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Infrared selected highly obscured QSO

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Abstract. We select a sample of candidate highly obscured, luminous QSO in the SWIRE fields among the sources with the highest mid-infrared to optical flux ratio (MIR/O). Some of these extreme MIR/O sources are missed by the present X-ray surveys performed below 10 keV. We show how the the unprecedented image quality and throughtput of Simbol-X above 10 keV will allow the detection and detailed study of the spectral properties of highly obscured AGN.

Key words. galaxies: active – galaxies: nuclei – quasar: general – X-rays: galaxies

1. Introduction

Highly obscured QSO are difficult to select, even in the deepest X-ray surveys performed so far by both *Chandra* and *XMM–Newton* below 10 keV. The reason is that their obscuring hydrogen column density may exceed 10^{24} cm^{-2}, implying an optical depth $\gtrsim$ 1 up to $\sim$ 10 keV and making them "Compton thick". Indeed, only a handfull of Compton thick AGN have been detected in the Chandra Deep Fields. Compton thick AGN can be recovered thanks to the reprocessing of the AGN UV emission in the infrared by selecting sources with AGN luminosity's in the mid-infrared but faint in the optical band, where dust and gas block most of the nuclear emission. More in detail, Fiore et al. (2007), using a sample drawn from the GOODS-CDFS surveys, found a strong correlation of the mid-infrared to optical flux ratio with the monochromatic 5.8 μm luminosity for moderately obscured AGN in the GOODS-CDFS field. This correlation recalls that between the X/O and the 2-10 keV luminosity for moderately obscured AGN selected in X-rays, suggesting that high luminosity obscured AGN can be selected among high MIR/O sources. Fiore et al. (2007) then selected a sample of sources with extreme infrared to optical flux ratis (MIR/O>1000 and red optical colors R-K> 4.5) and showed that their X-ray properties are consistent with that of Compton-thick AGN. Such AGN are faint at X-rays energies and may escape direct detection even in deep *Chandra* exposures. To overcome this problem Fiore et al. (2007) stacked together the *Chandra* images of a hundred of these sources, thus effectively increasing by tens of times the sensitivity of the X-ray instruments. A faint but highly significant signal is associated to the infrared selected Compton thick AGNs. Most intriguingly the signal is stronger at higher X-ray energies: this the "smoking gun" of photoelectric absorption,

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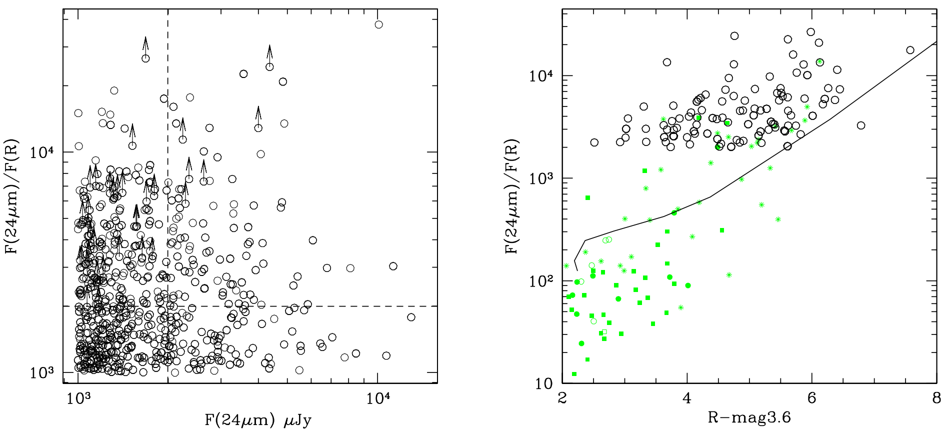

Fig. 1. Left panel: the selection of SWIRE sources with F(24μm)/F(R)>2000 and 24 μm flux >2 μJy. Right panel: the F(24μm)/F(R)as a function of R-mag[3.6 μm] for the GOODS-CDFS sample of Grazian et al. (2006)(small grey symbols) and the SWIRE sources (large dark symbols). The solid curve represents the colors of the obscured AGN A2690_75 from Pozzi et al. (2007).

confirming that the infrared selected sources are truly highly obscured AGN.

The previous analysis is limited to AGN of intermediate luminosity at z∼ 2. To extend the coverage of the luminosity-redshift plane and to search for Compton thick, high luminosity QSO requires a complementary observation strategy. Particularly useful to this purpose is the SWIRE survey, which has both Spitzer and optical medium-deep coverage on ∼ 50 deg^2 of sky. We use in the following the SWIRE survey to select a sample of candidate Compton thick QSO, which could be optimal targets for future Simbol-X observatios.

2. High MIR/O SWIRE sources

The five SWIRE fields (Elais N1-N2 and S1, Lockman Hole and XMM-LSS) cover an area of about 50 square degrees in the sky, and are therefore suitable for selecting highly obscured, luminous QSO. Such large area allows the selection of luminous, rare objects, which can hardly be found in pencil-beam surveys, such as the *Chandra* Deep Fields (see right panel of Figure 1). The five SWIRE fields have uniform Spitzer IRAC and MIPS coverage and optical photometry down to a typical magnitude R∼24. Only a small fraction of the total area is covered by rather shallow observations by *Chandra* or *XMM–Newton*. We selected about 50 sources in the SWIRE survey with MIR/O>2000, 24 μm flux density larger than 2 mJy and R-mag(3.6μm)>4.5 (Figure 1). These sources have faint or undetected optical counterparts (R>24). The right panel of Figure 1 shows that the extreme colors of these sources can be reproduced using obscured AGN SED templates. In this plot the solid line represents the color evolution at different redshifts for the obscured QSO A2690_75 from Pozzi et al. (2007) . About 50% of the high MIR/O sources has either *XMM–Newton* or *Chandra* coverage, and less than 1/4 of them (23%) are detected below 10 keV.

3. A template obscured QSO

To obtain an estimate of the intrinsic 2-10 keV luminosity starting from the 24 μm luminosity of our sample, we use IRAS 09104+4109 as a template obscured QSO. Its IRS spectrum shows the absorption band typical of obscured AGN and no PAH emission features, its infrared SED is dominated by the AGN emis-

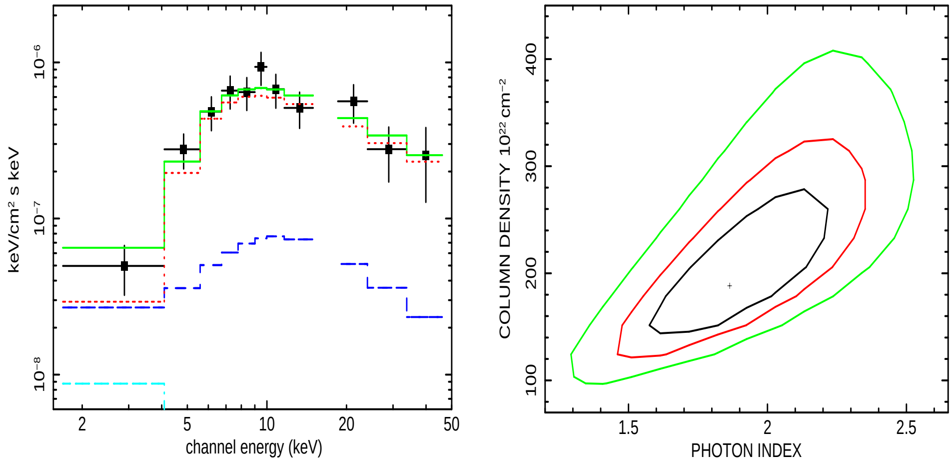

Fig. 2. Left panel: the Simbol-X simulated observed spectrum for the candidate obscured AGN SW110013.92+581034.9. Right panel: simulated χ^2 confidence contours for the two parameters N_H and photon index for the same source (67, 95 and 99 % levels).

sion. This source has a 2-10 keV luminosity of about 8×10^{44} cgs (Piconcelli et al. , 2007), and shows an extreme ratio of the 5.8 μm to 2-10 keV, i.e. log λL(5.8 μm)/ L(2-10 keV) =1.2. Typical values of this ratio observed for local Seyfert 2 are ~0.5 (Silva et al. , 2004). We use the SED of IRAS 09104+4109 and the observed 24 μm luminosities of our candidate obscured QSOs to evaluate their intrinsic 2-10 keV luminosity, assuming, as a first approximation, that they have the same infrared SED. The spectroscopic redshifts of the SWIRE sources are unknown. We assumed two redshift values , z=1 and z=1.5, which are consistent with those obtained fitting the observed infrared SED with the IRAS 09104+4109 template.

4. Simbol-X view of highly obscured QSO

The fluxes relative to the 2-10 keV luminosities were calculated assuming a column density of $N_H=2\times10^{24}$ cm^{-2}, a photon index Γ=1.8 and an equivalent width for the neutral Fe Kα emission line of 1 keV. We also assumed a reflection component with a power-law spectrum with Γ=1.8 and normalization =20% of the direct component, similar to that found for the Circinus galaxy by Matt et al. (1999). We simulated the Simbol-X observation of two candidate obscured AGN with exposure times of 200-300 ks, adopting the response matrices from the March 2007 release.

For the object SW110013.92+581034.9 at z=1, with an infrared luminosity of 3.2×10^{45} erg s^{-1} and a 2-10 keV luminosity of about 10^{44} erg s^{-1}, we infer a 2-10 keV flux of 7.1×10^{-15} and a 20-40 keV flux of 1.7×10^{-14} erg cm^{-2} s^{-1}. For the second source, SW163515.61+405607 at z=1.5, we estimate a infrared luminosity of about 6×10^{45} erg s^{-1} and L(2-10 keV)=4×10^{44} erg s^{-1}, which translates to the following fluxes: F(2-10 keV)=1.0×10^{-14} erg cm^{-2} s^{-1} and F(20-40 keV)=1.7×10^{-14} erg cm^{-2} s^{-1}.

Figures 2 and 3 show the simulated MPD+CZT spectra binned to have 20 counts per bin, after background subtraction. Iso-χ^2 confidence contours for the intrinsic column density and photon index are also plotted in the same figures.

These simulations highlight the unprecedent capabilities of Simbol-X, which will allow investigating in detail the spectral parameters of these high redshift sources, despite their extreme faintness in X-rays.

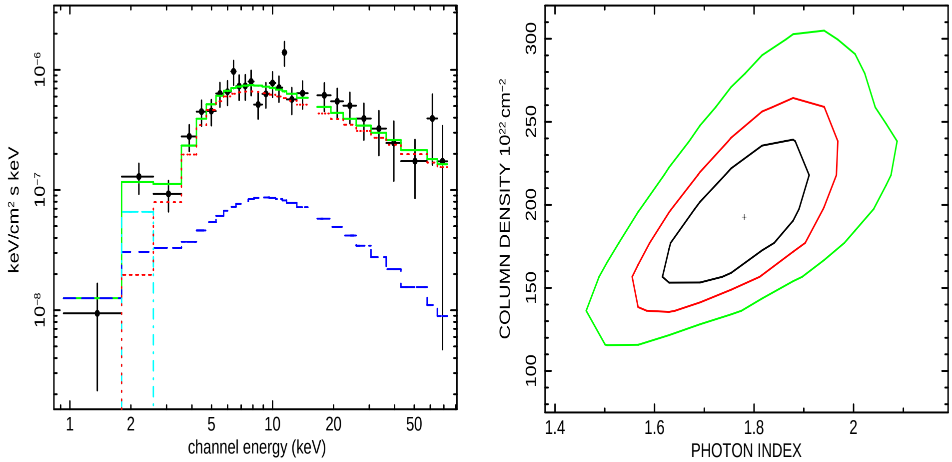

Fig. 3. Left panel: the Simbol-X simulated observed spectrum for the candidate obscured AGN SW163515.61+405607. Right panel: simulated χ^2 confidence contours for the two parameters N_H and photon index for the same source (67, 95 and 99 % levels).

5. Conclusions

We selected a sample of sources with extreme mid-infrared to optical flux ratio and red R-mag[3.6 μm] colors in the SWIRE area, which are likely to be highly obscured QSOs. These sources are very bright at 24 μm and are likely to be targets of several present and future observatories (*Chandra*, *XMM–Newton*, Herschel, ALMA).

We used the SED of IRAS 09104+4109 and the 24 μm flux to evaluate the intrinsic X-ray luminosity of our candidates, assuming N_H values typical of Compton-thick AGNs. The Simbol-X simulations show that the sources are clearly detected up to 60 keV and the 90% uncertainty on the measured value of N_H is $\lesssim$ 30%. We remark that our assumptions are the most conservative possible, since we assumed an extreme infrared-to-X-ray ratio (log L(5.8 μm)/ L(2-10 keV) =1.2). In fact, using the ratios found by Silva et al. (2004) for the local Seyfert 2 population, the derived X-ray fluxes would be up to 3 times higher.

Simbol-X observations of this sample of infrared selected QSOs will be crucial to obtain a complete census of super-massive black-holes up to z~1.5-2, and obtain a well constrained N_H distribution for this population, which remains almost unexplored so far.

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