The X-ray variability properties of PG quasars: XMM-Newton results

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Abstract. This paper presents preliminary results of a systematic study on the X-ray spectral variability of PG quasars with XMM-Newton. We concentrate on those objects, whose X-ray spectra are well fit in the framework of the “double Comptonization” model. On short (\(\Delta t \sim 10^3\) s) timescales, variability between the soft (\(E < 2\) keV) and the hard (\(E > 2\) keV) bands is uncorrelated. In the two objects, for which observations at different epochs are available, spectral variability in the soft X-ray regime is unveiled. Its timescale is constrained in the range between \(~1\) week and \(~1\) year.

1. Introduction

In this paper we present preliminary results of a systematic study on the X-ray spectral variability properties of the PG quasar sample (Schmidt & Green 1983) with XMM-Newton (Jansen et al. 2001). The main goals of this project are:

- the identification of the physical driver underlying spectral variability in Active Galactic Nuclei (AGN), by determining the typical timescales on which it occurs in X-ray unobscured AGN
- the study of the correlation between emission in the soft (\(E < 2\) keV) and hard (\(E \geq 2\) keV) energy bands. The results of this study can shed some light on the physical origin of the X-ray emission. While the hard X-ray emission is probably due to Comptonization of hard disk soft photons in a compact corona within a few Schwarzschild radii from the supermassive black hole (Haardt & Maraschi 1991), the nature of a prominent and almost ubiquitous “soft excess” is still matter of debate. Thermal emission from the disk (Czerny & Elvis 1987), bremsstrahlung emission from the ionized skin of the accretion disk (Nayakshin, Kazanas & Kallman 2000), Comptonization by cool, thick gas (O’Brien et al. 2001), or an extremely relativistic warm outflow (Gierliński & Done 2004) are among the possible explanations.

It is of paramount importance that X-ray variability studies are performed with the same instrument, as the cross-calibration among detectors flown on different mission is not yet accurate enough to guarantee against spurious results. XMM-Newton is ideally suitable for such a study, thanks to its unprecedented effective area in the whole 0.1–15 keV energy band, which allows to expand the pioneering studies conducted by RXTE (Markovitz et al. 2003; McHardy et al. 2004) to a larger sample of comparatively weaker AGN.
Figure 1. 3–10 keV/0.1–1 keV Hardness Ratio (HR) versus 0.1–10 keV count rate for the PG quasars observed by XMM-Newton, whose spectrum can be fit in the “double Comptonization” scenario. The cases where a (positive or negative) correlation is found at a confidence level larger than 99% are highlighted.

2. The sample

Our parent sample is the whole set of XMM-Newton observations of PG quasars available in the public archive as of August 2004. They cover 42 objects, with largely inhomogeneous exposure times. Their spectral properties are presented by Porquet et al. (2004) and Jiménez-Bailón et al. (2004). In this paper we will concentrate on the spectral variability pattern in objects dominated by Comptonization in the whole XMM-Newton energy bandpass (0.1–10 keV). Consequently, we will consider in the following only the 20 PG quasars, whose XMM-Newton EPIC spectra are well fit with a double power-law model by Jiménez-Bailón et al. (2004).

2.1. Short term (<1 day) variability

In Fig. 1 we show the 3–10 keV versus 0.1–1 keV hardness ratio (HR) against the 0.1–10 keV count rate as measured on light curves with a time binning $\Delta t = 1024$ s. In only 2 objects ($\sim$10% of the cases) one observes a correlation more significant than the 99% confidence level according to a K-S test. Moreover, these correlations have two opposite signs: positive in PG0947+396, and negative in PG1202+281. We conclude that on such short timescales variations of the X-ray emission produced by the two Comptonization media are largely independent. They are probably dominated by local fluctuations in the accretion flow or in the disk illumination, which do not affect the disk-corona system as a whole.
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2.2. Long-term (>1 day) variability

There are only two PG quasars, for which XMM-Newton observations at multiple epochs are available: PG1407+265 and PG1440+356. The former was observed twice, in January and December 2001. The latter was observed by XMM-Newton 4 times in the framework of a specific program to determine the timescale of the spectral variability pattern. The first observation was performed on December 2001, the remaining three in January 2003, at the relative distance of three days each. In order to spectrally characterize their variability properties, we fit the data with a combination of two Comptonizing continua, trying different geometries for the seed photons influx and the Comptonizing media. The following results refer to a physical scenario where the two spherical reservoirs of Comptonizing electrons (a two-phase corona) share the same soft photons input flux (a region at the peak of the accretion disk thermal distribution, and smaller than the disk gradient temperature scale). We show in Fig. 2 the iso-$\chi^2$ contour plot for the temperature ($kT$) versus plasma optical depth ($\tau$) for the Comptonizing medium producing the bulk of the X-ray emission in the soft X-ray band. In both cases the best-fit parameters corresponding to observations separated by the longer intervals (≃1 year) are different at a confidence level larger than 99% for two interesting parameters. Intriguingly enough, in PG1407+265 a change in the optical depth of the Comptonized medium is favored, whereas in PG1440+356 a feedback mechanism between these quantities may force the contours to follow a source-specific “track” in the $kT$ vs. $\tau$ plane. Given the well known degeneracy of the above parameters in Comptonization models (Brinkmann et al. 2004), one should refrain from attributing a too literal meaning to the best-fit parameters values. However, regardless of their true values, one can firmly conclude that in these two cases the mechanism responsible for the spectral variability operates on time scales longer than
about 1 week and shorter than about 1 year. Although this is still a rather loose constraint (which could be improved in the future if XMM-Newton will pursue similar monitoring programs sampling intermediate timescales), it already rules out dynamical timescales playing an important role. Viscous instabilities in the accretion flow are a more likely candidate for the ultimate physical driver of the long-term variability.

3. Conclusions

We are undertaking a systematic study of the X-ray variability pattern of the PG quasars using XMM-Newton observations. In this paper we focus our attention on the variability pattern in “naked” quasars, whose emission across the whole XMM-Newton band is due to Comptonization. The main results can be summarized as follows:

- on short (∼hours) timescales there is no correlation between the variability in the soft and the hard X-ray regime
- variability of the Comptonizing plasma physical parameters is observed when observations separated by more than 1 week (and less than 1 year) are compared

We propose an interpretation in terms of viscous instabilities in the accretion flow driving the observed changes in the properties of the Comptonizing plasma.

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