Variability is one of the hallmarks of Active Galactic Nuclei. The Burst Alert Telescope onboard of Swift, with its homogeneous coverage of the sky is a formidable tool to study variability at hard X-rays. We present here the analysis of the 1-month binned Swift/BAT lightcurves of the 20 brightest Active Galactic Nuclei in the hard X-ray sky. The sample consists of 2 blazars, 3 radio galaxies, 6 Seyfert 1/1.5s, 8 Seyfert 2s and 1 Narrow Line Seyfert 1. We found that all the objects show variability, and most of them have a value of the fractional root mean squared variability amplitude of $F_{\text{var}} \sim 0.2 - 0.3$. We did not find any significant correlation of $F_{\text{var}}$ with the column density or the luminosity in our sample.
1. Introduction

Active Galactic Nuclei (AGN) are amongst the most luminous X-ray sources in the sky. AGN are thought to be powered by accretion onto supermassive black holes (Rees, 1984), with their X-ray emission probably originating in a hot corona sandwiching the accretion disk (Haardt & Maraschi, 1991) in radio-quiet objects, and in the jet in radio-loud AGN (e.g., Boettcher 2010). Variability is one of the key features of AGN, and it was found to be significative in the X-ray band already in early observations of nearby Seyfert galaxies (Sy) performed by Ariel V (Marshall et al., 1981). The X-ray variability of AGN is aperiodic, and their power spectral density distribution (PSD) can be normally described with a broken power law, with indices ranging between $-1$ and $-2$ (McHardy & Czerny, 1987).

The Burst Alert Telescope (BAT) onboard of Swift (Barthelmy et al., 2005) scans continuously the whole sky in the 14–195 keV energy range, and is thus an extremely well suited instrument for studying AGN variability at hard X-rays. Here we report a study of the hard X-ray variability of a small sample of AGN. The sample consists of the 20 brightest AGN detected by Swift/BAT, of these 2 are blazars, 2 narrow-line radio galaxies (NLRG), 1 broad-line radio galaxy (BLRG), 6 Seyfert 1/1.5s, 8 Seyfert 2s and 1 Narrow Line Seyfert 1 (NLS1). The 1-month binned light curves have been taken from the NASA Swift/BAT 58 months catalog\(^1\) (Baumgartner et al., 2011).

2. Variability estimators

A way to estimate the variability is through the fractional root mean squared (rms) variability amplitude $F_{\text{var}}$ (Edelson et al., 1990), defined as

$$F_{\text{var}} = \sqrt{\frac{S^2 - \sigma_{\text{err}}^2}{\bar{x}^2}}.$$  \hspace{1cm} (2.1)

Where the sample variance $S^2$ is given by

$$S^2 = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2,$$  \hspace{1cm} (2.2)

while the mean square error $\sigma_{\text{err}}^2$ by

$$\sigma_{\text{err}}^2 = \frac{1}{N} \sum_{i=1}^{N} \sigma_{\text{err},i}^2.$$  \hspace{1cm} (2.3)

The error of $F_{\text{var}}$ is given by

$$\text{err}(F_{\text{var}}) = \sqrt{\left(\sqrt{\frac{1}{2N} \frac{\sigma_{\text{err}}^2}{\bar{x}^2 F_{\text{var}}}}\right)^2 + \left(\sqrt{\frac{\sigma_{\text{err}}^2}{N} \frac{1}{\bar{x}}}\right)^2}.$$  \hspace{1cm} (2.4)

In the following we will use $F_{\text{var}}$ to characterize the variability of the objects in our sample.

\(^1\)http://swift.gsfc.nasa.gov/docs/swift/results/bs58mon/
Table 1: Properties of the sources of our sample: (1) detection significances, (2) luminosities in the 14–195 keV energy range, (3) fractional rms variability amplitudes on a timescale of 30 days, (4) hydrogen column densities.

| Source              | Det. Significance | log $L_{14-195\text{keV}}$ | $F_{\text{var}}$ (30-days) | $N_H$ | Type |
|---------------------|-------------------|----------------------------|-----------------------------|-------|------|
| Cen A              | 428.7             | 44.01                      | 0.399 ± 0.002               | 12$^a$| NLRG |
| NGC 4151           | 275.0             | 44.11                      | 0.280 ± 0.004               | 6.9$^b$| Sy 1.5|
| 3C 273             | 156.8             | 47.47                      | 0.31 ± 0.01                 | 0.5$^b$| Blazar|
| NGC 4388           | 110.7             | 44.64                      | 0.31 ± 0.01                 | 27$^b$| Sy 2 |
| Mrk 421            | 109.5             | 45.46                      | 0.96 ± 0.01                 | 1.0$^b$| Blazar|
| Circinus Galaxy    | 101.7             | 43.09                      | 0.13 ± 0.01                 | 360$^b$| Sy 2 |
| IC 4329A           | 101.1             | 45.22                      | 0.19 ± 0.02                 | 0.4$^b$| Sy 1 |
| NGC 2110           | 98.1              | 44.60                      | 0.32 ± 0.01                 | 4.3$^c$| Sy 2 |
| NGC 5506           | 95.0              | 44.31                      | 0.27 ± 0.02                 | 3.4$^c$| NLS1 |
| MCG−05−23−016      | 90.4              | 44.50                      | 0.21 ± 0.01                 | 1.6$^c$| Sy 2 |
| IGR J21247+5058    | 83.3              | 45.25                      | 0.31 ± 0.01                 | 0.6$^b$| BLRG |
| NGC 4945           | 76.1              | 43.37                      | 0.35 ± 0.02                 | 400$^b$| Sy 2 |
| Mrk 348            | 70.4              | 44.91                      | 0.28 ± 0.02                 | 30$^c$| Sy 2 |
| NGC 3783           | 68.7              | 44.60                      | 0.26 ± 0.02                 | 0.1$^c$| Sy1.5 |
| NGC 4507           | 64.6              | 44.77                      | 0.29 ± 0.02                 | 29$^a$| Sy 2 |
| NGC 3516           | 62.3              | 44.33                      | 0.30 ± 0.02                 | 4$^c$ | Sy 1.5|
| NGC 7172           | 60.1              | 44.46                      | 0.35 ± 0.04$^a$             | 9$^c$ | Sy 2 |
| NGC 3227           | 56.2              | 43.57                      | 0.16 ± 0.21                 | 6.8$^a$| Sy 1.5|
| Cyg A              | 54.0              | 46.01                      | 0.34 ± 0.02                 | 11$^b$| NLRG |
| MCG +08−11−011     | 49.0              | 45.09                      | 0.35 ± 0.03                 | 0.2$^c$| Sy 1.5|
| Crab               | 7496              | –                          | 0.0215 ± 0.0004             | –     | –    |

Notes. $^a$ Beckman et al. (2011), $^b$ Beckmann et al. (2009) and references therein, $^c$ Ricci et al. (2011) and ref. therein, $^*$ "Flare" of January 2008 removed.

3. Results

In Table 1 are listed the values of the fractional rms variability amplitude of the objects of our sample, and as a check, the value obtained from the light curve of the Crab ($F_{\text{var}} \sim 0.02$). The value of the Crab can be associated to the systematic error of the Swift/BAT data. In Fig. 1 we show the light curves of 6 out of the 20 sources of our sample. All the sources of our sample show hard X-ray variability on the time-scale of one month. As it can also be seen from Fig. 2, the value of the fractional rms variability amplitude is $F_{\text{var}} \sim 0.2 - 0.3$ for most of the objects of the sample, with the average value being $F_{\text{var}} = 0.32$. The blazar Mrk 421 shows a much stronger variability ($F_{\text{var}} \sim 0.96$) than the average value of the sample. Amongst the radio-quiet NGC 7172 is the most variable, with a value of $F_{\text{var}} \sim 0.48$. This is due to what would appear to be a flare, registered
in January 2008. Excluding this outlier point NGC 7172 shows a variability consistent with the average of our sample ($F_{\text{var}} = 0.35 \pm 0.04$). At the other end of the distribution, the Compton-thick Seyfert 2 Circinus Galaxy and the Seyfert 1 IC 4329A show the smallest amounts of variability ($F_{\text{var}} \sim 0.13$ and $F_{\text{var}} \sim 0.19$, respectively). The low value of $F_{\text{var}}$ of Circinus Galaxy is very likely related to the reflection-dominated nature of its hard X-ray spectrum.

4. Variability vs Luminosity and Column density

An inverse correlation between the variability amplitude in the X-rays and the X-ray luminosity of AGN was found by (Barr et al., 1986) using EXOSAT data. More recently, Beckmann et al. (2007) studied the hard X-ray variability of the 44 brightest AGN detected by BAT after 9 months of operations, and found that possibly this anti-correlation is extended to the hard X-ray band (see also Soldi et al., 2010). They also found a possible correlation between the hydrogen column density $N_{\text{H}}$ and the variability amplitude. We investigated the existence of these two correlations in our
The variability amplitudes in our sample are confined in a small range of values, and no correlation with other parameters is evident. A Spearman rank test gives a correlation coefficient between $F_{\text{var}}$ and the luminosity of $r_s = 0.27$, while it is $r_s = 0$ between $F_{\text{var}}$ and $N_H$. These values correspond to a probability of correlation of 78% in the first case, and of 0% in the second case. Similar results are obtained also considering Mrk 421 as an outlier. No significant correlation is found also dividing the sample in three categories (Sy 1/1.5, Sy2, radio-loud). The lack of correlations might be due to the limited sample we used, and further studies are needed to better probe it.
5. Conclusions

Studying the 1-month binned Swift/BAT light-curves of the 20 brightest objects after 58 months of observations, we found that all the objects in our sample show variability, ranging between $F_{\text{var}} = 0.13$ and $F_{\text{var}} = 0.96$, for Circinus galaxy and Mrk 421, respectively. The average value of the variability amplitude is $F_{\text{var}} \sim 0.3$. We did not find any significant correlation of the variability amplitude with the luminosity and the hydrogen column density.

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