A search for relativistic outflows signatures in the X-ray spectra of Seyfert 1 galaxies

F. Tombesi (1,2,3,4), M. Cappi (2), M. Dadina (1,2), T. Yaqoob (3,4), G. Ponti (5), J. Reeves (6), V. Braito (7) and G.G.C. Palumbo (1)
(1) Dept. of Astronomy, University of Bologna (2) INAF-IASF Bologna (3) Dept. of Physics and Astronomy, Johns Hopkins University
(4) NASA-GSFC (5) APC Paris (6) Keele University (7) Dept. of Physics and Astronomy, University of Leicester

Evidence for the presence of relativistic outflows in the inner regions of Seyfert 1 galaxies have been claimed in recent years. These would indicate the existence of winds or ejection of material close to their super-massive black hole, possibly from the accretion disk. In particular, X-ray observations of several sources revealed the presence of absorption lines due to highly ionized iron with blue-shifted velocities of the order of 0.01-0.1c. We present preliminary results of an homogeneous analysis of a complete sample of local (z<0.1) bright Seyfert 1 galaxies observed with XMM-Newton. We performed a systematic search for blue-shifted absorption lines in their spectra, in the Fe K band (4-10 keV). We established the features detection significance, making use also of extensive Monte Carlo simulations. This study will help to establish the recurrence of such phenomena and to constrain several parameters, such as the composition and ionization state of the outflow, its overall energetic budget and kinematics.

We selected a sample of Seyfert 1 galaxies cross-correlating the RXTE and XMM-Newton catalogues, with a 2-10 keV flux greater than 10^{-11} erg s^{-1} cm^{-2}. We analyzed 17 sources, for a total of 42 EPIC pn observations. We extracted the mean specra and focused our study in the 4-10 keV band, looking for the presence of absorption due to highly ionized Fe K resonant lines. These choices will ensure to avoid the complexities due to cold absorption and directly study the innermost regions of the AGNs.

We detected lines in ~30% of the observations, i.e. in ~35% of the sources. The outflow velocities are consistent with ~0.01c and ~0.1-0.2c for the ~20% and ~10% of the cases, respectively. This is indicative of the presence of highly ionized absorber components with relativistic outflow velocities.

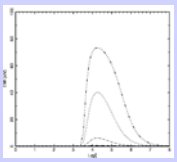
Source	Counts (1)	FeXXV Kα	FeXXV Kβ	FeXXVI Lyα	FeXXVI Lyβ	Blue-shift	Obs. (2)	Detection
NGC4151	1.3						0/3	
IC4329A	7.5			X		~0.1c	1/1	>99% (3) *
NGC3783	2.6	X				<0.01c	3/4	>99% (3)
NGC5548	1.3						0/3	
NGC3516	1.7	X	X	X	X	~0.01c	4/5	>99.9% (3)
MRK509	1.5			X		~0.1-0.2c	3/5	~99% (4) *
MCG-6-30-15	2.6	X		X		<0.01c	0/5	(5)
MCG+8-11-11	1.3						0/1	
MRK279	0.8	X	X			<0.01c	1/3	~99% (3)
AKN120	2.9						0/1	
NGC3227	1.8						0/2	
MRK590	0.3						0/1	
NGC7469	1.9						0/2	
MRK79	0.3			X		~0.1c	1/3	>99% (3)
FAIRALL 9	0.3						0/1	
ESO198-G24	0.9						0/1	
NGC7213	0.7						0/1	

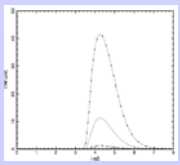
(1) Mean 2-10keV counts in units of 10^{-5} (2) Fraction of observations with detected lines. (3) Confidence level from Ftest. (4) Confidence level from Monte Carlo simulations. (5) The narrow absorption lines detected by Chandra (Young et al. 2005) are blended to the broad Fe emission line (Vaughan & Fabian 2004) given the low EPIC pn energy resolution. A deeper analysis with complex models is required. (*) We found discrepancies in the detection using different calibration files. This effect is under investigation.

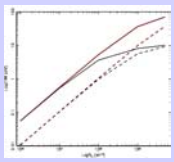
Curves of Growth analysis

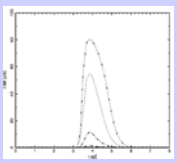
Ion	Transition	E (eV)	f
FeXXV[1]	Kα (1→)	6697	7.727×10^{-1}
	Kβ (1→)	7880	1.55×10^{-1}
FeXXVI[1]	Kα (1→2)	6966	4.2×10^{-1}
	Kβ (1→2)	8250	7.92×10^{-2}

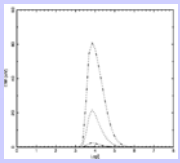
We performed extensive Xstar simulations in order to directly compare the observed quantities with theoretical expectations. We used as input the mean AGN SED from Mathews & Ferland (1987). We considered solar abundances, ionization parameter $\log\xi = 0\text{-}8$ erg s^{-1} cm and different hydrogen column densities of $N_H = 10^{20}, 10^{21}, 10^{22}, 10^{23}, 5\times10^{23}$ cm^{-2}. We then calculated the Curves of Growth, i.e. the lines Equivalent Width as a function of N_H, ξ and velocity broadening (b).

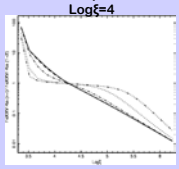

FeXXVI Kα b=1000km/s


FeXXVI Kβ b=1000km/s


FeXXV/XXVI Kα & Kβ b=100/1000km/s, Logξ=4


FeXXV Kα b=1000km/s

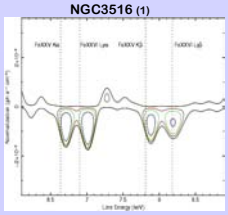

FeXXV Kβ b=1000km/s


Ratio FeXXV/XXVI Kα b=100km/s

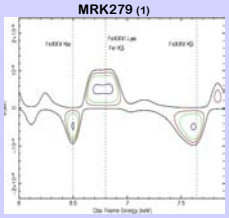
Lines search: contour plots

We performed a blind line search in the 4-10 keV band. We considered as baseline model a simple Galactic absorbed power law and include further neutral absorption and Fe K emission lines, if significantly required by the data. We then added a new narrow Gaussian, let its normalization free to be positive or negative, stepped its centroid energy and calculated the contours of $\Delta\chi^2$. We analyzed the detection confidence levels using both the Ftest and extensive Monte Carlo simulations (Porquet et al. 2004) .

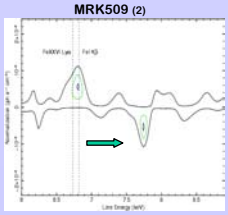
NGC3516 (1)



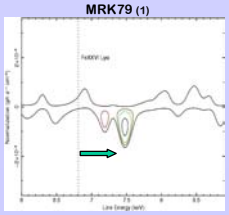
MRK279 (1)



MRK509 (2)



MRK79 (1)



(1) $\Delta\chi^2$ distribution from Ftest; 68%, 90% and 99% confidence levels.

(2) $\Delta\chi^2$ distribution from Monte Carlo simulations; 90% and 99% confidence levels.

Conclusions

From our preliminary results, we can derive that ~30% of Seyfert 1 galaxies present highly ionized absorber components. The absorption lines appear to be systematically blue-shifted by relativistic velocities of ~0.01-0.1c. We detected variability of the features among different observations. Therefore, these results are in agreement with the picture of formation of winds or ejection of material very close to the accretion disk. In the future, we planned to extend the number of sources in the sample, to perform an even more accurate study of the detection significance and to estimate the outflow parameters, such as the column density, ionization etc. from a direct comparison with theoretical expectations. It should be noted that this kind of study is affected by the limited sensitivity of current X-ray satellites at high X-ray energies. Further improvements in the field will be surely provided by the new Franco-Italian X-ray satellite Simbol-X.

37th COSPAR Scientific Assembly – Montreal (Canada), July 13th-20th 2008