THE BATSE 9 YEAR HISTORIES OF THE BRIGHTEST AGN

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ABSTRACT

The Burst and Transient Source Experiment (BATSE) aboard CGRO monitored the whole sky through 8 NaI(Tl) crystal scintillators sensitive in the 20 keV - 2 MeV energy band continuously from April 1991 until June 2000. Results are presented on the long term variability observed in the brightest Active Galactic Nuclei (AGN) present in the BATSE data archive. This was achieved through the application of the Earth Occultation technique to data flat-fielded using the BATSE Mass Model. Removal of the temporal background variations from the data should allow a more sensitive extraction of source parameters. Analysis of the general trends of the 9-year light curves are also presented.

Key words: AGN; gamma-rays; galaxies: active.

1. INTRODUCTION

The Burst and Transient Source Experiment (BATSE) aboard CGRO monitored the whole sky through 8 NaI(Tl) crystal scintillators sensitive in the 20 keV - 2 MeV energy band continuously from April 1991 until June 2000. Results are presented on the long term variability observed in the brightest Active Galactic Nuclei (AGN) present in the BATSE data archive. This was achieved through the application of the Earth Occultation technique to data flat-fielded using the BATSE Mass Model. Removal of the temporal background variations from the data should allow a more sensitive extraction of source parameters. Analysis of the general trends of the 9-year light curves are also presented.

2. CALIBRATION USING THE CRAB

The Crab is one of the brightest γ-ray sources in the sky and is well known for its lack of variability. As such it is the ideal ‘standard candle’ with which to test the flat-fielded data set and explore the capabilities of our methods. Fig. 1 shows the 9 year light curve of the Crab in the 30-230 keV energy band as measured on a daily basis and with a 53 day moving average fit; 53 days is the precession period of CGRO.

A histogram of this light curve is seen in Fig. 2. The Crab appears relatively constant in the light curve, hence the histogram should have a Gaussian profile. Fitting a Gaussian distribution to the histogram yields a centroid of $1.005 \pm 0.002$ Crabs with a reduced $\chi^2$ of $\sim 3$. Examining the residuals of this fit indicates a number of spurious points in the 0.6-0.9 Crab region which may be the result of an unknown low level systematic, removing these points renders a fit with a $\chi^2$ of 1.3. Rebinning the data into longer timescale averages, before generating the histogram, allows the estimation of the systematic component of any errors. As the time bins increase in size the standard deviation of the data set would ideally asymptotically approach 0. The inset graph of Fig. 2 shows that the curve approaches $\sim 2.5\%$, indicating this level of systematic error. This level is assumed in our studies of AGN light curves.

3. BATSE AGN

AGN are some of the most powerful persistent sources of γ-rays in the observable universe. However the low fluxes which arrive at Earth make them a very challenging subject to observe in this waveband. The three brightest AGN seen in BATSE are: Centaurus A, a radio galaxy; NGC4151, a seyfert galaxy; 3C273, a blazar. Fig. 3
Figure 1. The 9 year 30-230 keV light curve of the Crab Nebula as measured on a daily basis. The solid grey line is the 53 day (the satellite precession period) moving average.

Figure 2. The histogram of the Crab light curve seen in Fig. 1. The inset graph indicates how the standard deviation of the histogram decreases with increasingly large time bins. The broken black line indicates the power law decay. The broken grey line represents the asymptote which is indicative of the systematic error.
Figure 3. The 9 year BATSE light curves of Cen A, NGC4151 and 3C273. The broken black line with diamond points indicates the 20-50 keV flux; the solid black line with crosses indicates the offset 50-160 keV flux. The solid dark grey line is the offset 2-10 keV flux from the ASM on RXTE.
shows the light curves in the BATSE 20-50 keV and 50-160 keV band of these AGN. The data have been binned up to 30 day data points in order to minimise any errors. Additionally the RXTE-ASM 2-10 keV light curves are presented, scaled and offset from the BATSE curves to aid legibility. Fig. 4 is a hard flux - soft flux plot of the three AGN showing the flux in the 30-50 keV band against that of the 50-160 keV band.

3.1. Centaurus A

The hard and soft BATSE light curves seen in the upper panel of Fig. 3 appear to be well correlated apart from a short, ∼30 day outburst in the 20-50 keV band at TJD ∼10800 which appears to coincide with a drop in the 50-160 keV flux. However, the 20-50 keV flux continues to be correlated with the ASM light curve during this period. This appears to be corroborated by the hard - soft plot where the hard and soft fluxes indicate a positive correlation. A Spearman rank correlation coefficient of 0.56 with a probability of chance occurrence of p<0.0001 confirms this positive correlation. The ASM light curve follows the general trends exhibited by both of the BATSE light curves neglecting the outburst at TJD ∼10800.

3.2. NGC 4151

The hard and soft light curves shown in the middle panel of Fig. 3 appear to be well correlated although there appears to be a potential time lag between them of ∼30 days. Emission in the 50-160 keV band initially appears to precede that of the 20-50 keV band, however this is not obvious after TJD ∼8800. As this lag is on the same time scale as the data binning it is tenuous without a detailed statistical analysis. The hard-soft plot looks flat as the hard flux appears independent of the soft flux, however, a positive correlation is indicated by a Spearman rank correlation coefficient of 0.31 with a probability of chance occurrence of p=0.002.

3.3. 3C273

Both light curves seen in the lower panel of Fig. 3 are synchronized and well correlated. They both show the same general trends. The hard-soft plot indicates a positive correlation with a Spearman rank correlation coefficient of 0.45 with a probability of chance occurrence of p<0.0001.

4. DISCUSSION AND FUTURE WORK

The 9 year BATSE data set has been flat-fielded using BAMM to remove temporal variations in the instrument background. We have then applied the standard Earth Occultation Technique developed at Marshall Space Flight Centre (Harmon et al. 2002) on the flat-fielded data set and made measurements to the Crab Nebula and 3 AGN: Cen A; NGC4151; 3C273.

Figure 4. Plotting the 50-160 keV (hard) flux against the 20-50 keV (soft) flux of the AGN Cen A; NGC4151; 3C273. NGC4151 and 3C273 hard fluxes have been offset by +100 and +200 respectively for legibility.

The Crab light curve exhibits a constant flux of 1.005 ± 0.002 Crabs confirming that the flat-fielding had no adverse effect on the data. Additionally, the systematic error of the methods and analysis performed in the generation of the light curve is estimated to be limited to ∼2.5%. The AGN light curves show that BATSE is sensitive to the variations in their γ-ray fluxes.

Work is in progress to re-optimise the standard Earth Occultation technique for use with the flat-fielded data with the intention of improving sensitivity and precision of measurements. We are simultaneously using the flat-fielded data with new methods to generate all-sky images for the whole 9 years (Shaw et al. 2004; Hill et al. 2004).

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