The WISSH survey:
X-raying the most luminous QSOs in the universe

Zappacosta L., Martocchia S., Piconcelli E., Fiore F. (INAF-Osservatorio Astronomico di Roma)

The WISE All Sky Survey/SDSS hyper-luminous (WISSH) quasar survey consists of a sample of 87 Type 1 reddened quasars at z≈2-3. They represent the most luminous (L_{bol} >10^{14} $L_{\odot}$) quasars at their number density peak and, remarkably, show widespread signs of outflows in the UV/optical spectrum. We will:

1. present the current X-ray properties of the WISSH quasars;
2. show that in 1 Ms of Athena/X-IFU time we will be able to characterize 90% of the sample with good statistics;
3. report on the prospects for hunting for warm absorbers and supermassive black-hole winds in such extreme sources.

This project is relevant to the activities carried out in the SWG2.2 "Understanding the build-up of SMBH and galaxies"

Hyper-luminous quasars: AGN/galaxy co-evolution at its extreme

Physical models predict that the efficiency of driving powerful outflows increases with AGN luminosity ($M_{out} \propto L_{bol}^{1/2}$; Menci et al. 2008). Therefore the most luminous AGNs are the best places to hunt for AGN-driven winds epecially at 1 < z < 3, the golden epoch for AGN/galaxy co-evolution.

Unfortunately the properties of the most luminous (i.e. L_{bol}~10^{47} erg s^{-1}, hence called hyper-luminous), rare, quasars at z=2–3 are still poorly investigated. Only the recent advent of very sensitive large-area near-infrared (NIR; e.g. 2MASS) and mid-infrared (MIR; e.g. WISE) surveys has made possible to select clean samples avoiding strong biases against obscuration from dusty objects.

Larger and complete samples are required to statistically study their X-ray properties, and through multiwavelength data characterize and place them in the AGN/galaxy co-evolution scenario. Given their average faint X-ray fluxes (10^{-14} erg s^{-1} cm^{-2} at 2-10 keV) only a handful of such extreme AGNs have X-ray spectra good for basic spectral analysis. A complete characterization of such samples at high energies will only be feasible by the Athena observatory thanks to its high sensitivity coupled with the remarkable spectral resolution of the calorimeters boasted by the X-IFU instrument.

Sample selection and properties

We adopted a sample comprising the 87 most luminous Type 1 AGNs in the SDSS-surveyed sky. These objects are located at 1.5 < z < 5 and have been selected by Weedman et al. 2012 in the WISE All Sky Survey to have the highest MIR luminosities (>10^{14} $L_{\odot}$; i.e. hyper-luminous). They constitute our **WISE/SDSS Hyperluminous (WISSH)** quasar sample (Bischetti et al. in prep).

The WISSH quasars are the best targets to hunt for AGN-driven outflows. They already show widespread presence of nuclear winds: broad absorption lines for 40% of the sample, ~1000 km s^{-1} outflowing [OIII] components and pronounced (several 1000 km s^{-1}) disagreement on the CIV- and Hβ-based redshifts.

X-ray properties of WISSH quasars

We have analyzed all the X-ray data (38 archival and proprietary) available for WISSH quasars (Martocchia et al. in prep). We estimated the intrinsic N_H, flux and luminosity. The N_H distribution is on average low (~10^{22} cm^{-2}) never exceeding values of few 10^{23} cm^{-2}. For both low quality and high quality data the resulting fluxes in the 2-10 keV energy band range between few 10^{-15} and 10^{-13} erg s^{-1} cm^{-2} (Figure 1, left panel). Remarkably the WISSH quasars show surprisingly low levels of X-ray emission when compared to their MIR luminosity. This is shown in Figure 1 (right panel), where our objects lie well below the extrapolated trend for the X-ray/optically selected AGNs of lower MIR luminosities.

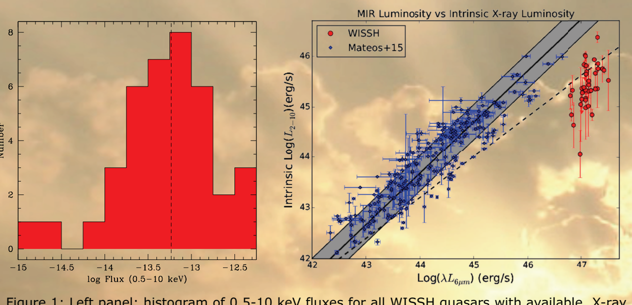

Figure 1: Left panel: histogram of 0.5-10 keV fluxes for all WISSH quasars with available X-ray data. The median flux of the sample, 5.9×10^{-14} erg s^{-1} cm^{-2}, is reported by the dashed line. Right panel: 6μm vs 2-10 keV luminosity for the WISSH quasars (red points) and X-ray selected AGNs (Mateos et al. 2015)). Solid line is L_{MIR}-L_X relation for standard X-ray/optically selected AGNs (the grey region is the intrinsic scatter) and dashed line is for dust obscured galaxies (Lanzuisi et al. 2009).

References

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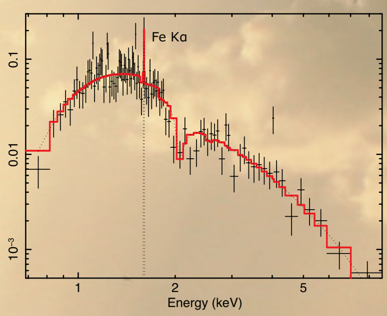
Observational predictions for Athena/X-IFU

The marked improvement in sensitivity and spectral resolution provided by Athena/X-IFU will allow us to characterize almost entirely the sample and therefore this rare population of extreme sources.

We simulated a X-IFU observation for a source at an average z=3 with a power-law spectrum absorbed by an intrinsic cold absorber with N_H=8×10^{21} cm^{-2} (i.e. the median value of the already analyzed spectral sub-sample) and with 0.5-10 keV flux of 5.9×10^{-14} erg s^{-1} cm^{-2}. We also added a narrow Fe Kα line with rest-frame equivalent width EW_{rf}=100 eV. With this baseline spectral model Athena/X-IFU can easily gather more than 1000 counts in only 10 ks observation (see Figure 2). This can give constraints on N_H and photon index of respectively 5-10% and 3%.

By assuming the flux distribution of the 38 sources with available X-ray data we estimated **to 1Ms the amount of time required to observe 90% of the sample** with single observations of at least ~1000 counts. With just 250 ks we can already observe the brightest 50%.

Figure 2: Athena/X-IFU simulated spectrum of 10 ks observation for a typical z=3 WISSH quasar with an absorbed power-law with N_H=8×10^{21} cm^{-2}, Γ=1.8 and 0.5-10 keV flux of 5.9×10^{-14} erg s^{-1} cm^{-2}. A core component of the neutral Fe Kα line (6.4keV) has been simulated with a redshifted Gaussian with EW_{rf}=100 keV (e.g. Krumpe et al. 2010) and FWHM=2000 km s^{-1} (see Shu, Yaqoob & Wang 2010).



Fe Kα line

Thanks to the exquisite resolving power of X-IFU, the Fe Kα line can be clearly detected and its redshift/position can be constrained so that we can probe bulk motions of the reflecting material with velocities lower than 1000 km s^{-1}. This will allow us to obtain a redshift estimate competing with low-dispersion optical spectrographs and probe the dynamics of the QSOs inner regions by comparing it with the conditions in more external and lower ionization.

Warm absorbers

We also explored the detectability of warm absorbers. We simulated a powerlaw spectrum with a warm absorber with column density N_H=10^{22} cm^{-2} (typical for QSOs, Blustin et al. 2005) and ionization parameter logξ=2 (we used model zxipcf in Xspec). Based on F-test we can significantly detect a warm absorber if the number of collected counts is > 10000. This can be achieved only **for the brightest 10% of objects with $F_{0.5-2}$ ≥ 10^{-13} erg s^{-1} cm^{-2}** and only for **exposure times larger than 30ks.**

Ultra-fast Supermassive Black-hole winds

For the relativistic highly ionized absorbers we simulated only the strongest transition from Fe XXV (Heα, at 6.7 keV), since all the other predicted lines have oscillator strenght much lower. We aim at significantly detecting the line over our baseline spectrum for the most favorable case of logξ≈3 and for an absorber of ~10^{23} cm^{-2}. This translates to an EW_{rf}~100 eV (Tombesi et al. 2011). We assumed a broadening of 5000 km s^{-1} and assumed the line produced by an absorber with velocity 0.15c. With an **exposure of 30 ks we can detect the line at more than 5σ** (Figure 3) and constrain its EW with an accuracy of 15%.

Figure 3: X-IFU 30ks simulation of the FeXXV Heα line at 6.7 keV rest-frame. This is the strongest absorption feature which could arise from relativistic highly ionized winds. We simulated a powerlaw with $F_{0.5-10}$=5.9×10^{-14} erg s^{-1} cm^{-2} with a Gaussian absorption profile of EW_{rf}~100 eV broadened by 5000 km s^{-1} blueshifted by 0.15c. The red line show the model folded with the instrumental response with the dotted line indicating the power-law continuum.