Mem. S.A.It. Vol. 79, 78
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Hard X-ray spectroscopy of obscured AGNs

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Abstract. A powerful tool to investigate the structure, composition and distance form the central source of the circumnuclear absorber in AGNs is the study of column density variability through time-resolved X-ray spectroscopy. I show recent results on this field, which revealed significant N_H variations in time scales as short as few hours, implying an extremely compact (on the scale of the Broad Line Region) and clumpy absorber. The key limitation for these studies is the degeneracy in spectral fitting between variations in continuum slope and in N_H, which can be removed only in few very high S/N cases in 1-10 keV spectra. Adding a high energy, high S/N spectrum would allow to perform this kind of analysis on a large sample of obscured sources, and to add important new elements to our understanding of the central region of AGNs.

Key words. Galaxies: Active – X-rays: Galaxies

1. Introduction

An analysis of the sample of local obscured AGNs with multiple 1-10 keV observations revealed that in almost all cases the absorbing column density shows significant variations in time scales from a few months to a few years (Risaliti et al. 2002).

Assuming that the obscuration is due to gas clouds moving with Keplerian velocity around the central X-ray source, the measurement of the amplitude and the typical time scale of the variations provides an indication of the distance from the center of the obscuring clouds (assuming a given cloud density). In particular, if the observed variations are on time scales as short as a few days or hours, the only plausible scenario is that of an absorber with a density and distance typical of Broad Line Clouds ($10^9 - 10^{11}$ cm^{-3} at $\sim 10^3\ R_S$ from the center).

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Prompted by these considerations, we searched for N_H variations on short time-scales in single observations of bright obscured Seyfert Galaxies.

Our method relies on a preliminar analysis of a hardness ratio light curve, which should indicate the time intervals during which significant spectral variations happen, and then on a complete analysis of the spectra obtained from these time intervals.

Here I concentrate on two interesting cases with important positive results, which also suggest the potential of Simbol-X in improving this kind od study.

2. Fast N_H variability: the case on NGC 1365

. NGC 1365 is a nearby (D∼ 19 Mpc) obscured Seyfert Galaxy, showing an exceptional X-ray variability. In particular, several tran-

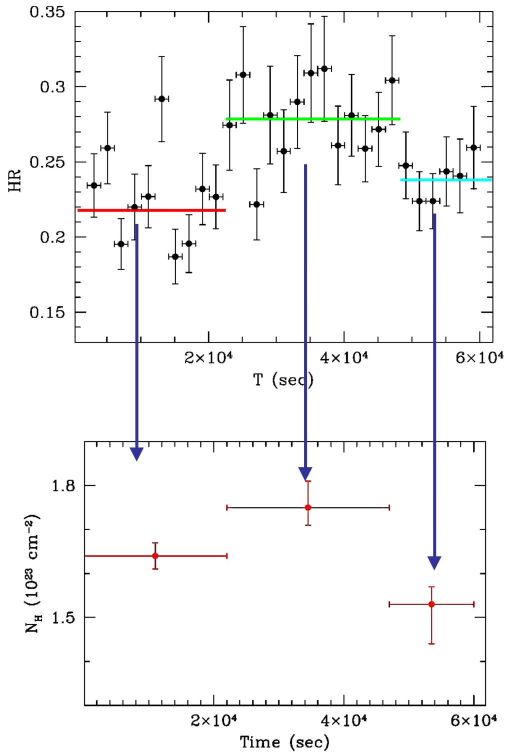

Fig. 1. Upper panel: hardness ratio (2-5 keV/7-10 keV) light curve of a 60 ks XMM-Newton observation of NGC 1365. Lower panel: best fit values of the absorbing column density obtained from a spectral fitting (with all the continuum parameters free to vary) of each of the three indicated time intervals.

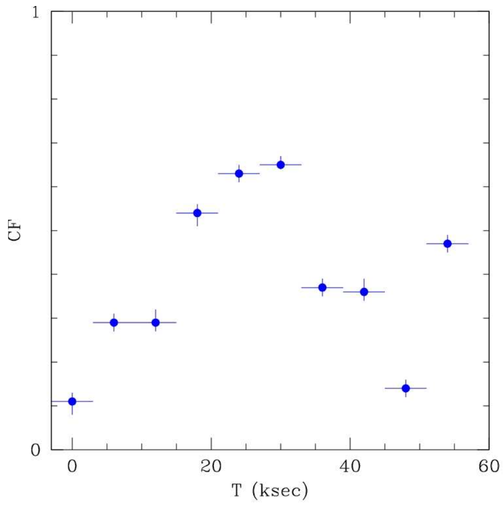

Fig. 2. Covering factor variation of the obscuring cloud crossing the line of sight during the XMM-Newton 60 ks-long observation of NGC 1365.

sitions from Compton-thick, reflection dominated states (implying an absorbing column density $N_H > 10^{24}$ cm^{-2}) to Compton-thin states (with $N_H \sim 2-5 \times 10^{23}$ cm^{-2}) have been observed in observational campaigns with increasingly small time lag between the single observations (Risaliti et al. 2005, Risaliti et al. 2007). In particular, Chandra revealed a reflection-dominated state only two days after an observation in a Compton-thin state. Two more days later the source was back in a thin state. These fast variations prompted us to investigate possible N_H variations within the two longest XMM-Newton observations (60 ks each). The hardness ratio light curve is shown in Fig. 1. A clear spectral variation is present in the marked intervals. A spectral analysis of the three intervals, allowing for variability of *all* the spectral parameters, demonstrated that the observed variability is due to a change in the average column density along the line of sight, while all the other parameters (in particular, the continuum slope) remain constant within the errors.

We then performed a further step, dividing the observation in ten intervals of 6 ks each, and fitting each spectrum with a fixed continuum and an absorber with fixed N_H and variable covering factor (in agreement with the physical scenario of a cloud passing through the line of sight). The result is shown in Fig. 2: the observed spectral variability is due to a cloud with $N_H \sim 3 \times 10^{23}$ cm^{-2} crossing the line of sight[1]

3. Limitations, and future opportunities

The example described above is an "ideal" case for at least two reasons: a) the column denisty variation is quite high (a cloud with $N_H \sim 3 \times 10^{23}$ cm^{-2} moving across the source, to

[1] In all the spectra the continuum is also absorbed by a fixed column density $N_H \sim 10^{23}$ cm^{-2}.

be comared with a constant component of only 10^{23} cm^{-2}); b) the preliminary analysis shown in Fig. 1 gave us a good reason to freeze the continuum in the subsequent analysis shown in Fig. 2, concentrating only on N_H variations.

However, these conditions are not valid in general. In many cases we found only slightly less significant spectral varability in the hardness-ratio light curves of other bright obscured sources (which, possibly, can be due to quite large N_H variations), but in the subsequent spectral analysis we were not able to distinguish between variations of spectral slope or of N_H.

It is quite impressive that, despite the large number of high quality XMM-Newton spectra of bright Seyfert 2s available, the second most convincing case of N_H variability within a single observation is that of NGC 4151, obtained with BeppoSAX (Puccetti et al. 2007, Fig. 3). In this case the much lower S/N in the 2-10 keV band than in XMM-Newton spectra is more than compensated by the availability of a high energy (10-100 keV) spectrum, which allows to remove the continuum slope/N_H degeneracy. We simulated the analysis of an event like the one shown in Fig. 1, performed with Simbol-X. The spectrum shown in Fig. 4 is obtained with a 6 ksec observation of NGC 1365. The spectral analysis leaving all the fitting parameters free to vary provides a precision of the N_H measurement of the same order (or slightly better) than that obtained with XMM-Newton freezing all the continuum parameters. It is then clear that this kind of analysis could be performed on a lage number of sources, and would be sensitive to much less extreme (and, therefore, less rare) variations than the ones we have been able to study until now.

Acknowledgements. This work is partially supported by contract ASI-INAF I/023/05/0.

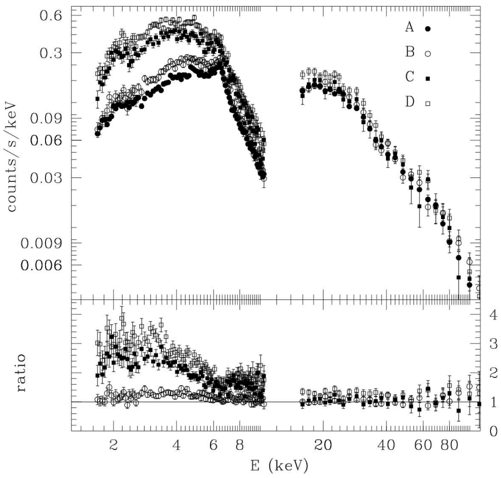

Fig. 3. BeppoSAX spectra of four intervals of a ~ 100 ksec long observation of NGC 4151. The lower panel shows the residuals with respect to the best fit spectrum of the first interval. The spectral variations are due to a fast N_H change. The availability of the high energy instrument PDS allowed to distinguish this scenario from that of spectral slope variability.

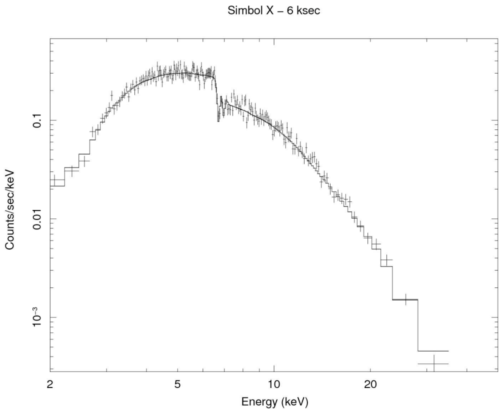

Fig. 4. Simulation of a 6 ks Simbol-X observation of NGC 1365. The precision achieved in the N_H measurement is greatly enenched with respect to XMM-Newton thanks to the high energy spectrum, which removes the degeneracy between N_H and continuum slope.

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