Broad-band spectra of Seyfert 1 galaxies

Alessandra De Rosa & Luigi Piro

IASF/CNR, Roma (Italy)

Abstract

The X-ray spectrum of Seyfert 1 galaxies is characterized by a wide variety of features resulting from the interaction of the hard X-ray continuum produced by the central source with the gas around the central black hole, from the innermost part to the outer regions. It is then by the study of these features and of the continuum that we can reconstruct the structure of the central source of an AGN and understand the nature of the primary emission. In this work we present a study of the X-ray properties of Seyfert 1 galaxies observed by *Beppo*SAX. The capabilities of the instrumentations of this mission have provided an important step forward compared to previous satellites in several respects.

The sample

Source	*Redshift*	$N_H(10^{20} cm^{-2})$	*Flux(2-10 keV)	Exposure (ks)
NGC 5548	0.017	1.7	3.5	200
NGC 3783	0.009	9.6	6.0	200
Mkn 509 (2)	0.034	4.4	5.6/2.6	87/150
NGC 4151	0.003	2.2	20	200
NGC 4051	0.002	1.3	1.9	12
MKN 335	0.025	3.7	0.8	87
Mkn 841	0.036	2.2	1.3	88

*In 10^{-11} erg cm^{-2} s^{-1}

The intrinsic continuum and the spectral variability

A **high energy cutoff** is a common feature in Seyfert 1 spectra. We were able to measure it in all the source esamined (see Figure 1). This, togheter with the observed spectral variability, strongly suggests a thermal coupled disc-corona emission model (Haardt & Maraschi 1993). In fact the broad band allowed us to resolve **the origin of the spectral variability** and attribute it to a change of the intrinsic photon index: the intrinsic slope increases with the flux (see Figure 2) as expected by a **Thermal Comptonization emission model.** A detailed Comptonization model was applied in a small sample of Seyfert observed by *SAX* (Petrucci et. al 2000, 2002)

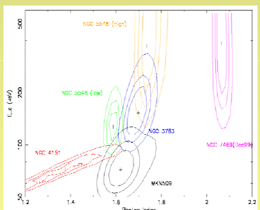

Fig. 1. 1σ, 2σ and 3σ high energies cut-off vs photon index in the Seyfert 1s observed byBeppoSAX. The plot shows that the sources exhibit different values of the slope and this value is changing with the flux (we plotted here the case of NGC 5548, Nicastro et al. 2000).

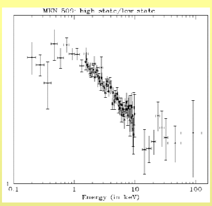

Fig 2. The ratio between the high and low flux level state in the case of Mkn 509 (De Rosa et al. 2003). The observed variability can be reproduced with a change of the intrinsic slope when the flux increases

The Compton hump and the iron lines

The good accuracy of the continuum shape we got, reached thanks to the broad-band observations and to the long-look strategy, allowed us to study the behaviour of the reprocessing gas features: the iron line and the Compton hump (see Figure 5). In the case of NGC 3783 and NGC 7469 a **double component of the iron line** is required to fit the spectra (see upper panel in Figure 7).

Chandra and *XMM* observations have shown that a **narrow component** to the iron line (see Fig. 6) is a common feature in Sy 1 galaxies (Padmanabhan & Yaqoob 2003, Reeves 2003). This suggests that its origin can be in the dusty torus far away the central black-hole. In Mkn 509 the contribution to the iron line from a distant medium is supported by the variability analysis. In fact when observed by *SAX* the intensity of this line does not show variations when the flux changes of about a factor two in 2-10 keV (De Rosa et al. 2003) and it is also consistent with *Chandra and XMM* observations. We argue that this far away region give a contribution also to the observed Compton reflection, this was clearly shown by *Beppo*SAX in the previous case of NGC 4051 (Guainazzi et al. 1998) and in recent *XMM-SAX* simultaneous observation of NGC 5506 (Matt et al. 2002). The origin of the second and **ionized line** (e.g. in the case of NGC 7469, De Rosa et al. 2002b) can be accounted by emission from an ionized accretion disc.

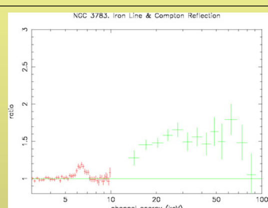

Fig 5. The broad band of SAX allow to observe simultaneously the iron line component and the refletion humo above 10 keV. In Figure we show the case of NGC 3783 (De Rosa et al. 2002a)

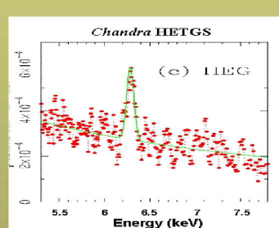

Fig 6. Narrow iron line component in NGC 5548 observed by Chandra (Yaqoob et al. 2001)

An **ionized disc reflection model** works to reproduce X-ray spectra of AGN. It represents often a good description of the whole broad band emission. In different cases we studied (NGC 3783, NGC 7469, NGC 4051, Mkn 335) an ionized disc is an attractive description of the broad band spectrum from 0.2 to 100 keV, because it is able to reproduce the curvature above 10 keV as well as the soft X-ray emission below 3 keV (see lower panel in Figure 7). A single one physical model to data in a wide energy range is more constraining than describing the spectrum as a superposition of phenomenological components (power law continuum and gaussian emission line, upper panel in Figure 7). However the data do not allow us to distinguish between two different scenarios. In a cold disc model the disc itself would represent the driver of the emission mechanism in AGN. While if a ionized disc reflection model is taken into account, the disc works only like a reprocessing medium and the primary X-ray emission comes from the hot corona.

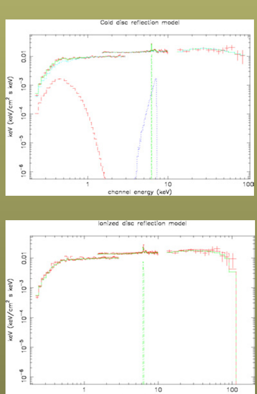

Fig. 7. NGC 7469, the broad band SAX spectrum can be reproduced either with a superposition of phenomenological components (upper panel) or with an ionized disc (with the ionization parameter $\log \xi$=1.21+/-0.02) reflection model (lower panel) wich is able to model the soft X-ray excess, the iron line and the hump above 10 keV.

Soft X-ray spectral features

The low energies spectrum of the objects we observed are characterized by different features.The **warm absorber component(s)** detected with the limited LECS sensitivity are derived mainly from the deep **OVII and OVIII absorption edges** (see Fig. 3). The presence of this component was confirmed in several sources (NGC 3783, NGC 5548, NGC 4051, Mkn 335).

If the observed **soft excess** is a thermal emission from the disc or the reprocessing (on the disc itself) of the primary hard X-ray emission from the hot corona is still matter of debate. In the sources we analysed a clear soft excess was detect in the case of NGC 3783 Mkn 509 (shown in the Figure 4), NGC 4051, Mkn 335 and NGC 7469. In all these objects the soft X-ray spectra could be reproduced by reprocessing on an ionized accretion disc (that can explains also the Compton bump above 10 keV as well as the iron line component). A by product of this description is that the primary (gravitational) energy is released directly into the corona. However when black body components are employed to fit the soft excess, they works as well, suggesting that the observed features can be a direct emission from a cold disc.

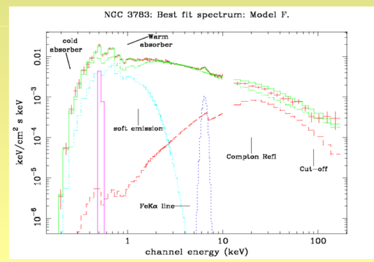

Fig 3. The SAX broad band spectrum of NGC 3783. Several features have been detected in addition to the intrinsic continuum. The presence of a warm absorber at E< 1 keV is derived by deep OVII and OVIII absorption edges

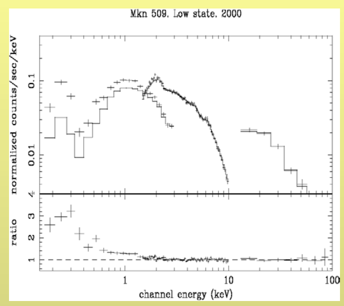

Fig. 4. Hard X-ray spectral fit for E> 3 keV extrapolated to 0.15 keV in the SAX-LECS energy band. A soft X-ray excess is present.

Conclusions

The properties of a sample of Seyfert 1 observed by *SAX* have been studied.

We find that the **instrinsic continuum** is well described by a power law up to about 200 keV, where a high energy cut-off sets in. In addition, the continuum shows systematic changes of the spectral slope, getting steeper with increasing luminosity. These results are shown consistent with a scenario in which X-ray photons are produced by Comptonization of optical-UV photons by electrons in a hot gas (kT_e ~10^9 K). The hot gas is in the form of a corona above the accretion disc, which is the source of the UV target photons.

We find that the **reflection features** are common to our sample of Seyfert galaxies, but their properties are not immediately consistent with a ``cold'' accretion disc. In this work we investigated the possibility that the disc is photoionized from the hard X-ray photons.

In this case the reflection hump and the energy of the **iron line** as well as its profile, can strongly differ from that expected from a cold and neutral gas. In particular we find that, by varying the ionization stage of the disc, we can account for the spread of the broad line intensity observed in the objects of our sample. Furthermore, due to the ionization of low-Z atoms, an ionized disc would produce a reflection continuum also in the **soft X-ray range**, in agreement with spectral data.

Finally, we find evidence of an additional component to the iron line: **a narrow core profile** with an intensity which remains constant notwithstanding the large variations of the continuum. This line component has to be produced in a region far away from the central source. We discuss about the location of this gas and its possible association with regions identified through observations in other wavelengths.

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derosa@rm.iasf.cnr.it