

X-Ray Variability in LINERs

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Abstract. Active galactic nuclei (AGN) are powered by energetic phenomena which cannot be attributed to stars. LINERs appears to be the low power end of the AGN sequence with the lowest Eddington ratios but hosting the most massive black holes (typically $10^9 M_{\odot}$). Whereas variability is common for high Eddington ratio emitting sources, in the low Eddington regime data are not so clear. Recent investigations at UV (Maoz *et al.* 2005) and X-ray frequencies (Younes *et al.* 2011, González-Martín *et al.* 2011) point out to the long term variable nature for some particular LINERs.

In this work we add more evidence about the X-ray variability in LINERs and investigate its nature. The data set comprises X-ray archival spectroscopy from observations taken from *Chandra* and *XMM-Newton*, selecting LINERs with several observations at different epochs. Up to now we analysed two LINER 1.9 objects, NGC 1052 and NGC 4278, and checked that variability is due to different mechanisms based on the results of spectral fittings.

Keywords. Galaxies, AGN, LINERs, variability, X-ray

1. Introduction

LINERs were classified in the optical using diagnostic diagrams (Heckman 1980, Ho *et al.* 1997). These diagrams represents emission line intensity ratios, being the spectra of LINERs dominated by low ionisation lines. Although there is controversy, it is thought that LINERs may be the low power end of the AGN sequence, having the lowest Eddington ratios and the most massive black holes (BHs). At X-rays we can asses the AGN nature of a source if it is detected at hard X-rays. In our previous work, 82 LINERs with *Chandra* and/or *XMM-Newton* data for single period observations were analysed, concluding that more than 80% of the objects hosted AGN (González-Martín *et al.* (2006, 2009)).

Now we deal with variability, since it is one of the main properties of AGNs. McHardy *et al.* (2006) found that variability time scale increases for bigger mass of the BH and/or lower bolometric luminosities. Because LINERs have high BH masses and low bolometric luminosities, this puts them into a variability time scale of months to years. Furthermore, González-Martín & Vaughan (2012) found that LINERs do not vary in time scales lower than tens of days. The first evidence of variability was reported by Maoz *et al.* (2005), where all but three objects in the sample of 17 LINERs 1 and 2 were variable in the UV. More recently, Younes *et al.* (2011) studied type 1 LINERs in X-rays and concluded that variability is a common property in these objects at long-term periods.

Table 1. Observational details.

NGC 1052				NGC 4278			
Satellite	OBSID	Date	Exptime (ksec)	Satellite	OBSID	Date	Exptime (ksec)
<i>XMM-Newton</i>	093630101	2001-08-15	16.3	<i>Chandra</i>	4741	2005-02-03	37.9
<i>XMM-Newton</i>	306230101	2006-01-12	54.9	<i>Chandra</i>	7077	2006-03-16	111.7
<i>XMM-Newton</i>	553300301	2009-01-14	52.3	<i>Chandra</i>	7078	2006-07-25	52.1
<i>XMM-Newton</i>	553300401	2009-08-12	59.0	<i>Chandra</i>	7079	2006-10-24	106.4
				<i>Chandra</i>	7081	2007-02-20	112.1
				<i>Chandra</i>	7080	2007-04-20	56.5

2. Sample and Data Reduction

We have identified 16 objects from the sample of González-Martín *et al.* (2009) which show hints of variability. Here we present the results for two LINERs 1.9: NGC 1052 and NGC 4278. We used the HEASARC[†] archive to search different observations with *Chandra* (ACIS-S) and *XMM-Newton* (EPIC pn), with public observations until January 2012. The observational details are summarised in Table 1. Only observations with enough exposure time to have good spectral quality are taking into account.

The reduction and analysis were made in a systematic, uniform way using CXC *Chandra* Interactive Analysis of Observations (CIAO[‡]), version 4.3, for *Chandra* data, and the Science Analysis Software (SAS[¶]), version 11.0.0, for *XMM-Newton* data. Both reductions were made analogously, eliminating background flares, extracting the nuclear source and the background from circular regions and grouping spectra. The response matrix (RMF) and ancillary reference files (ARF) were generated for each source region.

3. Analysis and Results

We fit all the spectra from the same object with the same model of XSPEC (v. 12.7.0) to identify which parameters are changing and to get clues on the nature of the observed variations. For this purpose we used five different models. Note that we used two absorbers when two components were present in the model (following the same prescription given by González-Martín *et al.* 2009): (a) MEKAL: A pure thermal model; (b) PL: A single power law; (c) 2PLs: Two power laws; (d) MEPL: A composite of a thermal plus a single power law; (e) ME2PL: A composite of a thermal plus two power laws.

We let different parameters vary in the model: column densities, N_{H} , slope of the power law, Γ , normalisations of each component and the temperature of the thermal model, kT.

For NGC 1052, we fit a model containing a thermal plus two power laws components. After varying the parameters in the model, the best fit let the $N_{\text{H}2}$ and the normalisation (Norm_2), associated to the hard energies, vary (Fig. 1, left).

This can be better seen if we plot the values of $N_{\text{H}2}$ and the Norm_2 of the power law (Fig. 1, right) or the luminosities calculated for this model (Fig. 3, left) for each observation. As expected, there is an anti-correlation between the $N_{\text{H}2}$ variations and luminosities, because the higher the absorption, the lower the luminosities. Because *XMM-Newton* has an optical monitor, we can compare these luminosities in X-rays to those in the UV. It is also seen the same behaviour on luminosities (Fig. 3, centre). There are

[†] <http://heasarc.gsfc.nasa.gov/>
[‡] <http://cxc.harvard.edu/ciao4.4/>
[¶] <http://xmm.esa.int/sas/>

only three observations with the optical monitor, coinciding with the last three dates in X-rays. Both hard X rays and UV luminosities show variations amounting to $\sim 25\%$.

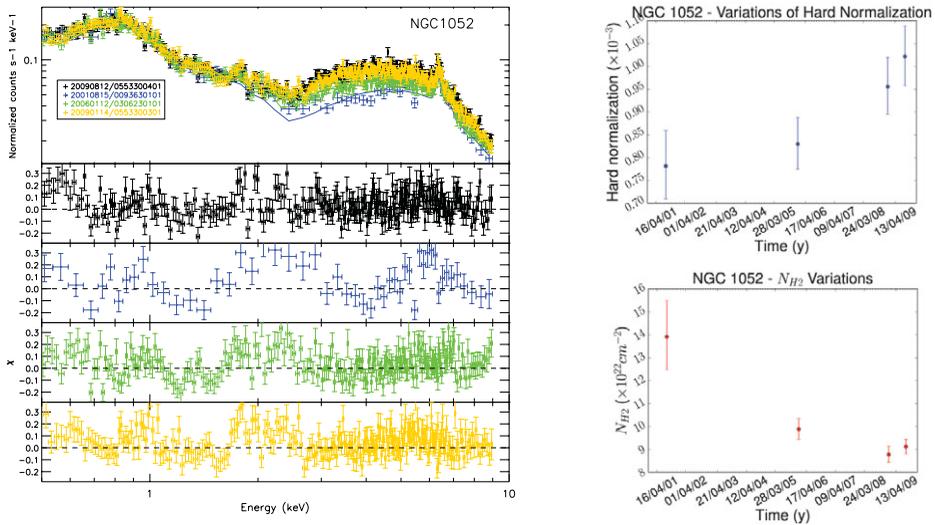


Figure 1. Best fit for NGC 1052 (left), where the variability is due to variations of the N_{H2} and the $Norm_2$ of the PL, associated to high energies (right).

For NGC 4278 we fit a model containing a thermal component plus a single power law (Fig. 2, left). The best fit implies variations of the Γ and the Norm of the power law (Fig. 2, right).

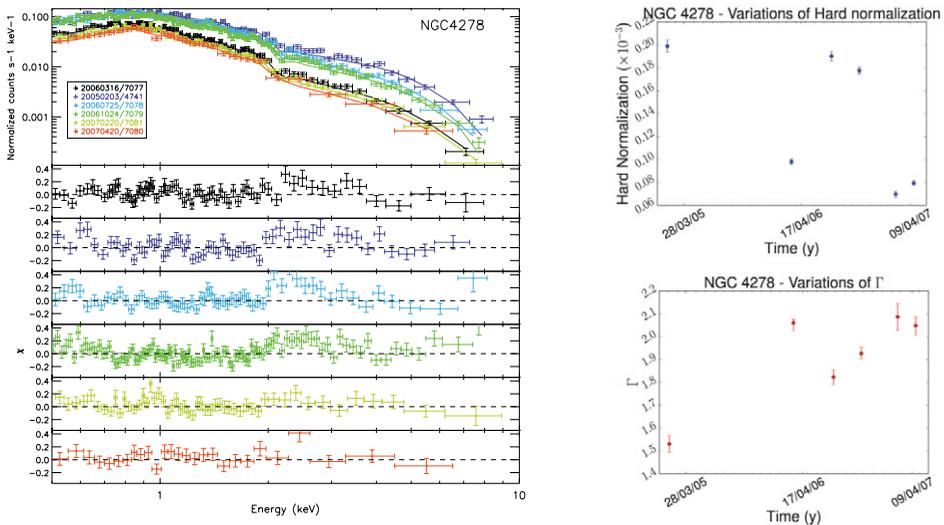


Figure 2. Best fit for NGC 4278 (left), where the variability is due to variations of the Γ and the Norm of the power law (right).

Here there is an anti-correlation between the variations of the Γ of the PL and the luminosities (Fig. 3, right). In this case we cannot compare the luminosities in the UV at the same dates since only *Chandra* data are available. However Cardullo *et al.* (2008), using data from *HST*, found a UV luminosity increase of a factor of 1.6.

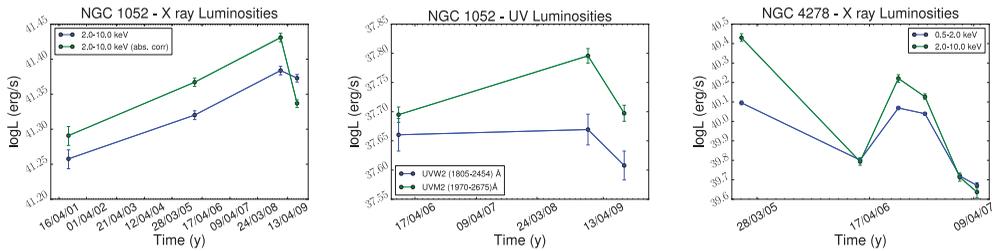


Figure 3. Luminosities calculated for: left) hard X-rays (2-10 keV) for NGC 1052, including absorption corrected luminosity; center) UV from the optical monitor (XMM-OM) with different filters for NGC 1052 and right) Soft (0.5-2 keV) and hard X-rays for NGC 4278.

4. Discussion and Conclusions

The scenario for NGC 1052 is consistent with those in Risaliti *et al.* (2007, 2010, 2011) for different Seyfert galaxies, where the variability is understood as clouds intersecting the line of sight of the observer. This can be conceivable within the framework of the clumpy torus model by Elitzur & Shlosman (2006) and Nenkova *et al.* (2008).

The fit by Younes *et al.* (2010) for NGC 4278 also left vary the Γ and the Norm of the power law. The difference with our model is that they used only one column density instead of two, but we can see the same behaviour in both results. About the anti-correlation between the slope and the luminosities, they suggest that this can be due to an Advection Dominated Accretion Flow (ADAF), where the accretion is inefficient. In this case the variability may be attributed to an intrinsic variation on the central engine.

The presence of different mechanisms for LINERs have to be confirmed with a larger sample of LINERs, which is under study. We plan to apply the same kind of analysis to the remaining fourteen LINERs from the sample of González-Martín *et al.* (2009) which show hints of variability. Studying these objects will allow to know more about the nature of such nuclei.

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