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Outflows and winds in AGNs: a case for Simbol-X

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Abstract. Chandra and XMM-Newton X-ray observations are accumulating evidence for massive, high velocity outflows in Seyfert galaxies and quasars, most likely originating very close to the central supermassive black hole. These results are offering new potential to probe the launching regions of relativistic jets/outflows, and to quantify their feedback impact on the host galaxy and/or cluster of galaxies. The most important signature of these phenomena is the detection of blueshifted absorption lines of highly ionized iron at energies usually greater than $\sim$ 7 keV. The lack of sensitivity of present day X-ray observatories at these energies gives rise to bias against the detection of more "extreme" outflows, with highest velocity and ionization, which would be blueshifted at energies > 10 keV. Thus, simulations with Simbol-X were carried out to test its capability of detecting absorption lines/edges between 5-20 keV, in order to probe the dynamics (i.e. measurement of velocity variations) of the absorbing gas, as well as the highest (up to relativistic speeds) velocity and ionization components. We found that the unprecedented sensitivity of Simbol-X between 5-30 keV is a great opportunity to obtain important improvements in this research field.

Key words. galaxies: active galaxies – galaxies: absorption lines – galaxies:Seyfert – X-rays: galaxies

1. Introduction

Manifestations of fast winds/outflows/ejecta in AGNs are seen at all wavelengths: from the relativistic jets in radio-loud AGNs (Bridle & Perley, 1984), to the optical/UV broad absorption lines detected in BAL QSOs (Weymann et al. 1991; Reichards et al. 2003), and the warm absorbers that are almost ubiquitous in X-ray bright AGNs (Crenshaw, Kraemer and George 2003). Detailed studies from soft X-ray grating observations indicate multiple ionization and kinetic components with velocities up to few 1000 km s^{-1} (Blustin et al. 2005). Understanding how winds forms and what are their physical characteristics is of fundamental importance to estimate their energetic impact onto ISM and IGM. Currently there are still order of magnitude uncertainties on the mass outflow rates involved (see the review by Elvis (2006) and references therein).

New results from Chandra and XMM-Newton (see Cappi 2006 for a review and references therein) show blue-shifted absorption lines which indicate very high velocities, even larger than the highest velocities ($\sim$0.2 c) ever observed in the optical/UV and implying larger

Send offprint requests to: cappi@iasfbo.inaf.it than expected outflow rates (King & Pounds 2003). The variability often associated to these absorption lines locates the absorbing gas very near the nuclear BH, potentially at the base of a wind from an accretion disk or at the base of a jet.

2. On the possibility of foreground contamination

It has been claimed that some of the most extreme outflows, in particular where (as is often the case) only one line is detected, may have been misidentified with ionized absorption produced locally in our Galaxy (Mc Kernan et al., 2004, 2005). To test this hypothesis, we have searched for a spatial correlaton between the sources with high-velocity outflows detected (taken from Cappi 2006) and any Galactic structures known to harbour metals and/or hot ionized gas such as Supenovae Remnants, the Local Bubble, the North Polar Spur, or similar. Figure 1 shows the AGN locations overlaid to the (a) 3/4 keV emission map obtained from the RASS (Snowden et al. 1997), which traces (at least part of) the hot diffuse Galactic emission, and to (b) the major known Galactic structures. These figures show that no clear correlation is found.

Moreover, following McKernan et al. (2004, 2005), we have plotted (Figure 2) the energy blue-shift of the absorption lines as a function of the source cosmological redshift. If due to local contamination, the two parameters should follow a one-to-one linear correlation which is not, however, seen in the data. Alternatively, contamination may be due to a very tenuous and pervasive medium such a Warm-Hot Intergalactic Medium (WHIM). It could be too tenuous to emit a detectable amount of bremsstrahlung radiation, but could be of high enough colun density (once integrating over a much longer than Galactic path lenght) to produce significant X-ray absorption. However, under this hypothesis, X-ray absorption lines should be detected in the spectrum of most extragalactic objects, including blazars and/or clusters of galaxies, etc., which is not the case. Moreover, in the few cases in which variability is detected on timescales of a

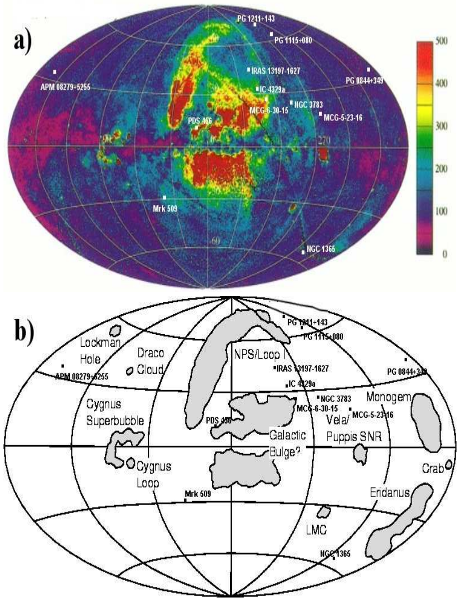

Fig. 1. Location of AGNs with detected relativistic outflows (from Cappi 2006) superimposed on: (a) the RASS map at 0.75 keV (Snowden et al. 1997). Color scale is in units of 10^{-6} counts/s/arcmin^2; (b) the major known Galactic structures.

few ks, the local diffuse origin would be clearly unlikely. We conclude that we do not find any evidence of Galactic or foreground contamination, strenghtening the connection between blueshifted absorption lines and outflows intrinsic to the AGNs.

It should be stressed that the FeK absorption lines at the highest energies have, up to now, suffered a number of biases against their detection. First, there is an "observational bias" against the highest-velocity (bluest) components in that orbiting telescopes are of limited sensitivity at energies greater than 7 keV. Then, the sporadic nature of these features has also likely generated a "detection bias". Finally, detecting gas with the highest velocities, i.e. likely highest ionization states, restricts our studies to a few ionization levels of Fe, rather than a "pletoria" of low-Z elements. All this, combined to the fact that high velocity, ionized and variable absorbing gas is naturally expected in models involving winds/ejecta/outflows (such as those predicted

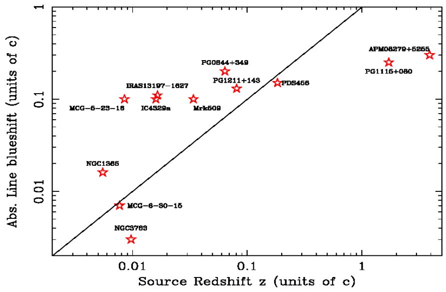

Fig. 2. Blueshift of AGNs absorption lines versus source cosmological redshift. Errors on the absorption blueshift measurements are typically at a few % level, i.e. smaller than the symbols plotted in the figure. The straight line indicates the local standard of rest.

in MHD simulations, i.e. Proga 2005, Kato et al. 2004), suggests that the parameter space for new discoveries in this field is large, i.e. we may have seen up to now only the tip of the iceberg! Two possible future directions for Simbol-X are thus addressed below.

3. Simbol-X capabilities

One among the most debated questions of modern astrophysics is to quantify the energy feedback of AGNs into the ISM and IGM. To do so, one important piece of information would be to have a detailed physical description (in terms of ionization state, geometry, kinematics, dynamics, mass outflow rate, etc.) of the outflows/winds that are known to be present in most AGNs, including QSOs (see review by Elvis 2006). X-ray sensitive observations are mandatory to achieve this goal because they can, at least in principle, probe directly (through absorption spectroscopy) the highest ionization and velocity outflowing gas which may carry most of the kinetic energy.

As shown below, we suggest to make use of the unprecedented throughput of Simbol-X (Ferrando et al. 2004) between 2-20 keV energy band (see Top panel in Figure 3 for a comparison with the pn onboard XMM-Newton) to obtain a great step forward in this direction. In particular, two main topics could be addressed in detail with Simbol-X: i) the study of the dynamics of the highly ionized gas, through detailed study of the time evolution of the spectral absorption structures, and ii) the study of the highest velocity components of these outflows, possibly up to relativistic speeds.

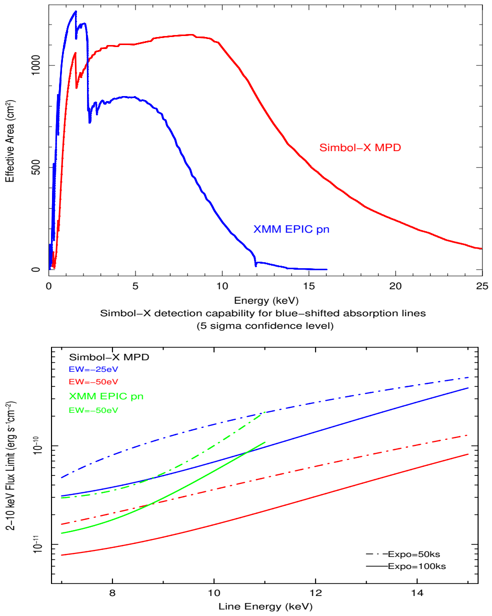

Fig. 3. Comparison between XMM-Newton EPIC-pn and Simbol-X low energy detector (MPD). (*Top*): Comparison of the effective areas: the MPD will have an effective area equivalent ($\simeq$ 30% better) than the pn at energies between $\sim$ 4-6 keV and from 2 to 5 times higher at energies greater than 7 keV; (*down*): Comparison of the sensitivity to absorption lines: the 2–10 keV flux limit is plotted against energy for the detection of an absorption line at 5 σ confidence level. Equivalent widths are −25 and −50 eV, exposure times of 50 and 100 ks and background level at nominal value.

Simulations of Simbol-X spectra have been performed using the latest response matrices and background files available[1]. Lower panel in Figure 3, taken from Tombesi et al. 2007, shows the results obtained from a number of Simbol-X simulations aimed at estimating the Simbol-X sensitivity at detecting absorption lines, to be compared to that of XMM-Newton. It is found that Simbol-X will be 2 to 5 times more sensitive than the pn onboard XMM-

[1] http://www.iasfbo.inaf.it/simbolx/faqs.php

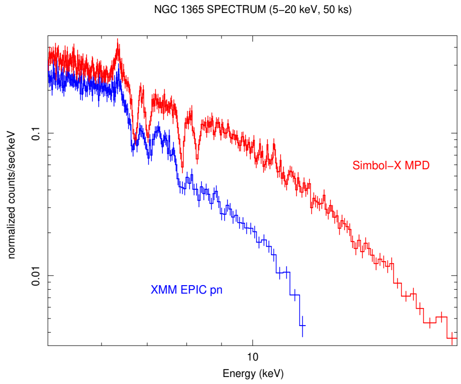

Fig. 4. The 5-10 keV spectrum of the Seyfert 1.8 NGC1365 ($F_{(2-10keV)}$ $\sim 10^{-11}$ ergcm^{-2}s^{-1}) clearly showing four absorption lines due to FeXXV and FeXXVI Kα and Kβ, outflowing with velocities varying between ~ 1000 and ~ 5000 km/s among the observations performed by XMM-Newton (Risaliti et al. 2005). Exposure time is 50 ks. The spectrum is compared to a simulated Simbol-X spectrum with same exposure.

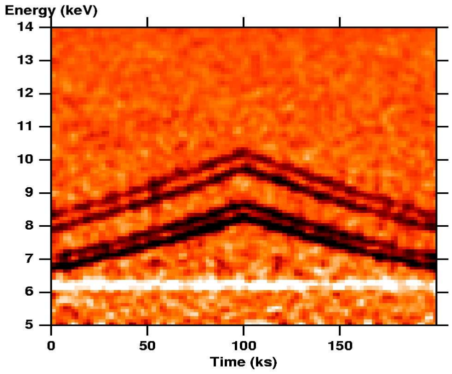

Fig. 5. The Simbol-X simulation of the time-energy map expected from a source with the same spectrum of NGC1365 (Risaliti et al. 2005), i.e. 4 variable absorption lines (from Kα and Kβ of FeXXV and XXVI; dark lines between 7-10 keV) plus a constant FeK emission line (white line at 6.4 keV). The time and energy bins are respectively 2 ks and 100 eV. The total exposure time is 200 ks. The highly ionized absorber is assumed to accelerate and decelerate between velocities of 0.02-0.2 c in 100 ks. This clearly shows that Simbol-X would be capable of detecting the outflow time evolution in bright AGNs, through detailed absorption lines spectroscopy.

Newton, and will also allow high detection capability up to 15 keV. This will allow detection of absorption lines down to EW of few tens eV for several tens of known X-ray emitting AGNs. It should be noted that these sensitivities, for sources brighter than few $\times 10^{-11}$ erg/cm2/s only weakly depend on the detailed background level that is assumed.

Based on our current knowledge of AGN winds build upon Chandra and XMM-Newton experience, we have then simulated two "text-book" examples of AGNs with strong warm absorbers: the Seyfert 1.8 NGC1365 (Risaliti et al. 2005), and the QSO PDS456 (Reeves et al. 2003). We have compared in Fig. 4 the real XMM-Newton observation of NGC1365 with a Simbol-X simulation of the same source, with the same exposure time. Clearly Simbol-X will be at least 2 to 5 times better than XMM-Newton in detecting absorption lines up to 10 keV, and may also allow to detect features (like absorption lines and/or edges) up to 15 keV.

Figure 5 shows the Simbol-X simulation of the time-energy spectral map obtained for a source like NGC1365 between 5-14 keV, during a 200 ks observation. Time intervals are binned at 2 ks and energy bins at 100 eV. The model consists of the four absorption lines detected in NGC1365 and described in Figure 4, plus a constant narrow emission FeK line. The ionized absorber is assumed to accelerate from v=0.02 c (as measured by XMM-Newton) up to 0.2 c during the first 100 ks, and decelerate from 0.2 c down to 0.02 c during the last 100 ks. Clearly, Simbol-X will open up the possibility to follow the outflow time evolution (i.e. acceleration/deceleration) on time-scales (few ks) comparable to the dynamical timescale at a few Schwarzshild radii from the black hole (Figure 5).

Finally, Simbol-X will be able to detect moderately strong (EW $\lesssim$ -25 eV) absorption lines or edge-like structures at energies up to ~12-15 keV. Considering that Fe edges and absorption lines are expected at rest-frame energies between E~7.1-9 keV, Simbol-X will be able to probe ionized absorbing gas with velocities up to ~0.5 c. This is illustrated in Figure 6 in the case of the bright ($F_{(0.5-10keV)}$ = 10^{-11}

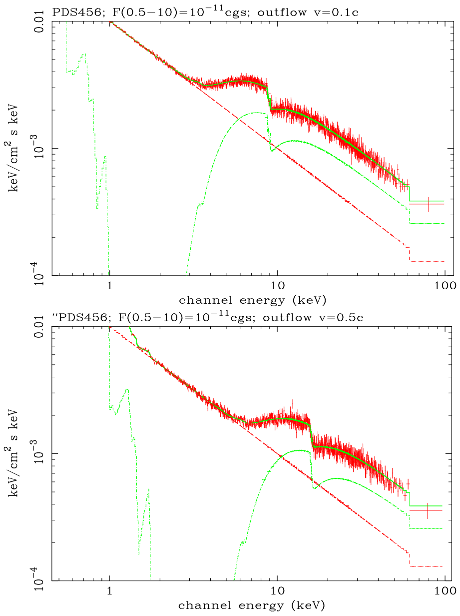

Fig. 6. Simbol-X simulations for the quasar PDS456, including both MPD (from 0.1 to 30 keV) and CZT (from 4 to 100 keV) detectors, for an exposure time of 100 ks. The best-fit model consists of a ionized absorber with Γ=2, N_W=5×10^{23} cm^{-2}, logξ=2.6, and a covering factor of 0.6. We assumed an outflow velocity of (*Top*) 0.1 c (similar to what found by Reeves et al. 2003), and a more extreme case (*Down*) with velocity of 0.5 c.

erg cm^{-2} s^{-1}) quasar PDS456 which, assuming the best-fit model obtained by Reeves et al. (2003), could well exhibit edge-like structures from 0.1 c up to 0.5 c.

4. Conclusions

Recent Chandra and XMM-Newton observations have revealed the presence in bright nearby Seyfert galaxies and more distant QSOs of high-velocity, ionized variable absorbers. This phenomenon is of outstanding interest because it offers new potential to probe the dynamics of the innermost regions of accretion flows, to probe the formation regions of outflows and jets, and to help constraining the rate of kinetic energy injected by AGNs into the ISM and IGM. We have shown that, thanks to its unprecedented sensitivity in the 2-20 keV energy band, Simbol-X may lead to remarkable new results in this reasearch field.

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