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# A wide search of obscured Active Galactic Nuclei using *XMM-Newton* and *WISE*

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**Abstract.** We use the *WISE* all sky survey observations to look for counterparts of hard X-ray selected sources from the *XMM-Newton*-SDSS survey. We then measure the 12 $\mu$m luminosity of the AGN by decomposing their optical to infrared SEDs with a host and an AGN component and compare it to the X-ray luminosity and their expected intrinsic relation. This way we select 20 X-ray under-luminous heavily obscured candidates and examine their X-ray and optical properties in more detail. We find evidence for a Compton-thick nucleus for six sources, a number lower than what expected from X-ray background synthesis models, which shows the limitations of our method.

## 1. Overview

Heavily obscured and Compton-thick AGN are missing even in the deepest X-ray surveys, and indirect methods are required to detect them. Here we use a combination of the *XMM-Newton* serendipitous X-ray survey with the optical SDSS, and the *WISE* all-sky survey in order to check the efficiency of the low X-ray to infrared luminosity selection method in finding heavily obscured AGN. From the initial sample of 39830 X-ray sources on the footprint of the SDSS, we select the sources which are detected in the hard X-ray band (2–10 keV), and also have a redshift determination (photometric or spectroscopic) in the SDSS catalogue. We match this sample with the *WISE* catalogue, and fit the spectral energy distributions (SEDs) of the 2844 sources which have three, or more, photometric data-points in the infrared. We use the 2MASS and *WISE* photometry and perform a 2-component fit with a host and an AGN component to measure the mid-infrared luminosity of the AGN. We then select the heavily obscured AGN candidates by comparing this to the observed 2–10 keV X-ray luminosity and the intrinsic relation between the X-ray and the mid-infrared luminosities. With this approach we find 20 candidate heavily obscured AGN and we then examine their SEDs in more detail using also the optical photometry and a stellar component, and also their X-ray and optical spectra. 8 out of the 12 candidates for which X-ray spectra can be fitted (67%) show signs of obscuration. Similarly 7 of the 9 sources for which we have [OIII] spectral information from the SDSS (78%) are classified as heavily obscured. Combining all three criteria, we determine the final number of heavily obscured AGN to be 15–20, and the number of Compton-thick AGN to be six. These numbers are smaller than what would be expected from X-ray background population synthesis models, which probably demonstrates how the optical-infrared selection limits the efficiency of selecting obscured AGN by their

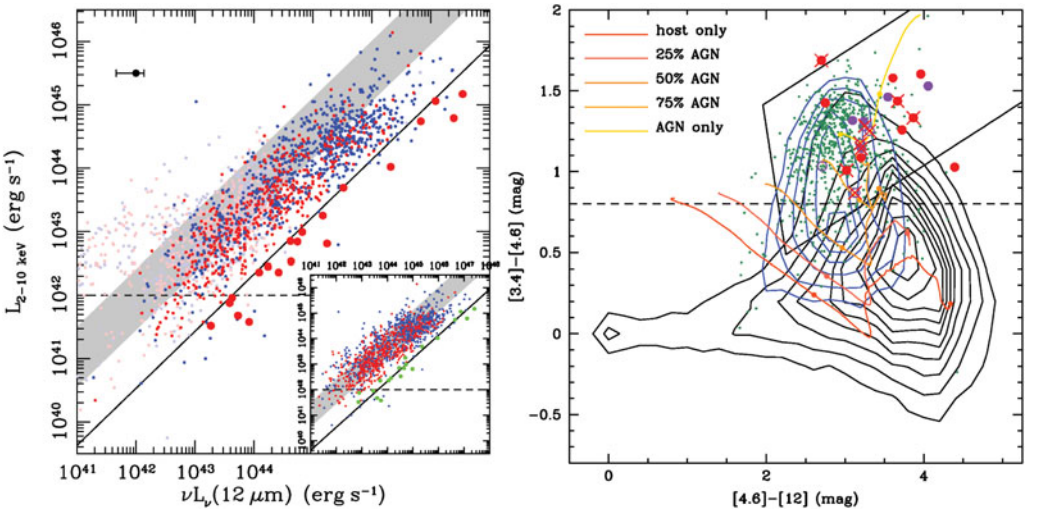


**Figure 1.** Left panel: In this figure we plot the hard X-ray (2-10 keV) luminosity against the 12 $\mu$m luminosities of the AGN component for soft (blue; HR<0.35) and hard (red; HR>0.35) X-ray sources. The expected relation from Gandhi *et al.*(2009) ($\pm\log(3)$) is shown by the grey area. The selection line (solid line) for our heavily obscured candidates represents a 4% reflection component from the obscured AGN, and the candidates are represented with the large red symbols. The dashed line represents the limit of $L_x = 10^{42}$ erg s$^{-1}$, below that the host galaxy contamination in the X-rays cannot be considered negligible. In the inset image we plot the same values but with the $2\sigma$ lower limit of the mid-infrared luminosity in the x-axis. The candidates are plotted with green colour, and half of them are below the black solid line. Right panel: The *WISE* colourcolour diagram. The black contours represent all the mid-infrared sources, while the blue contours represent the X-ray sources. The bulk of the X-ray sources is offset from the bulk of the infrared sources, but not in the areas where most of the luminous X-ray sources reside, according to Mateos *et al.*(2012) (solid lines) and Stern *et al.*(2012) (dashed line). The AGN with $L_{2-10\,keV} > 10^{44}$ erg s$^{-1}$ are plotted with green dots, and the majority of them are in the aforementioned areas. The heavily obscured candidates are plotted in red and purple lines, the red representing sources which are X-ray under-luminous even if we take into account the $2\sigma$ lower limit of their mid-infrared AGN luminosities (inset of the plot on the right). Red crosses mark sources that have an indication of heavy obscuration in their X-ray spectra ("X-ray obscured" sample). The orange to yellow contours are the tracks of a pure host SED gradually contaminated with an AGN (torus) SED.

X-ray to mid-infrared luminosity ratios. Finally, we test popular obscured AGN selection methods based on mid-infrared colours, and find that the probability of an AGN to be selected by its mid-infrared colours increases with the X-ray luminosity. The (observed) X-ray luminosities of heavily obscured AGN are relatively low ($L_{2-10\,keV} < 10^{44}$ erg s$^{-1}$), even though most of them are located in the "QSO locus". However, a selection scheme based on a relatively low X-ray luminosity and mid-infrared colours characteristic of QSOs would not select 25% of the heavily obscured AGN of our sample.

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