual clouds \citep[e.g.][]{RamosAlmeida2009, Honig2010, Mullaney2011, Nenkova2008} present a model describing the infra-red emission of such a torus and find that at 12 $\mu$m, and at all IR wavelengths, the torus emission is isotropic, in contrast to the smooth torus models. A key observational test of this would be the ratio of the X-ray to mid-IR fluxes, which should be higher for heavily absorbed systems in smooth torus distributions, when absorption in the X-ray band has been accounted for, due to the higher mid-IR emission in the face-on systems. The models of \cite{Pier&Krolik1992} predict an order of magnitude difference in the 12 $\mu$m flux for an increase in the $N_{\text{H}}$ from $\sim 10^{23}$ to $\sim 10^{24}$ for a torus seen edge on. \cite{Horst2008}, however, show that Seyfert 1s, Seyfert 2 and even Compton thick AGN show the same tight correlation between their X-ray and mid-IR fluxes, which supports the clumpy torus model over the smooth one. They also rule out any contamination of the mid-IR flux from the host galaxy by using high resolution, adaptive optics assisted, 12.3 $\mu$m imaging, isolating the torus spatially. These results are in support of 12 $\mu$m being a relatively unbiased selection method for AGN.

In this paper, we aim to broadly investigate the nuclear activity in local ($z < 0.1$) galaxies, using the 12MGS
as a relatively unbiased and representative parent sample. We base this investigation on a sub-sample of 126 galaxies in the 12MGS which we presented in a previous publication (Brightman & Nandra 2010, paper I hereafter). This sub-sample consists of all galaxies in the 12MGS for which an XMM-Newton observation was available as of December 2008 (which included serendipitous observations of NGC 0214, 4559 and 7771), and for which the X-ray spectrum could be at least fitted with the most basic spectral model. For more details regarding the X-ray observations and spectral analysis, the reader is referred to paper I. In paper I, we presented a detailed X-ray spectral analysis of these galaxies, assessing the intrinsic luminosity, $L_X$, the photon index, $\Gamma$ and the line of sight absorption, $N_H$, which are key parameters for our investigation here. We start in Section 2 where we uniformly classify the activity type in our sample using optical emission line data from the literature and BPT (Baldwin, Phillips & Terlevich 1981) diagnostics. Secondly in Section 3 we characterise the different optical types in 2-10 keV, 12 $\mu$m and [OIII] luminosities and in Section 4 we investigate the X-ray properties of these types, including the continuum slope, $\Gamma$ and the obscuration, $N_H$. Finally in Section 5 we investigate the relationship between the X-ray and MIR emission in this sample. We discuss these results within the context of AGN selection and unification in Section 6 and present our conclusions in Section 7.

## 2 OPTICAL EMISSION LINE ACTIVITY CLASSIFICATION

In paper I we used an observed 2-10 keV X-ray luminosity of $10^{42}$ erg s$^{-1}$ to identify unambiguous AGN activity in our sample. This method is clearly very crude as it will miss all low luminosity AGN. The classical method of defining activity type is via so called BPT diagrams which use the ratios of optical emission lines to determine the dominant source of ionising radiation of emission line galaxies, be it photo-ionisation by stars, by a harder non-thermal source such as an AGN or by collisional excitation by shocks, may be the case in LINERs. Here we apply such a scheme in order to investigate the X-ray properties of the various optical types.

We use the scheme of Kewley et al. (2006) to classify the galaxies in our sample from optical narrow line emission (Fig. 1). This scheme uses theoretical 'maximal starburst' lines from Kewley et al. (2001) which are derived from stellar population and photoionisation models and define the limit of 'pure' stellar photoionisation. Any sources which lie above these lines are likely to be photoionized by another source of ionization such as an AGN or shocks. This scheme relies on three diagrams, diagram (1) using [OIII]/H$\beta$ vs. [NII]/H$\alpha$, diagram (2) using [OIII]/H$\beta$ vs. [SII]/H$\alpha$ and diagram (3) using [OII]/H$\beta$ vs. [O I]/H$\alpha$. They also define a region of composite 'starburst/AGN' activity on diagram 1, which lies below the theoretical starburst limit, but above an empirically defined pure-starburst limit (Kauffmann et al. 2003).

They argue that since the [NII]/H$\alpha$ ratio is most sensitive to the presence of an AGN due to the ratio "saturating" at high metallicities, which exist in extreme H II galaxies, any source beyond the pure starburst limit must contain an AGN. On diagrams 2 and 3, they derive new empirical separation lines between Seyfert 2s and LINERs using high signal-to-noise SDSS data, which show distinct branches on these diagrams, belonging to these emission line galaxy types.

We have obtained narrow line ratios from a compilation of unpublished data from Rodriguez et al. (in preparation) for 70 of the galaxies in our sample of 126 sources. For the rest, where they exist, we have compiled from the literature the [OIII]/H$\beta$, [O I]/H$\alpha$, [NII]/H$\alpha$ and [SII]/H$\alpha$ line ratios which are needed for this classification method. In five cases we have used SDSS DR7 emission line data, where no literature line ratio data exists. These data originate from the SPECBS code which extracts emission line data from the SPECTRO2D pipeline reduced spectra done at Princeton University. Table 1 presents these data, including the reference for the line ratio data. Fig. 1 presents the BPT classifications diagrammatically.

We adopt a classification based on the three diagrams. In the cases where the classification differs on one or two diagrams for the same galaxy, we use a composite classification such as 'H II/AGN', 'Sy2/LINER' or 'H II/LINER'. If the classification differs between diagram 2 and diagram 3, we choose the classification given by diagram 3, as [SII]/H$\alpha$ is said to be the least effective diagnostic in activity classification and [O I]/H$\alpha$ is most sensitive to shocks, making it better at identifying LINERs (Kewley et al. 2001). Each diagram requires 4 emission lines for the classification. If data for all 4 lines are not available, we cannot use that diagram for the classification.

Finally we supersede this activity classification, which is based on narrow line diagnostics, if a classification of a Seyfert 1-1.9 has been given in the literature. The classification of these sources based on the detection of broad lines is dependent on the methods used by each author, and thus differing classifications can be given for one source. It is also possible that a source changes classification. We have attempted to be as uniform as possible with our literature choice, taking the majority of the broad line classifications from Rodriguez, et al (25/33), and de Grijp et al. (1992) (4/33).

The results of this classification are also presented in Table 1. Our sample then consists of 12 Seyfert 1 galaxies, 16 Seyfert 1.2-1.5 galaxies, 5 Seyfert 1.8-1.9 galaxies (21 Seyfert 1.2-1.9 galaxies), 37 Seyfert 2 galaxies, 11 LINERs, 2 ambiguous Seyfert 2/LINERs, 13 H II galaxies, 18 H II/AGN composites, 3 ambiguous H II/LINERs, and 9 galaxies which remain unclassified due to insufficient optical emission line data existing in the literature.

The 12MGS as published by RMS contained 893 galaxies. At the time of publication these included 53 Seyfert 1s, 63 Seyfert 2s, 29 LINERs and 38 star forming galaxies, whereas the rest of the sample were called normal galaxies. Table 3 lists the proportions of the various optical types in the complete 12MGS and in our XMM-Newton sub-sample in percentage form with their binomial errors. The ratio of Seyfert 2s to Seyfert 1 in the original sample was 1.19. If we group Seyfert 1, 1.2 and 1.5s together as Seyfert 1s and Seyfert 1.8, 1.9 and 2s together as Seyfert 2s as is commonly done, we have a ratio of 1.5 in our sub-sample. We also note, however, a ratio of 1.12 narrow line (Sy2) to broad line (Sy 1 http://www.sdss.org/dr7/products/spectra/index.html
been detected, either using near-IR spectroscopy, or optical
there are 70 in our sample. If a hidden BLR (HBLR) has
any galaxy with a Seyfert classification an AGN, of which
of AGN within the sample based on optical data. We call
classify the galaxies in this sample, we can then define a set
1.
reddening correction. These data are also presented in Table
\[ \alpha \] and assumes an intrinsic value of H\text{\textsc{ii}}
which makes use of the observed Balmer decrement, H\text{\textsc{ii}}
engine. We apply reddening corrections to these fluxes us-
us-
ics, we also gather \([\text{O}\text{\textsc{iii}}]/\text{H}\text{\textsc{ii}}\) and \([\text{S}\text{\textsc{iii}}]/\text{H}\text{\alpha}\),
In addition to the optical line ratios used for diagnos-
spectropolarimetry, we classify this as an AGN, regardless
of the classification based on non-polarimetric optical spec-
trospectroscopy. Eight objects without a Seyfert classification, but
of the classification based on non-polarimetric optical spec-
\text{H}\text{\alpha}, \text{H}\text{\textsc{ii}} galaxies (black), Seyfert 2s (blue) and LINERs (green) are separated
using the classification scheme of Ke{	extsc{ley}} et al. (2006). Diagram 1 identifies pure \text{H}\text{\alpha} galaxies (black), \text{H}\text{\alpha}/AGN composites (light blue) and pure AGN (turquoise), but does not distinguish between Sy 2s and LINERs. We plot the types classified in diagram 1 on the following two diagrams to display the agreement between the two.

1-1.9) in our sample. The ratio of LINERs to Seyfert galaxies
in the original sample is 0.25, whereas our sample contains
0.14 LINERs to Seyferts. And finally, the ratio of star-
forming galaxies to Seyferts in the original sample was 0.33,
whereas our sample contains 0.44 when \text{H}\text{\alpha}/AGN composite
galaxies are included, or 0.19 when only pure star-forming
galaxies are counted. We show here that the XMM-Newton
subsample we use is thus representative of the complete
12MGS as published by RMS, and not biased towards AGN.
We do note however, that since RMS, optical type propor-
tions have changed, for example, by the discovery of many
Seyfert 2 galaxies in normal/star-forming galaxies (eg. Dap-
pita et al. 1998) Thean et al. 2001). Furthermore, the 12MGS
is not spectrophotometrically complete (Hunt & Malkan 1999),
since there may yet be undiscovered active galaxies within
the normal galaxy population. However, the majority of sources
not spectrophotometrically identified are southern galaxies, so we
posit that the incompleteness is not caused by a bias against
faint sources, rather by observability. The classification
of the entire sample has not been done uniformly with a single
classification scheme, but this will be the subject of future
work by Rodriguez et al. (in preparation). In this study, we
benefit from a uniform classification of all the galaxies in
our sub-sample, which is almost spectrophotometrically complete.

In addition to the optical line ratios used for diagnostics,
we also gather \([\text{O}\text{\textsc{iii}}]/\lambda5007\) line fluxes, which are often
used as an indicator of the intrinsic luminosity of the central
engine. We apply reddening corrections to these fluxes us-
ging the method described by Veilleux & Osterbrock (1987)
which makes use of the observed Balmer decrement, \text{H}\text{\alpha}/\text{H}\beta
and assumes an intrinsic value of \text{H}\alpha/\text{H}\beta=2.85 for \text{H}\alpha like
galaxies, and \text{H}\alpha/\text{H}\beta=3.1 for AGN. For Balmer decrements
less than the assumed intrinsic value, we do not apply the
reddening correction. These data are also presented in Table

Having used optical emission line diagnostics to clas-
sify the galaxies in this sample, we can then define a set of
AGN within the sample based on optical data. We call
any galaxy with a Seyfert classification an AGN, of which
there are 70 in our sample. If a hidden BLR (HBLR) has
been detected, either using near-IR spectroscopy, or optical

Table 3. Proportion of optical types in our XMM-Newton sub-
sample compared with the proportions from the entire 12MGS
(RMS, Rush, Malkan & Spinoglio 1993) with binomial errors. ‘all
galaxies’ refers to all 893 members of the 12MGS, ‘active galaxies’
refers to all Seyferts, LINERs and \text{H}\text{\alpha} galaxies and ‘comp’ refers
to \text{H}\alpha/AGN composites.

| Proportion          | 12MGS (RMS) | XMM-Newton sub-sample |
|---------------------|-------------|----------------------|
| Sy/all galaxies     | 13 ± 1.1%   | -                    |
| Sy/active galaxies  | 63 ± 3.1%   | 56 ± 4.4%            |
| Sy 1.8-2/Sy         | 54 ± 4.6%   | 60 ± 5.9%            |
| Sy 2/Sy             | -           | 53 ± 5.9%            |
| LINER/(LINER+Sy)    | 20 ± 3.3%   | 14 ± 3.9%            |
| \text{H}\alpha/(\text{H}\alpha+Sy) | 25 ± 3.5%   | 16 ± 4.0%            |
| (\text{H}\alpha+comp)/(\text{H}\alpha+comp+Sy) | - | 31 ± 4.6% |

3 LUMINOSITY CHARACTERISTICS OF THE 12MGS

Following the optical emission line activity classification we
have conducted for our sub-sample, we go on to investigate
the luminosity characteristics of the different optical types.
Table 4 presents the mean luminosities of each optical type
including the standard deviation of the distribution. Plotted
in Fig. 2 are histograms of the luminosity distributions for
pure \text{H}\alpha galaxies and \text{H}\alpha/AGN composites, Seyfert 1s and
intermediate Seyfert 1.2-1.9s and Seyfert 2s and LINERs at

![Figure 1. BPT diagrams showing diagram (1) on the left using [O\text{\textsc{ii}}]/\text{H}\beta vs. [N\text{\textsc{ii}}]/\text{H}\alpha, diagram (2) in the middle using [O\text{\textsc{ii}}]/\text{H}\beta vs. [S\text{\textsc{ii}}]/\text{H}\alpha and diagram (3) on the right using [O\text{\textsc{ii}}]/\text{H}\alpha. H\text{\alpha} galaxies (black), Seyfert 2s (blue) and LINERs (green) are separated using the classification scheme of Ke{	extsc{ley}} et al. (2006). Diagram 1 identifies pure H\alpha galaxies (black), H\alpha/AGN composites (light blue) and pure AGN (turquoise), but does not distinguish between Sy 2s and LINERs. We plot the types classified in diagram 1 on the following two diagrams to display the agreement between the two.](image-url)
2-10 keV (intrinsic), 12 µm and the [O iii] line. We exclude 3C273 in our luminosity analysis due to its blazar nature.

In X-rays, it would appear that H II/AGN composite galaxies, thought to harbour at least a low level AGN, have very similar luminosity distributions to pure H II galaxies. Strict Seyfert 1s have a greater average luminosity than the intermediate types and Seyfert 2s and these in turn have a greater average luminosity than LINERs. A Kolmogorov-Smirnov (K-S) test shows a significant difference between Seyfert 1s and Seyfert 2s at the 99.4% confidence level, but does not show a significant difference for other associated pairs at the greater than 99% confidence level. The X-ray luminosities are absorption corrected, and thus, the difference seen between the Seyfert 2s and Seyfert 1s must be intrinsic, rather than due to obscuration.

At 12 µm, H II galaxies and H II/AGN composites have the same average luminosity. Strict Seyfert 1s however, show a much larger average 12 µm luminosity than the intermediate type Seyferts and Seyfert 2s. Seyfert 2s again have a greater average luminosity than LINERs. A K-S test shows that Seyfert 1s are distinctly different from both Seyfert 1.2-1.9s and Seyfert 2s at the 99.99% confidence level.

Finally, for extinction corrected [O iii] luminosities, we find a greater average luminosity for H II/AGN composites when compared to pure H II galaxies. Seyfert 1s have on average almost a two orders of magnitude greater [O iii] luminosity than the intermediate Seyferts and Seyfert 2s. Again, we find a greater average luminosity for Seyfert 2s when compared to LINERs, though this may be expected as Seyfert 2s and LINERs are split using the [O iii]/Hβ line ratio. A K-S test, however, only shows Seyfert 2s and LINERs to be belonging to different populations at the 99% confidence level. Furthermore, we note that for $L_{[OIII]} > 10^{42}$ erg s$^{-1}$ there are no pure star forming galaxies. Although selecting AGN above this luminosity would yield sources 100 times more luminous than X-ray selection at $10^{42}$ erg s$^{-1}$, it is still useful to know for sources where standard BPT diagnostics are not possible due to Hα having been redshifted out of the optical band and/or X-ray data are not available. In this case the [O iii]/Hβ ratio would still be available for AGN/LINER separation.

At all three wavelengths, after accounting for reddening/absorption, Seyfert 1s are intrinsically more luminous than Seyfert 2s. This has been found similarly in the Swift/BAT hard X-ray sample by Winter et al. (2010) for [O iii] and 2-10 keV luminosities.

We also investigate the distribution of luminosities for Seyfert 2s with a detection of an HBLR (either in optical spectropolarimetry, or near-IR spectroscopy) and without a detection. The mean luminosities of the Seyfert 2s with an HBLR detection is over an order of magnitude higher than those without a detection, and a K-S test shows that these distributions are significantly different at the 99.7% confidence level. Fig. 3 plots these X-ray luminosity distributions along with the Seyfert 1.1-1.9 X-ray luminosity distribution for comparison. This results was originally presented by Tran (2003), also working on the 12MGS.

Further to the luminosity distributions of these optical types, we also investigate optical type fractions as functions of luminosity. These are presented in Fig. 4 which shows the Seyfert type 2 fraction of all Seyferts, the Seyfert intermediate type fraction of all type 1 Seyferts and the LINER fraction of all Seyfert and LINER galaxies against 12 µm and intrinsic X-ray luminosity. The vertical error bars we plot here are 68% confidence intervals calculated using a Bayesian based method presented in Cameron (2010) which is particularly useful for fractions at or close to 1 or 0. For cases where the fractions are 1 or 0, we plot only the confidence interval, marked by a grey bar. We find here that the Seyfert type 2 fraction is a strong decreasing function of X-ray luminosity, dropping significantly from ~ 60% to ~ 30% above $10^{43}$ erg s$^{-1}$. A weaker and less significant decline is also seen with 12 µm luminosity. We do find however that the fraction of intermediate Seyfert types of all type 1 Seyferts is a strong decreasing function of 12 µm luminosity, though this is not evident in X-ray luminosity. The LINER fraction declines with both 12 µm and X-ray luminosities.

### Table 4. Mean luminosities of the different optical types at 2-10 keV (intrinsic), 12 µm and the [O iii] line, with their standard deviations, σ.

| Type       | $L_X$  | $\sigma$ | $L_{12}$ | $\sigma$ | $L_{[OIII]}$ | $\sigma$ |
|------------|--------|----------|----------|----------|--------------|----------|
| Sy 1       | 43.34  | 0.72     | 44.75    | 0.64     | 43.00        | 1.07     |
| Sy 1.2-1.9 | 42.60  | 1.32     | 43.44    | 0.79     | 41.17        | 1.24     |
| Sy 2       | 41.97  | 1.29     | 43.68    | 0.63     | 41.23        | 1.27     |
| LINERs     | 40.80  | 1.63     | 42.87    | 0.90     | 39.26        | 1.82     |
| H II       | 40.00  | 0.93     | 43.33    | 0.89     | 39.30        | 1.29     |
| H II/AGN   | 40.51  | 1.42     | 43.47    | 1.07     | 40.41        | 1.51     |
| Sy 2 (HBLR)| 42.83  | 0.78     | 44.01    | 0.67     | 41.83        | 0.90     |
| Sy 2 (non-HBLR)| 41.51 | 1.27   | 43.50    | 0.54     | 40.91        | 1.34     |

![Figure 3. X-ray luminosity distribution of Seyferts 2s with detected HBLRs (blue with hatching), Seyfert 2s with no HBLR detected (black) and Seyfert 1-1.9s (red).](image)

**4 X-RAY PROPERTIES OF THE 12MGS**

We now explore the X-ray properties of our sub-sample according to optical type, building on the analysis in paper I.
Figure 2. Luminosity distribution of the sources by optical type. Left panels - Seyfert 1s (red) and Seyfert 1.2-1.9 galaxies (yellow). Middle panels - Seyfert 2 galaxies (blue) and LINERs (green). Right panels - H\textsc{ii} galaxies (black) and H\textsc{ii}/AGN composites (light blue). Top panels - intrinsic 2-10 keV luminosity. Middle panels - 12 µm luminosity. Bottom panel - [O\textsc{iii}] (corrected) luminosity.
Figure 4. Optical type fractions versus 12 µm luminosity and intrinsic 2-10 keV X-ray luminosity with 68% confidence intervals plotted as vertical error bars. Lone grey vertical bars represent confidence intervals on the fraction where the computed fraction is 1 or 0 (described in text). Top - Seyfert type 2 fraction of all Seyferts; middle - intermediate Seyfert (type 1.2-1.9) fraction of all type 1 Seyferts; bottom - LINER fraction of all Seyfert and LINERs galaxies.
There are 78/126 (=62%) galaxies defined as AGN in our sample using our optical definitions, compared to 60/126 (=48%) using an observed 2-10 keV X-ray luminosity of \(10^{42}\) erg s\(^{-1}\) as a discriminator. In general we find good agreement between the unambiguous X-ray AGN we found in paper I and the optical definitions we have determined here. All Seyfert 1s, 17/21=81% of Seyfert 1.2-1.9s and 23/37=62% of Seyfert 2s have their optical classifications as AGN confirmed in X-rays. For LINERs, 2/10=20% have \(L_X > 10^{42}\) erg s\(^{-1}\) as do 3/18=17% composite H\(\Pi\)/AGN galaxies. Finally, none of the 13 H\(\Pi\) galaxies present an X-ray luminosity greater than \(10^{42}\) erg s\(^{-1}\).

Table 5 presents the relative number of each optical class that would be solely selected by the X-ray luminosity. Here we also show how adding \(N_H\) information might aid in determining AGN activity in X-rays, given in columns 4 and 6, as heavily absorbed sources are strong candidates for being AGN. We chose a \(N_H\) cut off of \(\geq 10^{23}\) cm\(^{-2}\) as none of the pure H\(\Pi\) galaxies in our sample exhibit absorption above this level. We also explore the use of \(10^{41}\) erg s\(^{-1}\) as an effective discriminator for AGN activity in columns 5 and 6.

In both limiting luminosities, adding the \(N_H\) information increases the number of AGN selected (from 56 to 64 for \(L_X > 10^{42}\) erg s\(^{-1}\) and from 64 to 69 for \(L_X > 10^{41}\) erg s\(^{-1}\)), and does not add to the number of non-AGN, except for two additional LINERs which probably harbour an AGN. We should also note that two pure H\(\Pi\) defined galaxies, NGC 1482 and NGC 1808 display a large amount of absorption in their X-ray spectra (\(N_H \approx 9 \times 10^{22}\) cm\(^{-2}\)). Though this is slightly less than our \(10^{23}\) cm\(^{-2}\) criterion above, it is still a strong indication that these galaxies may host an AGN. It is possible though, that these don’t host an AGN, and that H\(\Pi\) galaxies can be heavily obscured.

Lowering the X-ray luminosity to \(10^{41}\) erg s\(^{-1}\) includes a further eight optical AGN types, with the inclusion of only two H\(\Pi\) galaxies, which represents a 20% contamination level for the \(\log_{10}(L_X/\text{erg s}^{-1})\) \(\approx -41\) to \(-42\) range. This lower luminosity limit also includes a further two Compton thick sources. This shows that a lower X-ray luminosity of \(10^{41}\) erg s\(^{-1}\) is an effective discriminator for AGN activity.

Fig. 6 shows the BPT diagrams of Fig. 1, but with X-ray luminosity indicated. Here it can be seen that most of the galaxies with \(L_X \geq 10^{42}\) erg s\(^{-1}\) lie in the AGN regions of these diagrams. 8/60 (=13%) galaxies have \(L_X \geq 10^{42}\) erg s\(^{-1}\) (observed), but are not unambiguous Seyferts (i.e. Seyfert 1.9s or galaxies with a Seyfert 2 classification from all three diagrams). We note VV705, ESO286-IG019, ESO148-IG002, NGC7213 on these diagrams as being X-ray luminous AGN, but with H\(\Pi\) line ratios. VV705 and ESO286-IG019 are classed as H\(\Pi\)/AGN composite galaxies using diagram 1, which supersedes the H\(\Pi\) classification in the other two diagrams. ESO148-IG002 and NGC7213 are classified as H\(\Pi\) on diagrams 1 and 2, but as Seyfert 2 and LINER respectively on diagram 3. We call ESO148-IG002 a H\(\Pi\)/AGN composite and NGC7213 an H\(\Pi\)/LINER. Furthermore, NGC 4388 and MCG 03-58-007 are Sy2/LINERs from their optical line ratios, NGC 6240 is a pure LINER and NGC 6552 has no line ratios available for classifications, but all of these sources are unambiguously powered by an AGN due to their X-ray luminosity. Overall, the X-ray luminosity is in agreement with the optical classification.

### Table 5. The number of each optical type that would be selected using various X-ray information. ‘CT sources’ are X-ray sources that are Compton thick. Column (1) gives the optical type; Column (2) gives the number in our XMM-Newton sub-sample; Column (3) gives the number that would be selected with \(L_X > 10^{42}\) erg s\(^{-1}\); Column (4) gives the number that would be selected with \(L_X > 10^{42}\) erg s\(^{-1}\) OR \(N_H > 10^{23}\) cm\(^{-2}\); Column (5) gives the number that would be selected with \(L_X > 10^{41}\) erg s\(^{-1}\); Column (6) gives the number that would be selected with \(L_X > 10^{41}\) erg s\(^{-1}\) OR \(N_H > 10^{23}\) cm\(^{-2}\). \(L_X\) is the observed 2-10 keV luminosity.

| Type                  | this sample | \(L_X\) | \(L_X+N_H\) | \(L_X\) | \(L_X+N_H\) |
|-----------------------|-------------|---------|-------------|---------|-------------|
|                       | (1)         | (2)     | (3)         | (4)     | (5)         | (6)         |
| Sy 1                  |             | 12      | 12          | 12      | 12          |
| Sy 1.2-1.9            |             | 21      | 17          | 18      | 18          | 19          |
| Sy 2                  |             | 37      | 23          | 29      | 27          | 31          |
| Non Sy HBLR           |             | 8       | 4           | 5       | 7           | 7           |
| All Sy+/HBLR          |             | 78      | 56          | 64      | 64          | 69          |
| LINERs                |             | 10      | 2           | 4       | 5           | 5           |
| Sy 2/LINERs           |             | 2       | 1           | 1       | 2           | 2           |
| H\(\Pi\)              |             | 13      | 0           | 0       | 2           | 2           |
| H\(\Pi\)/AGN          |             | 18      | 3           | 3       | 5           | 5           |
| CT sources            |             | 16      | 11          |         | 13          |

#### 4.1 Continuum

Fig. 6 gives the distribution of the X-ray power-law index, \(\Gamma\), for the various optical types. We have grouped H\(\Pi\) galaxies, H\(\Pi\)/AGN composite galaxies and LINERs into one non-Seyfert category, Seyfert 1-1.9s into another category and Seyfert 2s into the last category. We use the maximum likelihood method of Maccacaro et al. (1988) to determine both the mean and the intrinsic dispersion for each of these distributions, accounting for the measurement errors. We find that for non-Seyferts, \(< \Gamma >= 1.78^{+0.08}_{-0.08}\) and \(\sigma = 0.07^{+0.06}_{-0.07}\) for Seyfert 1-1.9s, \(< \Gamma >= 1.83^{+0.06}_{-0.06}\) and \(\sigma = 0.29^{+0.06}_{-0.06}\) and for Seyfert 2s, \(< \Gamma >= 1.90^{+0.17}_{-0.16}\) and \(\sigma = 0.34^{+0.16}_{-0.16}\). Statistically, we find that there is no difference in \(\Gamma\) between the different optical AGN types. This is in general support of AGN unification schemes as it suggests that the intrinsic properties of the central engines of Seyfert 1s and 2s are the same. On the other hand, the spectral properties of non-Seyferts are more uniform, showing no significant intrinsic dispersion in their X-ray spectral indices, in contrast to Seyferts.

#### 4.2 Obscuration

Fig. 7 plots the distribution of neutral absorbing columns that were detected in the XMM-Newton spectra. As expected Seyfert 2 galaxies exhibit the largest amounts of absorption in their spectra with an average \(\log_{10} N_H = 23.08\), whereas Seyfert 1s have an average \(\log_{10} N_H = 21.42\) and Seyfert 1.2-1.9s have an average \(\log_{10} N_H = 21.64\). Nonetheless we do note that a naive interpretation of optical broad line AGN as being X-ray unobscured and narrow lined AGN as being X-ray obscured is incorrect, as 8/37 (22 ± 7%)
Seyfert 2s show low levels of X-ray absorption \((< 10^{22} \text{ cm}^{-2})\), e.g. [Pappa et al. 2001] [Panessa & Bassani 2002] and 4/12 (33 ± 14%) Seyfert 1s exhibit high levels of neutral absorption \((> 10^{22} \text{ cm}^{-2})\), e.g. [Wilkes et al. 2002]. The uncertainties on the \(N_H\) values are also consistent with the mismatch. Together these amount to 12/49 (24 ± 6%) cases where there is a mismatch between the measured X-ray absorption and the obscuration inferred from the optical type. The absorbed Seyfert 1s tend to be optically reddened, for example IRASF13349+2438 [Wills et al. 1992], suggesting that the spectrum is attenuated by a dusty torus, as we see in X-rays. We previously investigated the nature of the unabsorbed Seyfert 2s of the 12MGS in [Brightman & Nandra 2008], finding that in about half of cases, it is possible that X-ray absorption has been missed by wide-beam X-ray telescopes due to host galaxy contamination (see also [Ghosh et al. 2007] [Shu et al. 2010]). The remaining unabsorbed Seyfert 2s are possible 'true Seyfert 2s' which are missing the BLR altogether [Bianchi et al. 2008]. Thus in reality, 24% is an upper limit to the X-ray - optical mismatch. Also we show no difference between the average absorption occurring in strict Seyfert 1 and intermediate Seyferts, as would be expected from models that describe the weakness of the broad lines in the intermediate types due to absorption.

Furthermore, LINERs show moderate absorption levels on average as \(\log_{10} N_H = 21.92\), but the distribution is bimodal, with roughly half showing low absorption and half showing heavy absorption. As expected, H II and H II/AGN composites exhibit low absorption levels with \(\log_{10} N_H = 20.99\) and \(21.24\) respectively. However, a few show heavy absorption, so it is a key question as to whether these are in fact AGN or not.

In Fig. 7 we plot the absorption characteristics of the different optical types in our sample. In paper I, we also investigated absorption, but for X-ray luminous \((L_X > 10^{42} \text{ erg s}^{-1})\) AGN. Shown in Fig. 8 is a comparison plot of the distribution of neutral column densities for X-ray luminous AGN and optically defined AGN. The distributions are fairly similar, with the most notable difference being that optical selection includes a greater proportion of X-ray unabsorbed
Sources (32/78 = 41%) over X-ray luminous sources (19/60 = 32%). In paper I we also showed that the obscured fraction for X-ray sources decreases for luminosities less than \(10^{42}\) erg s\(^{-1}\). It follows then that if one selects sources only above this luminosity there is a bias against lower absorbed sources.

We can investigate directly the variation of the obscured fraction for optically defined AGN with both intrinsic X-ray and 12 \(\mu\)m luminosity. Fig. 8 presents the scatter of \(N_{\text{H}}\) against \(L_{12\mu\text{m}}\) and \(L_X\), the obscured fraction, defined as the ratio of the number of AGN with \(N_{\text{H}} > 10^{22}\) cm\(^{-2}\) to the total number of AGN for each luminosity bin and the Compton thick fraction. We choose to bin in equal steps of luminosity in logarithmic space. The errors on this plot represent 68% confidence intervals and have been calculated using a Bayesian method particularly useful for fractions at or close to 0 or 1 (described earlier in the text). The lone vertical error bars represent 68% confidence intervals on fractions that have been calculated to be 0 or 1. We also plot the obscured fraction against X-ray luminosity as presented by Burlon et al. (2010) from their X-ray luminosity function analysis of Swift/BAT data for comparison. As the ratio of 15-55 keV fluxes to the 2-10 keV flux is approximately equal to 1 for a model power-law with \(\Gamma = 1.9\), we do not scale the X-ray luminosity. The hard X-ray samples extend to higher X-ray luminosity than the 12 \(\mu\)m sample, but the 12 \(\mu\)m sample probes to lower X-ray luminosity. Our results agree very well here, despite different wavelength selections, and support not only a decrease in the obscured fraction at high luminosities, but also at low luminosities. The Compton thick fraction shows a similar behaviour in X-ray luminosity, though the statistics are not as good. The variation of the obscured fraction with 12 \(\mu\)m luminosity also hints at a decrease at higher luminosities and possibly at lower luminosities, however, the simplest case of non-varying obscured fraction fits the data too. We do see a hint that the Compton thick fraction is dependent on 12 \(\mu\)m luminosity though, suggesting that obscuration is in fact also dependent on 12 \(\mu\)m luminosity.

From our analysis of the XMM-Newton spectra of these galaxies, we found a total of 16 Compton thick sources in our sample. All but three of these are optically defined as Seyfert 2, two are H II/AGN composites (NGC 3690 and ESO 148-IG 002), and the final source, NGC 6552, has not been optically classified here. NGC 6552 is classified as a Seyfert 2 however, by de Grijp et al. (1992), though they do not present line ratio data. The Compton thick nature of NGC 6552 was serendipitously discovered by Reynolds et al. (1994) and Fukazawa et al. (1994) with an ASCA observation which shows a reflection dominated spectrum and
Figure 9. $N_H$, obscured fraction and Compton thick fraction versus 12µm and intrinsic 2-10 keV luminosity, for AGN types only (non-AGN plotted as dots). Red, yellow and blue diamonds are Seyfert 1s, 1.2-1.9s and 2s respectively, whereas green diamonds are LINERs with an HBLR. Red outlines indicate an HBLR detected in the source. Obscured and Compton thick fractions are calculated in equal logarithmic luminosity bins, as the number of sources with $N_H > 10^{22}$ cm$^{-2}$ divided by the total number of sources in that bin, where more than one source exists per bin. The dotted line in the middle right panel is that from Burlon, et al, from their X-ray luminosity function analysis of Swift/BAT data.
it also has a HBLR revealed in optical spectropolarimetry (Tran 2001). Thus, all of our Compton thick sources are AGN. Combining optical and X-ray selection, we find a total of 82 AGN in this sample, which gives us 16/82 (20 ± 4%) Compton thick AGN in this sample with 51/82 (62 ± 5%) obscured AGN ($N_{\text{H}} \geq 10^{22} \text{ cm}^{-2}$).

Combining X-ray data with data at other wavelengths has been used previously to assess the Compton thick nature of AGN. Bassani et al. (1999) use the ratio of the X-ray flux to $[\text{O III}]$ line flux, known as the ‘T’ ratio, to pick out potentially Compton thick candidates not recognised in their X-ray spectra alone. The $[\text{O III}]$ line is thought to be an isotropic indicator of AGN strength as it is produced in the NLR. However this line is also subjected to extinction along the line of sight and a reddening correction is often applied which is derived from the Balmer decrement. Here we investigate this ratio and its effectiveness at identifying Compton thick AGN. Fig. 10 presents the distribution of this ratio for measured Compton thin (black) and thick (red) sources. We show this for the observed $[\text{O III}]$ flux and the extinction corrected $[\text{O III}]$ flux, for Seyfert 2s alone, and for all Seyferts. We present the means and standard deviations of these distributions in Table 6. Although it can be seen that Compton thick AGN have on average a lower T ratio than Compton thin AGN, the ratio does not separate Compton thick sources from the Compton thin population completely in any case, and many Compton thin AGN have low T ratios. We investigate the Seyferts which are not directly measured to be Compton thick, but have T ratios consistent with Compton thick obscuration ($T<0.1$) is generally taken to be the criterion for a candidate Compton thick AGN (Bassani et al. 1999). Four of these sources exist, being IRAS07599+6508, MRK2073, NGC 5775 and UGC 09944. IRAS07599+6508 is a Seyfert 1 ULIRG weak in X-rays and also has a large extinction correction ($H_\alpha/H_\beta=33.6$). MRK 0273 is a heavily obscured Seyfert 2, but not Compton thick and NGC 5775 is also a Seyfert 2 with no apparent indications of heavy obscuration in its X-ray spectrum. NGC 5775 also has an extremely large extinction correction ($H_\alpha/H_\beta=126$). Finally UGC 09944 is also a Seyfert 2 with a low measured $N_{\text{H}}$, however we do note an excess around 6.4 keV, which we can fit with a gaussian with high, but badly constrained EW (3.02 ± 2.51 keV) and unconstrained energy ($E=6.50_{-0.28}^{+31.4}$). This source is potentially a Compton thick Seyfert 2. However, in 2 out of 4 cases, the extinction correction to the $[\text{O III}]$ flux is likely to have given the source an unreliably low T. In the other two cases, one source is heavily obscured but not Compton thick, which leaves us with only one true Compton thick candidate. Our clear conclusion is that the T ratio is not a reliable Compton thick indicator, especially when uncertainties regarding extinction corrections are considered. It can, however, be used to exclude the possibility of a source being Compton thick, if it has a high T ratio ($>10$ when using extinction corrected $[\text{O III}]$), as these sources have been shown to be almost exclusively Compton thin. We also note that our Compton thick Seyfert 2s have a range of T values that extend to higher values than Bassani et al. (1999), up to 6.3 compared to ~1. This may be due to our higher signal-to-noise data, with which we have managed to directly measure the Compton thickness in four of our sources, whereas Bassani et al. (1999) mostly infer the Compton thickness from a low T and high Fe Kα EW.

**Figure 10.** Histograms showing the distribution of the ‘T’ ratio, defined as $F_X/F_{[\text{O III]}}$ for Compton thin (black) and Compton thick (red) sources. The top panels show only Seyfert 2, whereas the bottom panels show all Seyferts. The left panels use the observed $[\text{O III}]$ flux, whereas the right panels use the extinction corrected $[\text{O III}]$ flux. The X-ray flux is observed in all cases. The dotted lines show the means of the distributions, given with their standard deviations in Table 6.

**Table 6.** Mean ‘T’ ratios with their standard deviations, $\sigma$, for Sy 2s, all Sys, using both the observed $[\text{O III}]$ flux and the extinction corrected $[\text{O III}]$ flux.

| Type            | $\log_{10}T$ ([$[\text{O III}]$ obs.]) | $\sigma$ | $\log_{10}T$ ([$[\text{O III}]$ ext. corr.]) | $\sigma$ |
|-----------------|----------------------------------------|---------|----------------------------------------------|---------|
| Compton thin Sy 2s | 1.17                                   | 0.93    | 0.12                                         | 1.31    |
| Compton thick Sy 2s | 0.49                                   | 0.71    | -0.50                                        | 0.65    |
| Compton thin Sys | 1.51                                   | 0.89    | 0.59                                         | 1.22    |
| Compton thick Sys | 0.49                                   | 0.71    | -0.50                                        | 0.65    |

5. X-RAY - INFRARED RELATIONSHIP IN GALAXIES

Barcons et al. (1995) and McKernan et al. (2009) both find a correlation, though a non-linear one, between X-ray and IRAS 12 µm luminosities of AGN. These authors attribute some of this to a contribution to the 12 µm luminosity by emission from the host galaxy, but Barcons et al. (1995) also points to a break down of the unification scheme as this non-linear relationship implies that the covering fraction of the torus is a function of X-ray luminosity. In the top panel of Fig. 11 we plot the 12 µm luminosity against the intrinsic X-ray luminosity for all 126 galaxies in our sample, colour coded by optical type. The dotted lines on this diagram represent $L_{12\mu m} = L_X$, $L_{12\mu m} = 100 \times L_X$ and $L_{12\mu m} = 10^4 \times L_X$. The X-ray luminosities have been corrected for absorption. It is clear here that the relationship between 12 µm luminosity and X-ray luminosity is non-linear, and there is a large scatter, even for AGN only. Star-forming galaxies also have a much larger $L_{12\mu m}/L_X$ than AGN. The dot-dashed lines on this plot mark the $10^{31}$ and $10^{42}$ erg s$^{-1}$
X-ray luminosities, again showing that all but two galaxies with $L_X > 10^{41}$ erg s$^{-1}$ are AGN.

The lower plot in Fig. 11 highlights the luminosities of the different type 1 Seyferts. Most striking, is the separation almost exclusively have $L_{12\mu m} > 3 \times 10^{44}$ ergs s$^{-1}$, whereas Seyfert 1-2.9 have luminosities exclusively less than this.

Horst et al. (2008) find that Seyfert 1s and Seyfert 2s have the same intrinsic distribution of $L_{MIR}/L_X$, which is not expected from smooth dusty torus models, as the $12\mu m$ flux should be suppressed in edge on, Seyfert 2 type systems (Pier & Krolik 1992). This is a key result when considering 12$\mu$m selection, and using the 12MGS to infer properties of obscuration in local AGN, so we also test if there is any dependence between the X-ray to 12 $\mu$m flux ratio and absorption measured in the X-ray band. In Fig. 12 we show the observed 2-10 keV flux to the 12 $\mu$m flux against the neutral column density measured. The dashed line plot is the ratio of the 12 $\mu$m to 2-10 keV bolometric corrections for AGN, $\kappa_{12\mu m}/\kappa_{2-10keV}$. We use the average $\kappa_{2-10keV}$, from Vasudevan & Fabian (2007) with the total 1 dex spread that they present, and we calculate $\kappa_{12\mu m}$ from the bolometric luminosities of the AGN given in Spinoglio et al. (1995) which we calculate to be 10.1, with a standard deviation of 0.34 dex. This gives $\kappa_{12\mu m}/\kappa_{2-10keV} = 0.40$ with a spread of 0.6 dex represented by the dotted line in each plot. This is consistent with the results of Horst et al. (2008) and their nuclear 12.3 $\mu$m observations (0.42 for Seyfert 1s and 0.36 for Seyfert 2s). The bolometric ratio is also plotted as a function of the X-ray column density, where the 2-10 keV contribution has been suppressed by a factor calculated from our Monte Carlo model presented in paper I. We place AGN found to be Compton thick in our previous analysis at $N_H = 1.5 \times 10^{24}$ cm$^{-2}$, which is a lower limit to their $N_H$. The symbols are colour coded to represent their optical types.

We find that most Seyfert 1s have X-ray to MIR flux ratios consistent with the bolometric corrections, as do some Seyfert 2s, however, most Seyfert 2s have a lower than expected ratio, even when taking the suppression of the X-ray flux by absorbing columns into account. Star-forming galaxies are seen to have a much lower ratio than AGN. It is likely that the lower than expected X-ray to MIR flux ratio seen in Seyfert 2s is due to MIR dust emission from their host galaxies which have been heated by star formation.

6 DISCUSSION

6.1 X-ray properties of Seyfert galaxies

We have presented the average intrinsic X-ray ($L_X$ and $\Gamma$) and X-ray absorption ($N_H$) properties of our sample for each optical class that we have determined here, be it Seyfert 1s, Seyfert 1-2.9s, Seyfert 2s, LINERs, H II galaxies or composite H II/AGN galaxies. For Seyfert galaxies, much of our existing knowledge of these properties comes from analysis of the X-ray selected sample of Piciocnotti et al. (1982). Here we can compare the properties we derive from our MIR selected sample to those earlier results. The Seyfert 1s in our sample have an average intrinsic X-ray luminosity of $\log_{10}L_X = 43.3 \pm 0.72$, $< \Gamma > = 1.83_{-0.06}^{+0.06}$ and $\sigma_{\Gamma} = 0.29_{-0.05}^{+0.05}$. For the X-ray selected sample of Seyfert 1s measured by ASCA from Nandra et al. (1997), they find an average $\log_{10}L_X = 43.3 \pm 0.91$ and $< \Gamma > = 1.90 \pm 0.17$ and $\sigma_{\Gamma} = 0.15 \pm 0.05$. Our mean luminosities are the same, and our $< \Gamma >$ are consistent with each other, however, we find a significantly broader distribution of $\Gamma$ than in the Nandra et al. (1997) sample. The Seyfert 2s in our sample have an average intrinsic X-ray luminosity of $\log_{10}L_X = 42.0 \pm 1.29$ with a spread of $0.6 \sigma$.

The lower plot in Fig. 11 highlights the luminosities of AGN galaxies. For Seyfert galaxies, much of our knowledge of these properties comes from analysis of the X-ray selected sample of Piciocnotti et al. (1982). Here we can compare the properties we derive from our MIR selected sample to those earlier results. The Seyfert 1s in our sample have an average intrinsic X-ray luminosity of $\log_{10}L_X = 43.3 \pm 0.72$, $< \Gamma > = 1.83_{-0.06}^{+0.06}$ and $\sigma_{\Gamma} = 0.29_{-0.05}^{+0.05}$ for Sy 1-1.9s and $\log_{10}N_H = 21.42$. For the X-ray selected sample of Seyfert 1s measured by ASCA from Nandra et al. (1997), they find an average $\log_{10}L_X = 43.3 \pm 0.91$ and $< \Gamma > = 1.90 \pm 0.17$ and $\sigma_{\Gamma} = 0.15 \pm 0.05$. Our mean luminosities are the same, and our $< \Gamma >$ are consistent with each other, however, we find a significantly broader distribution of $\Gamma$ than in the Nandra et al. (1997) sample.

6.2 AGN selection and classification

We have found that our X-ray data generally support MIR AGN selection, as we have found a higher fraction of obscured AGN (62 ± 5%) than optically selected samples (40 ± 5%), eg, Cappi et al. (2006) and hard X-ray selected (50%, Tueller et al. 2008) AGN samples, as well as a higher Compton fraction (discussed below).

As for finding AGN in non-Seyfert galaxies, we find an X-ray luminosity in excess of $10^{42}$ erg s$^{-1}$ in 17% of the composite H II/AGN defined galaxies, whereas we find no such indications in any of the pure H II defined galaxies. The H II/AGN composites also have on average a greater [O III] luminosity than H II galaxies. As the [O III] line is used in the classification of these galaxies, this may be interpreted straightforwardly as a selection effect. However, it is mostly the [N II] line which is used to distinguish these from pure H II defined galaxies, so a greater [O III] luminosity indicates AGN activity in the H II/AGN composite galaxies. From infrared SED fitting, Patel et al. (2010) find 3% of composite galaxies in the SWIRE, XMM-LSS and Lockman Hole surveys require an AGN component, suggesting that X-ray observations are more efficient at identifying AGN activity.
Figure 11. 12µm luminosity versus intrinsic 2-10 keV luminosity for our sample. (top) The dotted lines on this diagram represent $L_{12\mu m} = L_X$, $L_{12\mu m} = 100 \times L_X$ and $L_{12\mu m} = 10^4 \times L_X$. (bottom) Only Seyfert 1-1.9 (broad line Sy) types are plotted here. We show Sy 1.8-1.9s as open yellow symbols.
Figure 12. Observed 2-10 keV to 12µm flux ratio versus measured column density for our sample. The colour of each symbol represents the optical type of galaxy, whereas the size of the symbol represents the X-ray luminosity of the galaxy. The dashed line is the ratio of the respective bolometric corrections for AGN for the quantities given, which we find to be $0.40 \pm 0.06$ dex, where the dotted lines indicate the spread in this value. The ratio is also plotted as a function of the X-ray column density, where the 2-10 keV contribution has been suppressed by a factor calculated from our Monte-Carlo model. Named are galaxies where interesting cases where the X-ray obscuration is in contradiction to the optical type (eg. obscured Seyfert 1s).

Our findings support such a ’composite’ classification based on optical line ratios.

We also find evidence for AGN activity in a large number (40%) of LINERs from the X-ray data. This includes NGC 6240, well known for its LINER classification in the optical, but unambiguously powered by a heavily obscured AGN in the X-rays, as Beppo-SAX showed with the detection of a hard component (Mitsuda 1995). However González-Martín et al. (2009) have recently reported that a much larger fraction, 80%, show indications for AGN activity in LINERs. However, as well as X-ray luminosity and absorption, they also use X-ray morphology, and data at other wavelengths to suggest AGN activity. By contrast, Goulding & Alexander (2009) find only a 25% AGN fraction in IR bright LINERs from the detection of the [NeV] line. It would seem that LINERs are mostly low luminosity AGN, but that in a few cases, they are more powerful Compton thick AGN. The decline in the LINER fraction of Seyfert and LINER galaxies with 12 µm and X-ray luminosity also supports this conclusion.

6.3 AGN obscuration

The most commonly compared study of the distribution of X-ray absorbing columns in AGN is that by Risaliti, Maiolino & Salvati (1999), who showed that $\sim 75\%$ of their optically selected Seyfert 2s were heavily absorbed ($N_H > 10^{23}$ cm$^{-2}$) and $\sim 50\%$ were Compton thick. The authors applied an [OIII] flux cut off of $4 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ to their sample however, leaving them with a sample of bright Seyfert 2s, so a direct comparison to their work is not straightforward. However, for the [OIII] fluxes we have compiled, if we apply the same cut off and include Seyfert 1.8 and 1.9s, we find that $75 \pm 8\%$ of them are heavily absorbed and $39 \pm 9\%$ are Compton thick. This agrees well with the Risaliti et al. (1999) study, though with a smaller, but not significantly so, proportion of heavily obscured Seyfert 2s being Compton thick. Furthermore, some of the Seyfert 2s in the Risaliti et al. (1999) study have since been shown to be probably not Compton thick (Treister et al. 2009), so the true Compton thick fraction for these bright Seyferts is probably closer to $\sim 40\%$ as our results suggest.

We find a Compton thick fraction of $20 \pm 4\%$ in the 12 µm sample. Akylas & Georgantopoulos (2009) find 3/38 (8%) of their optically selected sample of Seyferts, which has a similar range in $L_X$ to our sample ($10^{38}$ to $10^{43}$ erg s$^{-1}$), to be Compton thick from direct measurements of the $N_H$. However they also note a low $T$ ratio in many other AGN in their sample, which, if they include these as inferred Compton thick objects, would increase their Compton thick fraction to $20\%$, in rough agreement with our statistic. Their 8% statistic is still within 3-$\sigma$ of our own though and can thus...
be considered as consistent with our results. Cappi et al. (2006) also find a 20% Compton thick fraction from their analysis of the same survey. The hard X-ray selected sample also reveal a significantly lower (3-σ) Compton thick fraction (∼ 4%, e.g. Beckmann et al. 2009). In paper I we showed the effect of heavy obscuration on X-ray transmission above 10 keV. At a column density of ∼ 4 × 10^{24} cm^{-2} the observed flux is half that of the intrinsic flux in the 10-40 keV band, and at ∼ 10^{25} cm^{-2} it is 10% of that level, presenting a real bias against heavily obscured systems in hard X-ray surveys, and indeed Malizia et al. (2009) show that when considering only the closest INTEGRAL sources, the Compton thick fraction they derive is in better agreement. For the Swift/BAT survey, Burlon et al. (2010) account for the selection bias in the hard X-ray band, and recover a 20% Compton thick AGN fraction in doing so.

We have shown however, that using the T ratio to consider an AGN as Compton thick is misleading in many cases, especially when taking the extinction correction into account. We found that 2/4 Seyferts with a T ratio consistent with Compton thick obscuration have extremely large Balmer decrements leading to huge extinction corrections, and probably unreliable T ratios. LaMassa et al. (2010) investigated the reddening correction of [O iii] for the 12MGS finding that applying the correction based on the Balmer decrement widened the dispersion in the flux ratio of the [O iii] line to other isotropic indicators, whereas the dispersion tightened for their optically selected sample. They conclude that the extinction correction, which is based on heterogeneous literature values for the 12MGS, overestimate the reddening due to dust. One Seyfert however, UGC09944, does seem to be a reliable Compton thick candidate based on the T ratio, shown from a large EW but not well constrained Fe Kα line. We do find though that a source with a high T ratio can be excluded from being Compton thick as almost all sources which present a high T ratio are Compton thin.

6.4 AGN unification

Our analysis of the Γ distribution of Seyfert 1-1.9 and Seyfert 2s shows that there is not a significant difference in the spectral slopes of the two classes, suggesting that the power generation mechanism in the two classes is essentially the same, and thus in support of the unification of the Seyfert types. Several authors have reported a difference in the two distributions, finding that Seyfert 2s tend to have a harder spectral slope (e.g. Tueller et al. 2008; Middleton et al. 2008). These studies have the advantage of data above 10 keV and therefore are less subjected to absorption effects. However, Malizia et al. (2003) also make use of data above 10 keV, and although they find a systematic difference between the two types initially, this difference disappears when more complex absorption models are used to model the Seyfert 2 data. Dadina (2008) also draws the same conclusion from Beppo-SAX data.

Arguing against unification schemes are the finding of cases where Seyfert 1s are X-ray absorbed and Seyfert 2s are X-ray unabsorbed, and finding that Seyfert 1s are intrinsically more powerful than Seyfert 2s at 12 µm, [O iii] and X-ray wavelengths. Furthermore, we also show that AGN obscuration depends on X-ray luminosity, finding that rather than declining with L_X, the obscured fraction peaks at L_X ∼ 10^{42} erg s^{-1}. Other authors have previously reported that the obscured fraction of AGN decreases at high luminosities (e.g. Ueda et al. 2003; Hasinger 2008), but their samples do not generally extend into the lower luminosity range probed by the 12MGS. The decline in the obscured fraction at high luminosities is supported by the decline we see in the Seyfert 2 fraction above ∼ 10^{43} erg s^{-1}. This has also been previously reported (e.g. Simpson 2005 in [O iii] luminosity), though this is still a subject of debate (see Lawrence & Elvis 2010 for a discussion on this). As for the decline in the obscured fraction towards low luminosities, Akylas & Georgantopoulos (2009) also find evidence for less obscuration at low luminosities, as do Zhang et al. (2009), both for nearby AGN. Burlon et al. (2010) similarly find a peak in the obscured fraction for the Swift/BAT selected AGN from luminosity function analysis. The variation of the obscured fraction with 12 µm luminosity is not as statistically significant as seen in X-rays, and is consistent with a non-varying obscured fraction, but better statistics are needed to test this definitively. The Compton thick fraction does, however, seem to vary with 12 µm luminosity, suggesting that obscuration does in fact depend on 12 µm luminosity as well as X-ray luminosity.

Hopkins et al. (2009) attribute the disappearance of the BLR to low accretion rate, radiatively inefficient systems as observationally found by Nicastro et al. (2003) who show that the detection rate of HBLRs in Seyfert 2s decreases with accretion rate. Modelling of outflows in low luminosity AGN by Blitz & Shlosman (2006) predicts that both the torus and the BLRs disappear at low bolometric luminosities, which would explain both the decline we see in the obscured fraction at low X-ray luminosities and the lower incidence of HBLRs at low X-ray luminosities.

Another interesting difference our data reveal is that strict Seyfert 1s have a distinctly different 12 µm luminosity distribution from the intermediate type 1.2-1.9s Seyferts, which is shown to be highly statistically significant from a K-S test. This is also seen in the decline of the intermediate type fraction with 12 µm luminosity. The progression from strict type 1 through to type 1.5 is dependent on the ratio of the total Hβ flux to the [O iii] flux, i.e. the relative strengths of the BLR and NLR, where Seyfert 1.5s have the weakest BLR to NLR ratio. The difference in the relative strengths between these Seyfert sub-types may be due to reddening of the BLR, or due to an intrinsic difference in the ionising flux (Tran et al. 1992). A difference in 12 µm luminosity between the Seyfert 1s and intermediate Seyferts suggests that the 12 µm luminosity in some way connected to the relative strength of the BLR to the NLR in unobscured AGN. It should be noted that the X-ray luminosity distributions of Seyfert 1s and intermediate Seyferts are not shown to be significantly different. If we then presume that the X-ray luminosity is an indicator of nuclear power; higher 12 µm luminosities in Seyfert 1s might suggest a higher covering fraction of the torus in Seyfert 1s with respect to intermediate Seyferts. This in turn suggests that the strength of the BLR is dependent on the torus covering fraction, and implies an origin in the torus for the BLR. This supports the model presented by Gaskell (2009), which describes the BLR as the inner part of the torus, where material has lost angular momentum and the dust has sublimated. This sub-
sequently forms into an accretion disk and is accreted by the black hole.

In conclusion, it seems that our data suggest some intrinsic link between the torus, the BLRs and the accretion disk, and finds good cause for modifications to be made to the simplest AGN unification schemes.

6.5 Implications for the X-ray background

The predictions of the recent X-ray background synthesis models of Gilli et al. (2007) claim to match the observed Compton thick fraction as found by hard X-ray telescopes. However, since publication of the hard X-ray samples, the Compton thick fraction has fallen due to ongoing observations (Beckmann et al. 2009). Treister et al. (2009) argue that the discrepancy between observations and models is due to degeneracies in the models used to fit the background spectrum, in particular, the normalisation of the Compton reflection component. They argue that only direct observations can be used to constrain the properties of Compton thick AGN in the local universe. Alternatively, or in addition, consideration of blazars in the synthesis models lead to a lower required CT AGN fraction (Draper & Ballantyne 2009). As we have shown, the 12MGS is well suited to directly constraining the Compton thick fraction of AGN in the local universe due to its representative nature and the relative lack of bias towards heavily obscured systems, so we conclude that the true Compton thick fraction of local AGN is only $\sim 20\%$.

Furthermore, the intrinsic dispersion on $\Gamma$ is an important parameter when considering XRB models. Gilli et al. (2007) directly investigated the effect of introducing a non-zero $\sigma_\Gamma$ into the synthesis models, and evaluated the effect of varying the size of the dispersion. They found that the larger the dispersion, the greater contribution to the 30 keV peak from unobscured AGN there was. For their baseline model they use $\sigma_\Gamma = 0.2$ based on results from Mateos et al. 2005 on faint sources in the Lockman Hole. Here we find that for local AGN, $\sigma_\Gamma \sim 0.3$, which would introduce a greater contribution to the 30 keV peak from unobscured AGN than the Gilli et al models produce, and hence require a smaller contribution from Compton thick AGN.

6.6 Implications for high redshift studies

Mid-IR observations by *Spitzer* are being used extensively for deep field, high redshift studies of AGN. This is due to the fact that much of the reprocessed primary energy of the AGN is re-emitted in the mid-IR. Our local study at 12 µm corresponds exactly to the *Spitzer/MIPS* 24 µm selected sources at z=1, and provides valuable insight into the nature of these sources. Building on results from Horst et al. (2008) and finding that 12 µm selected AGN contain a higher fraction of Compton thick sources than optically or X-ray selected samples, we have concluded that mid-IR selection is indeed ideally suited to selecting AGN and is relatively unbiased against obscuration, bolstering these deep field efforts. We have found that using a lower X-ray luminosity of $10^{41}$ erg s$^{-1}$ rather than $10^{42}$ erg s$^{-1}$ will increase the number of AGN selected in X-ray surveys, with minimal inclusion of star forming galaxies, which is valuable information for the high-z searches.

Additionally, the 24 µm band of *Spitzer/MIPS* is often used to select ‘infrared excess’ (IRX) sources, where the flux in the 24 µm band is in excess compared to a wavelength which is more subjected to absorption, such as the optical R band or X-rays (e.g. Fiore et al. 2008; Georgantopoulos et al. 2009). These IRX sources are candidates for high-z Compton thick AGN, but as we have shown for our local sources, there are cases where low X-ray to mid-IR AGN (infrared excess sources) are not in fact heavily obscured and have intrinsically low ratios (e.g. IRASF 07599+6508, NGC 3147, IRASF 01475-0740.). Recently Georgakakis et al. (2010) investigated the nature of z$\sim 2$ IRX sources and showed that only a small fraction of them displayed tentative evidence for being Compton thick.

7 CONCLUSIONS

In summary, we have uniformly determined the optical types for the 126 galaxies that form a sub-sample of the 12MGS, for which we have good X-ray data from paper I using BPT line ratio diagnostics. We have conducted a study comparing the optical and X-ray selection methods and have also characterised the optical types in the X-ray and we have investigated X-ray properties of the sample by optical type.

The main conclusions from this study have been that:

- strict Seyfert 1s are distinctly more powerful at X-ray luminosities than Seyfert 2s and distinctly more powerful at 12 µm luminosities than both intermediate Seyferts and Seyfert 2s.
- Seyfert 2 galaxies with a detection of an HBLR show a significantly higher X-ray luminosity than those without a detection, supporting the findings of Tran (2003).
- The Seyfert 2 fraction of Seyfert galaxies is a strong decreasing function of X-ray luminosity dropping from $\sim 60\%$ to $\sim 30\%$ at $10^{41}$ erg s$^{-1}$.
- our X-ray data are in general support of the classification of AGN using optical emission lines, though we find seven ‘hidden’ AGN from X-ray data in galaxies optically defined as H II/AGN composite or LINER, and two further candidates in the H II defined NGC 1482 and NGC 1598 due to their large detected absorption columns.
- H II/AGN composites show a higher average [O III] luminosity than pure H II galaxies indicating AGN power in the composites, plus 17% show X-ray indications of AGN power, supporting claims that these galaxies harbour at least a low level active nucleus.
- X-ray indications of AGN power, being heavy absorption and/or high X-ray luminosity, are found in 40% of MIR selected LINERs.
- using a lower X-ray luminosity of $10^{41}$ erg s$^{-1}$, rather than the widely used $10^{42}$ erg s$^{-1}$, to select optical AGN is effective, with only a 3% contamination rate by star-forming galaxies. Including heavily obscured X-ray sources with $N_{H}> 10^{23}$ cm$^{-2}$ also adds to the number of AGN selected with the exclusion of star-forming galaxies.
- we find general support for AGN unification schemes due to the distribution of power-law indices, $\Gamma$, for Seyfert 1s and 2s being consistent with each other implying that the power generation mechanism is the same in both. We also find that on average the $N_{H}$ measured in Seyfert 2s is higher than Seyfert 1s, as expected from unification schemes.
• however, in 24% of cases the absorption measured in the X-ray spectra does not correspond directly with that implied in the optical band from the visibility of the BLRs.
• a luminosity dependent modification to the AGN unified scheme is required. This is to account for the decrease in the obscured fraction at high X-ray luminosities ($L_X > 10^{43}$ erg s$^{-1}$), possibly due to the recession of the torus at these high source powers; and also a decrease in both the obscured fraction and HBLR detection at low X-ray luminosities ($L_X < 10^{42}$ erg s$^{-1}$).
• 12 micron selected galaxies contain a higher fraction of obscured (62 ± 5%) and Compton thick (20 ± 4%) AGN than hard X-ray and optically selected samples, supporting MIR selection as a relatively unbiased method of selecting AGN.
• use of the 'T' ratio to find candidate Compton thick sources can often be unreliable, partly due to large extinction corrections. We can support the use of the ratio to exclude Compton thickness though, as a high ratio almost exclusively belongs to Compton thin sources.
• our work on the locally selected 12MGS is important for high redshift AGN studies, especially for IR selected samples, as we have shown that this selection method is relatively unbiased, and that X-ray luminosity and accurate $N_{\text{H}}$ information can be valuable for selecting AGN.

8 ACKNOWLEDGEMENTS

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Table 1: Optical line ratio data compiled from the literature and nuclear activity classification based on the scheme of Kewley et al. (2006). Also included are the observed fluxes of the [O \text{III}] emission line, the Balmer decrement, and the derived absorption corrected [O \text{III}] fluxes. Column (1) Galaxy name; Column (2) the emission line flux ratio [O \text{III}]/H\text{\beta}; Column (3) the emission line flux ratio [O \text{I}]/H\alpha; Column (4) the emission line flux ratio [N \text{II}]/H\alpha; Column (5) the emission line flux ratio [S \text{II}]/H\alpha; Column (6) the observed flux of the [O \text{III}] $\lambda$5007 line in 10$^{-16}$ erg s$^{-1}$; Column (7) the Balmer decrement H\alpha/H\beta; Column (8) the flux of the [O \text{III}] line corrected for absorption using the Balmer decrement; Column (9) reference for the line ratio data: 1=Armus et al. (1989), 2=Baan et al. (1998), 3=Corbett et al. (2003), 4=de Grijs et al. (1992), 5=Gonzaga et al. (1999), 6=Ho et al. (1997), 7=Kewley et al. (2001), 8=Kim et al. (1995), 9=Kong et al. (2002), 10=Kopylov et al. (1974), 11=Maia et al. (1987), 12=Rodriguez, et al. In prep, 13=Seigle & Wolstencroft (1993), 14=Vaceli et al. (1997), 15=Veron-Cetty & Veron (1986), 16=SDSS; Column (10) the activity classification based on diagram 1; Column (11) the activity classification based on diagram 2; Column (12) the activity classification based on diagram 3; Column (13) the adopted activity classification.

| Name                  | [O \text{III}]/H\beta | [O \text{I}]/H\alpha | [N \text{II}]/H\alpha | [S \text{II}]/H\alpha | F_{[O \text{III}]} (obs) | F_{[O \text{III}]} (cor) | ref | classification | adopted |
|----------------------|------------------------|-----------------------|------------------------|------------------------|--------------------------|--------------------------|-----|----------------|---------|
| MRK 0335             | 0.25                   | -                     | -                      | -                      | -                        | 2250                      | 12  | -              | Sy1.2   |
| NGC 0017             | 2.86                   | 0.11                  | 1.20                   | 0.52                   | 91                       | 20.6                     | 23800 | 12  | AGN           | Sy2     | Sy2    | Sy2    |
| NGC 0150             | 1.32                   | 0.03                  | 0.55                   | 0.27                   | -                        | -                        | 7   | H\text{\beta}/AGN | H\text{\beta} | H\text{\beta} | H\text{\beta}/AGN |
| NGC 0214             | -                      | -                     | -                      | -                      | -                        | -                        | 7   | H\text{\beta}/AGN | H\text{\beta} | H\text{\beta} | H\text{\beta}/AGN |
| NGC 0262             | 9.17                   | 0.26                  | 0.95                   | -                      | 5170                     | 3.2                      | 5470 | 12  | AGN           | -       | Sy2    | Sy2    |
| UGC 00545            | 0.24                   | -                     | 0.15                   | -                      | 743                      | 2.4                      | 743  | 12  | H\text{\beta} | -       | -     | Sy1    |
| NGC 0424             | 4.55                   | 0.06                  | 0.30                   | 0.16                   | 7000                     | 2.9                      | 7000 | 14  | AGN           | H\text{\beta} | Sy2    | Sy2    |
| NGC 0526A            | 11.52                  | 0.25                  | 0.71                   | 0.56                   | 8400                     | 1.4                      | 490  | 12  | AGN           | H\text{\beta} | Sy2    | Sy2    |
| NGC 0513             | 3.05                   | 0.11                  | 0.75                   | 0.46                   | 490.7                    | 3.1                      | 490  | 12  | AGN           | H\text{\beta} | Sy2    | Sy2    |
| NGC 0520             | 0.74                   | 0.01                  | 0.39                   | 0.29                   | 41                       | 4.2                      | 126  | 6   | H\text{\beta} | H\text{\beta} | H\text{\beta} | H\text{\beta} |
| NGC 0660             | 2.53                   | 0.05                  | 0.85                   | 0.43                   | 84                       | 14.3                     | 7520 | 6   | AGN           | H\text{\beta} | H\text{\beta} | Sy2    |
| 2MASX J01500266-     | 5.25                   | -                     | 0.55                   | -                      | 535                      | 7.5                      | 7190 | 12  | AGN           | -       | -     | Sy2/LINER |
| NGC 0695             | 0.30                   | 0.05                  | 0.45                   | 0.17                   | -                        | 7.7                      | -    | 8   | H\text{\beta} | H\text{\beta} | H\text{\beta} | H\text{\beta} |
| NGC 1052             | 2.00                   | 0.05                  | 1.12                   | 0.22                   | 2110                     | 2.9                      | 2110 | 12  | AGN           | LINER   | LINER | LINER |
| MESSIER 077          | 9.13                   | 0.07                  | 1.88                   | 0.36                   | 163000                   | 4.3                      | 438000 | 12 | AGN          | Sy2     | Sy2    | Sy2    |
| ARP 118              | 12.57                  | 0.12                  | 1.45                   | 0.63                   | 465                      | 6.5                      | 4160 | 12  | AGN           | Sy2     | Sy2    | Sy2    |
| MCG -02-08-039       | 18.14                  | 0.18                  | 0.53                   | 0.27                   | 1730                     | 6.9                      | 18100 | 12 | AGN           | Sy2     | Sy2    | Sy2    |
| NGC 1194             | 23.77                  | 0.09                  | 0.49                   | 0.56                   | 229                      | 16.5                     | 31400 | 16 | AGN           | Sy2     | Sy2    | Sy2    |
| NGC 1291             | -                      | -                     | -                      | -                      | 219                      | -                        | -    | -   | -              | -       | -     | -     |
| NGC 1313             | -                      | -                     | -                      | -                      | 219                      | -                        | -    | -   | -              | -       | -     | -     |
| NGC 1316             | -                      | -                     | -                      | -                      | 210                      | -                        | -    | -   | -              | -       | -     | -     |
| NGC 1320             | 10.49                  | 0.12                  | 0.71                   | 0.43                   | 1240                     | 5.6                      | 6860  | 12 | AGN           | Sy2     | Sy2    | Sy2    |
| NGC 1365             | 1.83                   | 0.04                  | 0.48                   | 0.16                   | 620                      | 8.8                      | 13100 | 15 | H\text{\beta}/AGN | H\text{\beta} | H\text{\beta} | Sy1.8  |
| NGC 1386             | 16.67                  | 0.24                  | 1.94                   | 0.82                   | 7800                     | 2.8                      | 7800  | 14 | AGN           | Sy2     | Sy2    | Sy2    |
| NGC 1482             | 0.21                   | -                     | 0.42                   | 0.29                   | -                        | -                        | 7    | H\text{\beta} | -       | -     | H\text{\beta} |
| 3C 120               | 1.26                   | 0.01                  | 0.05                   | -                      | 3820                     | 6.9                      | 39600 | 12 | H\text{\beta} | -       | H\text{\beta} | Sy1    |
| NGC 1614             | 1.05                   | 0.03                  | 0.57                   | 0.22                   | 912                      | 11.1                     | 38900 | 12 | H\text{\beta}/AGN | H\text{\beta} | H\text{\beta} | H\text{\beta}/AGN |
| MRK 0618             | 19.50                  | 0.07                  | 0.71                   | 0.41                   | 1410                     | -                        | 7    | 12 | AGN           | Sy2     | Sy2    | Sy1    |
| NGC 1672             | 0.39                   | -                     | 0.47                   | 0.24                   | 998                      | 6.8                      | 12600 | 12 | AGN           | H\text{\beta} | H\text{\beta} | H\text{\beta} |
| Object         | R.A.  | Dec. | Brightness | Distance | Type    | AGN Type | LINER | Sy | H II |
|---------------|-------|------|------------|----------|---------|----------|-------|----|------|
| NGC 1667      | 5.82  | 0.13 | 0.99       | 0.52     | 603     | 10.3     | 20600 | 12 | AGN | Sy2  |
| NGC 1808      | 0.16  | 0.02 | 0.54       | 0.21     | 145     | 14.2     | 16200 | 7.12| H II| H II |
| ESO 362- G 018| 1.79  | 0.05 | 0.13       | 0.04     | 3650    | 4.0      | 7660  | 12 | H II| H II |
| 2MASX J05210136 | 36.85 | 0.12 | 1.69       | 0.32     | 799     | 14.5     | 74200 | 12 | AGN | Sy2  |
| 2MASX J05580206 | 0.52  | -    | -          | -        | -       | 701      | 9.1   | 16400| -    | -    |
| IC 0450       | 2.12  | -    | 0.10       | -        | 7000    | 7.6      | 97000 | 4  | H II| -    |
| UGC 03973     | 1.23  | 0.02 | 0.12       | 0.11     | 14      | 6.4      | 120   | 16 | H II| H II |
| IRASF07599+6508 | 0.30  | -    | -          | -        | 33      | 33.6     | 36500 | 12 | -    | -    |
| NGC 2639      | 3.37  | 0.39 | 3.62       | 1.77     | 234     | 4.3      | 596   | 12 | AGN | Sy2  |
| NGC 2655      | 3.83  | 1.04 | 2.91       | 1.93     | 391     | 5.0      | 1590  | 6  | AGN | Sy2  |
| IC 2431       | 0.61  | 0.03 | 0.36       | 0.30     | 62      | 4.7      | 263   | 16 | H II| H II |
| MRK 0704      | 0.49  | -    | -          | -        | 1410    | 7.9      | 22200 | 12 | -    | -    |
| NGC 2841      | 1.85  | 0.17 | 1.84       | 1.13     | 109     | 3.3      | 130   | 12 | AGN | LINER|
| UGC 05101     | 2.29  | 0.08 | 1.27       | 0.40     | 45      | 19.7     | 10300 | 12 | Sy2 | Sy2  |
| NGC 2992      | 10.85 | 0.05 | 0.16       | 0.84     | 5920    | 7.3      | 36300 | 12 | AGN | Sy2  |
| MESSIER 081   | 1.14  | 0.21 | 0.37       | 0.23     | 2260    | 5.8      | 13900 | 12 | H II| LINER|
| MESSIER 082   | 0.36  | 0.01 | 0.56       | 0.18     | 316     | 25.0     | 14600 | 6  | H II| AGN|
| NGC 3079      | 3.60  | 0.18 | 1.59       | 0.86     | 18      | 23.6     | 7030  | 12 | AGN | LINER|
| NGC 3147      | 6.14  | 0.15 | 2.71       | 1.14     | 172     | 5.3      | 828   | 12 | AGN | LINER|
| NGC 3227      | 2.71  | 0.08 | 0.43       | 0.22     | 6180    | 6.3      | 50400 | 12 | H II| Sy2  |
| NGC 3310      | 0.95  | 0.04 | 0.66       | 0.26     | 340     | 4.8      | 1200  | 6  | H II| H II |
| NGC 3486      | 4.52  | 0.09 | 1.04       | 0.93     | 131     | 3.3      | 159   | 12 | AGN | LINER|
| NGC 3516      | 0.42  | -    | 0.06       | -        | 3630    | 3.0      | 36300 | 12 | H II| -    |
| MESSIER 066   | 2.89  | 0.13 | 1.44       | 0.74     | 295     | 5.9      | 19600 | 12 | AGN | Sy2  |
| NGC 3690      | 1.37  | 0.03 | 0.40       | 0.25     | 492     | 5.9      | 3230  | 6  | H II| H II|
| NGC 3735      | 7.06  | 0.05 | 0.85       | 0.38     | 374     | 6.3      | 2940  | 12 | AGN | Sy2  |
| NGC 3976      | 3.50  | 0.10 | 1.95       | 0.83     | 77      | 4.4      | 210   | 12 | AGN | Sy2  |
| NGC 3982      | 14.54 | 0.42 | 0.99       | 0.64     | 1810    | 3.5      | 2480  | 12 | AGN | Sy2  |
| NGC 4013      | 0.71  | 0.11 | 1.13       | 0.83     | 7       | 2.0      | 7     | 6  | AGN | LINER|
| MESSIER 090   | 1.18  | 0.06 | 0.90       | 0.40     | 340     | 4.8      | 1200  | 6  | H II| H II|
| MESSIER 100   | 0.79  | 0.11 | 1.18       | 0.48     | 52      | 4.6      | 160   | 6  | AGN | LINER|
| MESSIER 099   | 0.90  | 0.02 | 0.48       | 0.23     | 29      | 6.3      | 226   | 6  | H II| AGN|
| MESSIER 100   | 0.79  | 0.11 | 1.18       | 0.48     | 52      | 4.6      | 160   | 6  | AGN | LINER|
| NGC 4388      | 12.04 | 0.39 | 0.43       | 0.27     | 4890    | 4.8      | 17600 | 12 | AGN | Sy2  |
| NGC 4414      | 0.58  | 0.14 | 0.59       | 0.50     | 19      | 3.0      | 19    | 6  | H II| LINER|
| NGC 4449      | 2.41  | 0.02 | 0.14       | 0.23     | 1780    | 3.2      | 2570  | 6  | H II| H II|
| 3C 273        | -     | -    | -          | -        | -       | -        | -     | 12 | -    | -    |
| NGC 4490      | 2.55  | 0.12 | 0.25       | 0.71     | 33      | 6.3      | 262   | 6  | H II| LINER|
| MESSIER 088   | 5.31  | 0.19 | 2.10       | 0.94     | 369     | 3.6      | 559   | 6  | AGN | Sy2  |
| NGC 4559      | 0.35  | 0.03 | 0.42       | 0.40     | 9       | 3.7      | 19    | 6  | H II| H II|
| MESSIER 090   | 1.18  | 0.06 | 0.90       | 0.40     | 552     | 5.0      | 2250  | 6  | AGN | H II|
| MESSIER 058   | 2.87  | 0.50 | 2.07       | 1.69     | 724     | 3.4      | 941   | 12 | AGN | LINER|
| NGC 4593      | 22.91 | 0.12 | 1.26       | 0.29     | 1630    | 5.8      | 10400 | 7,12| AGN | Sy2  |
| Object          | Distance (kpc) | Distance Error (%) | Distance Error (kpc) | Mass (M☉) | Mass Error (%) | Mass Error (M☉) | Classification | Type          |
|-----------------|---------------|--------------------|----------------------|-----------|---------------|----------------|----------------|---------------|
| MESSIER 104     | 1.57          | 0.18               | 0.17                 | 3.0       | 0.67          | 0.67           | AGN            | LINER         |
| NGC 4631        | 1.53          | 0.03               | 0.02                 | 3.0       | 0.78          | 0.78           | AGN            | LINER         |
| NGC 4666        | 1.31          | 0.06               | 0.05                 | 3.0       | 0.78          | 0.78           | AGN            | LINER         |
| NGC 4725        | -             | -                  | -                    | -         | -             | -              | -              | -             |
| UGC 08058       | 0.37          | -                  | -                    | -         | -             | -              | -              | -             |
| NGC 4968        | 20.88         | 0.21               | 0.15                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 5005        | 2.27          | 0.65               | 0.49                 | 3.0       | 0.78          | 0.78           | AGN            | LINER         |
| MESSIER 063     | 1.89          | -                  | -                    | -         | -             | -              | -              | -             |
| MCG -03-34-064  | 11.72         | 0.22               | 0.12                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 5170        | -             | -                  | -                    | -         | -             | -              | -              | -             |
| NGC 5194        | 12.64         | 0.15               | 0.27                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| ESO 383-G 035   | 0.71          | 0.18               | 0.15                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| MESSIER 083     | 0.29          | 0.02               | 0.01                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| IRASF13349+2438 | 0.40          | -                  | -                    | -         | -             | -              | -              | -             |
| NGC 5256 (S)    | 2.65          | 0.13               | 0.07                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 5253        | 4.17          | 0.03               | 0.01                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| MRK 0273        | 5.87          | 0.13               | 1.04                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| IC 4329A        | 0.64          | 0.01               | -                    | -         | -             | -              | -              | -             |
| UGC 08850 (E)   | 8.30          | -0.02              | 0.40                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 5506        | 8.59          | 0.12               | 0.67                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 5548        | 10.09         | 0.36               | 0.88                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 5775        | 18.41         | 0.10               | 0.75                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| 2MASX J15115979- | 1.27          | -                  | 0.09                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| VV 705          | 0.92          | 0.03               | 0.50                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| UGC 09944       | 9.54          | 0.15               | 0.99                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| 2MASX J15504152- | 17.92         | 0.08               | 0.57                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 6240        | 1.43          | 0.31               | 1.26                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 6286        | 0.45          | 0.08               | 0.49                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 6552        | -             | -                  | -                    | -         | -             | -              | -              | -             |
| AM 1925-724     | 5.25          | 0.14               | 1.15                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 6810        | 0.60          | -                  | 0.62                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 6890        | 33.33         | 0.16               | 1.25                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| MRK 0509        | 0.40          | -                  | 0.18                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| ESO 286-IG 019  | 0.68          | 0.06               | 0.44                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 7090        | -             | -                  | -                    | -         | -             | -              | -              | -             |
| NGC 7172        | 4.77          | 0.10               | 0.99                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 7213        | 1.04          | 0.16               | 0.14                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| IC 5169         | 1.58          | 0.03               | 0.68                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 7252        | -             | -                  | -                    | -         | -             | -              | -              | -             |
| 3C 445          | 2.89          | 0.02               | 0.04                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2            |
| NGC 7314        | 1.27          | 0.01               | 0.08                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2/LINER     |
| MCG -03-58-007  | 7.91          | -                  | 1.02                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2/LINER     |
| NGC 7469        | 0.44          | -                  | -                    | -         | -             | -              | -              | -             |
| NGC 7479        | 3.97          | 0.22               | 1.20                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2/LINER     |
| ESO 148-IG 002  | 2.69          | 0.04               | 0.82                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2/LINER     |
| NGC 7552        | 0.14          | 0.01               | 0.58                 | 3.0       | 0.78          | 0.78           | AGN            | Sy2/LINER     |
| NGC 7582  | 2.99 | 0.04 | 0.69 | 0.31 | 4530 | 7.0 | 49000 | 12 | AGN | Sy2 | Sy2 | Sy2 |
|----------|------|------|------|------|------|------|-------|----|-----|-----|-----|-----|
| NGC 7674 | 10.55 | 0.18 | 0.92 | 0.53 | 4780 | 3.4 | 6210  | 12 | AGN | Sy2 | Sy2 | Sy2 |
| NGC 7714 | 1.35  | 0.01 | 0.35 | 0.15 | -    | -   | -     | -  | Hii/AGN | Hii | Hii | Hii/AGN |
| NGC 7771 | 1.04  | 0.04 | 0.48 | 0.41 | -    | -   | -     | 8  | Hii/AGN | Hii | Hii | Hii/AGN |
| MRK 0331 | 0.39  | 0.03 | 0.54 | 0.27 | 84   | 8.3 | 1540  | 12 | Hii/AGN | Hii | Hii | Hii/AGN |

XMM survey of the 12MGS
Table 2: This table presents multi-wavelength data for our sample, which has been in the analysis in this chapter. Column (1) Galaxy name; Column (2) Optical type as determined in Table 1; Column (3) Broad line region information taken from [Véron-Cetty & Véron] (2006). h: hidden BLR detected in optical polarised light. i: broad lines detected in the near-IR, b: broad lines detected in the optical spectrum of a LINER or H II region; Column (4) Logarithm of the observed 2-10 keV luminosity (erg s$^{-1}$); Column (5) Logarithm of the 12 $\mu$m luminosity (erg s$^{-1}$); Column (6) Logarithm of the absorption corrected [O III] luminosity (erg s$^{-1}$); Column (7) log$_{10}$ $N_H$ measured, cm$^{-2}$; Column (8) log$_{10}$(T=F$_{2−10}$/F$_{[OIII]}$) where F$_{2−10}$ is the observed X-ray flux, and F$_{[OIII]}$ is the absorption corrected [O III] flux.

| Name          | Type   | BLR  | $L_X$  | $L_{12\mu m}$ | $L_{[OIII]}$ | $N_H$ | T                  |
|---------------|--------|------|--------|---------------|--------------|-------|--------------------|
| MRK0335       | Sy1.2  | -    | 43.45  | 44.01         | -            | 20.56 | -                  |
| NGC0017       | Sy2    | -    | 41.98  | 43.94         | 42.32        | 23.67 | -0.93              |
| NGC0150       | H II/AGN | -    | 40.37  | 43.00         | -            | 20.18 | -                  |
| NGC0214       | -      | -    | 41.19  | 43.74         | -            | 23.24 | -                  |
| NGC0262       | Sy2    | h    | 43.34  | 43.79         | 41.44        | 23.12 | 1.71               |
| UGC00545      | Sy1    | -    | 43.65  | 45.02         | 41.82        | 20.68 | 1.82               |
| NGC0424       | Sy2    | h    | 42.52  | 43.98         | 41.34        | 23.37 | 0.29               |
| NGC0526A      | Sy1.5  | h    | 43.29  | 43.68         | 41.31        | 22.06 | 1.96               |
| NGC0513       | Sy2    | h    | 42.66  | 43.73         | 40.62        | 22.83 | 1.92               |
| NGC0520       | H II   | -    | 39.95  | 43.40         | 39.21        | 20.49 | 0.68               |
| NGC0660       | Sy2    | -    | 39.41  | 43.00         | 40.11        | 21.42 | -0.70              |
| 2MASXJ01500266 | Sy2/LINER | h   | 41.74  | 43.75         | 41.71        | 21.32 | 0.04               |
| NGC0695       | H II   | -    | 41.62  | 44.52         | -            | 20.84 | -                  |
| NGC1052       | LINER  | h    | 41.49  | 42.48         | 40.07        | 23.49 | 1.34               |
| MESSIER077    | Sy2    | h    | 42.15  | 44.51         | 42.14        | 24.18 | -0.95              |
| ARP118        | Sy2    | -    | 43.61  | 44.09         | 41.90        | 23.81 | 0.90               |
| MCG-02-08-039 | Sy2    | h    | 42.93  | 44.25         | 42.57        | 23.67 | -0.34              |
| NGC1194       | Sy2    | -    | 42.32  | 43.46         | 42.11        | 23.83 | -0.49              |
| NGC1291       | -      | -    | 39.65  | 42.23         | -            | 20.20 | -                  |
| NGC1313       | -      | -    | 39.32  | 42.13         | -            | 21.18 | -                  |
| NGC1316       | -      | -    | 40.33  | 42.97         | -            | 20.38 | -                  |
| NGC1320       | Sy2    | -    | 42.65  | 43.14         | 41.08        | 24.31 | -0.16              |
| NGC1365       | Sy1.8  | -    | 42.46  | 43.87         | 40.94        | 23.24 | 1.00               |
| NGC1386       | Sy2    | i    | 40.88  | 42.38         | 40.16        | 24.18 | -0.39              |
| NGC1482       | H II   | -    | 40.74  | 43.57         | -            | 22.94 | -                  |
| 3C120         | Sy1    | -    | 44.19  | 44.43         | 43.00        | 21.03 | 1.06               |
| NGC1614       | H II/AGN | -    | 41.17  | 44.32         | 42.34        | 21.28 | -1.17              |
| MRK0618       | Sy1    | -    | 43.44  | 44.49         | -            | 20.68 | -                  |
| NGC1672       | H II   | -    | 39.59  | 43.43         | 40.73        | 20.48 | -1.15              |
| NGC1667       | Sy2    | -    | 42.76  | 43.91         | 42.03        | 24.43 | -1.31              |
| NGC1808       | H II   | -    | 40.39  | 43.52         | 40.59        | 22.94 | -0.20              |
| ESO362-G018   | Sy1.5  | -    | 42.37  | 43.30         | 41.42        | 23.19 | 0.64               |
| 2MASXJ05210136 | Sy2    | h    | 44.17  | 44.88         | 43.50        | 22.82 | -0.37              |
| 2MASXJ05580206 | Sy1    | -    | 44.07  | 44.63         | 42.64        | 20.59 | 1.41               |
| Name          | Type   | X-ray   | Radio   | Optical  | Others     |
|---------------|--------|---------|---------|----------|------------|
| IC0450        | Sy1.5  | 43.06   | 43.72   | 42.89    | 22.46      | 0.11 |
| UGC03073      | Sy1.2  | 43.78   | 44.00   | 40.13    | 20.72      | 3.00 |
| IRASF07599+6508 | Sy1    | 42.08   | 45.69   | 44.34    | 20.62      | -2.26 |
| NGC2639       | Sy1.9  | 40.14   | 43.22   | 40.21    | 20.48      | -0.08 |
| NGC2655       | LINER  | 41.72   | 42.61   | 39.89    | 23.36      | 0.82 |
| IC2431        | Hii    | 41.37   | 44.79   | 41.19    | 20.57      | 0.18 |
| MRK0704       | Sy1.5  | 43.39   | 44.31   | 42.64    | 22.21      | 0.66 |
| NGC2841       | LINER  | 39.19   | 42.34   | 38.10    | 20.15      | 1.09 |
| UGC05101      | Sy2    | 42.45   | 44.50   | 42.57    | 23.70      | -0.76 |
| NGC2992       | Sy1.9  | 43.05   | 43.23   | 41.68    | 21.61      | 1.37 |
| MESSIE.R081   | Sy1.8  | 38.77   | 40.89   | 37.86    | 20.71      | 0.90 |
| MESSIE.R082   | Hii/AGN| 40.11   | 43.25   | 40.20    | 20.71      | -0.08 |
| NGC3079       | Sy2    | 40.87   | 43.29   | 40.33    | 24.18      | -0.32 |
| NGC3147       | Sy2    | 41.44   | 43.68   | 40.21    | 20.46      | 1.23 |
| NGC3227       | Sy1.5  | 41.57   | 42.90   | 41.23    | 22.90      | 0.24 |
| NGC3310       | Hii/AGN| 40.32   | 42.99   | 39.46    | 20.85      | 0.86 |
| NGC3486       | Sy2    | 39.93   | 42.28   | 38.27    | 20.28      | 0.80 |
| NGC3516       | Sy1.5  | 43.77   | 43.23   | 40.80    | 23.51      | 1.63 |
| MESSIE.R066   | Sy2    | 39.48   | 43.12   | 39.40    | 20.32      | 0.07 |
| NGC3690       | Hii/AGN| 41.30   | 44.39   | 40.89    | 20.78      | 0.41 |
| NGC3735       | Sy2    | 40.21   | 43.45   | 40.72    | 20.48      | -0.51 |
| NGC3976       | Sy2    | 40.09   | 42.96   | 39.51    | 20.04      | 0.52 |
| NGC3982       | Sy2    | 40.16   | 42.55   | 39.87    | 23.34      | -0.12 |
| NGC4013       | LINER  | 39.02   | 42.38   | 37.07    | 22.95      | 1.77 |
| ARP244        | Hii    | 40.39   | 43.55   | 39.26    | 20.51      | 1.12 |
| NGC4051       | Sy1.5  | 40.91   | 42.60   | 39.72    | 23.27      | 1.07 |
| NGC4151       | Sy1.5  | 42.09   | 43.07   | 41.48    | 22.78      | 0.57 |
| NGC4214       | Hii    | 38.95   | 42.21   | 39.37    | 20.78      | -0.43 |
| NGC4253       | Sy1.5  | 42.96   | 43.51   | 41.85    | 20.26      | 1.11 |
| MESSIE.R099   | Hii/AGN| 40.00   | 44.12   | 39.51    | 20.46      | 0.49 |
| MESSIE.R100   | LINER  | 40.06   | 43.59   | 38.98    | 20.30      | 1.07 |
| NGC4388       | LINER  | 42.89   | 43.61   | 41.44    | 23.60      | 1.08 |
| NGC4414       | Hii/LINER| 39.33  | 42.98   | 37.38    | 20.20      | 1.95 |
| NGC4449       | Hii    | 38.51   | 41.57   | 38.44    | 20.30      | 0.05 |
| 3C273         | Sy1    | 45.82   | 46.15   | -        | 20.26      | -    |
| NGC4490       | Hii/AGN| 39.49   | 42.57   | 38.32    | 21.30      | 1.16 |
| MESSIE.R088   | Sy2    | 41.69   | 43.87   | 39.86    | 24.18      | 0.33 |
| NGC4559       | Hii    | 39.91   | 42.29   | 37.49    | 21.04      | 2.41 |
| MESSIE.R090   | Hii/AGN| 37.25   | 40.52   | 37.60    | 20.45      | -0.35 |
| MESSIE.R058   | LINER  | 41.35   | 43.23   | 39.73    | 20.45      | 1.62 |
| NGC4593       | Sy1    | 42.84   | 43.33   | 41.27    | 20.30      | 1.56 |
| MESSIE.R104   | LINER  | 38.89   | 41.10   | 36.18    | 20.85      | 2.71 |
| NGC4631       | Hii    | 38.90   | 43.08   | 37.39    | 21.32      | 1.51 |
| NGC4666       | Hii/LINER| 40.48  | 43.71   | -        | 20.23      | -    |
| NGC4725       | Hii    | 39.25   | 42.31   | -        | 19.95      | -    |
| UGC08058      | Sy1    | 42.47   | 44.70   | -        | 22.85      | -    |
| Object            | Type   | a    | b    | c    | d    | e    |
|-------------------|--------|------|------|------|------|------|
| NGC4968           | Sy2    | 43.22| 43.53| 41.91| 24.48| -1.15|
| NGC5005           | LINER  |     | 39.91| 42.97| 39.03| 20.04| 0.88 |
| MESSIE R063       | LINER  |     | 39.17| 42.95| 38.19| 20.60| 0.94 |
| MCG-03-34-064     | Sy2    |     | 42.95| 44.16| 42.08| 23.60| 0.12 |
| NGC5170           |        |     | 39.34| 42.74|      |      |      |
| NGC5194           | Sy2    |     | 40.43| 43.13| 40.25| 24.18| -0.93|
| ESO383-G035       | Sy1.2  |     | 42.75| 43.04| 41.08| 20.59| 1.64 |
| MESSIE R083       | Hr     |     | 39.41| 43.62| 39.29| 20.60| 0.11 |
| IRASF13349+2438   | Sy1    |     | 43.81| 45.66| 44.26| 22.02| -0.46|
| NGC5256           | Sy2    |     | 42.21| 44.13|      |      | 23.24|
| NGC5253           | Hr/AGN |     | 37.94| 41.66| 40.47| 20.60| -2.53|
| MRK0273           | Sy2    |     | 42.84| 44.26| 43.17| 23.78| -1.08|
| IC4329A           | Sy1.2  |     | 43.75| 44.21| 42.88| 20.66| 0.87 |
| UGC08850          | Sy2    | h   | 43.15| 44.85|      |      | 23.59|
| NGC5506           | Sy2    | i   | 42.85| 43.43| 41.92| 22.51| 0.84 |
| NGC5548           | Sy1.5  |     | 43.43| 43.86| 41.69| 20.20| 1.74 |
| NGC5775           | Sy2    |     | 39.84| 43.50| 42.36| 21.72| -2.74|
| 2MASX J15115979   | Sy1    |     | 43.94| 44.54| 43.26| 20.92| 0.35 |
| VV705             | Hr/AGN |     | 42.35| 44.47| 41.84| 23.93| -0.19|
| UGC09944          | Sy2    |     | 41.60| 44.04| 42.16| 20.45| -1.32|
| 2MASX J15504152   | Sy2    | h   | 43.00| 44.10| 42.59| 24.18| -0.62|
| NGC6240           | LINER  |     | 43.49| 44.34| 42.12| 24.05| 0.30 |
| NGC6286           | Hr/AGN |     | 40.58| 43.96|      |      | 20.26|
| NGC6552           | h      |     | 42.88| 43.95|      |      | 24.18|
| AM1925-724        | Sy1    |     | 42.79| 44.77|      |      | 23.58|
| NGC6810           | Hr/AGN |     | 39.91| 43.53| 40.62| 20.70| -0.71|
| NGC6890           | Sy2    |     | 42.18| 43.12| 42.02| 24.18| -1.41|
| MRK0509           | Sy1.2  |     | 44.00| 44.31| 42.48| 20.62| 1.52 |
| ESO286-IG019      | Hr/AGN |     | 42.31| 44.55|      |      | 23.69|
| NGC7090           |        |     | 39.82| 42.27|      |      | 21.15|
| NGC7172           | Sy2    |     | 42.74| 43.26| 38.98| 22.93| 3.57 |
| NGC7213           | Hr/LINER |     | 42.66| 43.08| 41.44| 20.04| 0.77 |
| IC5169            | Hr/AGN |     | 40.72| 43.20|      |      | 20.04|
| NGC7252           |        |     | 40.36| 43.69|      |      | 20.30|
| 3C445             | Sy1    |     | 43.94| 44.94| 43.45| 23.54| 0.27 |
| NGC7314           | Sy1.9  | h   | 42.33| 42.85| 39.94| 21.78| 2.37 |
| MCG-03-58-007     | Sy2/LINER |     | 42.74| 44.11| 41.69| 23.44| 0.58 |
| NGC7469           | Sy1.2  |     | 43.25| 44.37|      |      | 20.64|
| NGC7479           | Sy2    |     | 42.04| 43.69| 39.87| 24.30| 0.79 |
| ESO148-IG002      | Hr/AGN |     | 43.21| 44.59| 42.58| 24.18| -0.68|
| NGC7552           | Hr     |     | 40.21| 43.79|      |      | 20.11|
| NGC7582           | Sy2    | i   | 42.61| 43.56| 41.48| 24.18| -0.34|
| NGC7674           | Sy2    | h   | 43.62| 44.49| 42.08| 24.18| -0.01|
| NGC7714           | Hr/AGN |     | 40.52| 43.27|      |      | 21.15|
| NGC7771           | Hr/AGN |     | 40.92| 44.05|      |      | 20.70|
| Name  | Hα/AGN | RA  | Dec  | MRR0331 |  |  |
|-------|--------|-----|------|---------|  |  |
| MRK0331 |  | 40.67 | 43.95 | 41.08 | 21.08 | -0.41 |

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