Short Time-scale Gamma-Ray Variability of Blazars and EGRET Unidentified Sources

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Abstract.
We have begun to examine the EGRET database for short term variations in the fluxes of blazars and the unidentified sources at high Galactic latitudes. We find that several AGN show previously unreported variability. Such variations are consistent with inverse Compton scattering processes in a shock propagating through a relativistic jet.

INTRODUCTION

Previous gamma-ray variability studies of EGRET detected blazars and unidentified sources have focused on long time-scale (weeks to years) variability \cite{7}, \cite{6}. However, observations of bright flares, such as the outbursts of PKS 1622-297 \cite{4} and 3C 279 (\cite{2}, \cite{12}), clearly show variability on time-scales much less than a week. We therefore have set out to examine the EGRET data for variations on short time-scales (roughly, 2–14 days).

In general, observations of at least two weeks had been scheduled for most EGRET projects in order to detect weak sources. The standard counts maps were generated for the entire viewing period, and thus fluxes and spectral information determined from them are \textit{averaged} properties over many days. Thus, any shorter time-scale variations would have been washed out. Since several blazars are known to vary dramatically on time-scales \(\sim 1\) day–1 week at gamma-ray energies, we would expect that there are other blazars with similar, though probably less dramatic, variability properties. We have thus started an examination of EGRET data for such fluctuations. This process will also bring our attention to bright transients that only appear in part of one viewing period.
METHOD

In order to concentrate on blazars and potential blazars we have limited our study to viewing periods (VP’s) centered on $b > |20^\circ|$. A similar study on the Galactic anticenter region is reported on by Thompson et al [10]. Similar to Thompson et al [10], we have divided each viewing period into new two-day maps of $> 100$ MeV counts (accomplished for 35 VP’s). A standard maximum likelihood analysis was performed on each map [3] to determine fluxes over two-day scales. An estimated systematic uncertainty of 6.5 % has been added to the statistical uncertainties [6]. We have then used a $\chi^2$ analysis on fluxes and determined probability, $P$, that the data are consistent with a constant flux. The variability parameter of Mc Laughlin et al [6] is used to easily compare significance of variability among sources (and different VP’s on the same source):

$$V \equiv |\log P|$$

RESULTS

The blazar PKS 0208-512 (Figure 1) shows a factor of 2–3 increase over 3 weeks, followed by a rapid (2 day) factor of 3 decrease, and then another factor of 2–3 increase over the last week. The time history of the unidentified source 2EG J1835+5919 (Figure 2) is consistent with no variability over the 30 day period. However, inspection of Figure 2 reveals that there may have been a drop in flux over the last 10 days. The possible blazar 2EG J0220+4228 (0219+428) (Figure 3) shows a factor of 2–3 increase and decrease within one week. The blazar 0446+112 (Figure 4) undergoes a nearly factor of 4 decrease over one month, and nearly a factor of two within the last two weeks. No transients were found in any of the viewing periods studied.

DISCUSSION

The shortest time-scales of variability observed in this study are consistent with the model of Romanova and Lovelace [8]. They consider inverse Compton processes within a shock moving through a relativistic jet. A sudden acceleration of particles causes a brief synchrotron flare ($<< 1$ day) which will be accompanied by a simultaneous synchrotron self-Compton (SSC) flare over similar time-scales. However, since external inverse Compton models, such as the “mirror” model of Ghisellini & Madau [1], occur over larger spatial scales than the SSC models, the high energy flares will be delayed from the synchrotron flare and occur over several days. It is beyond the scope of this study to attempt any multiwavelength analysis and detailed theoretical modeling. In addition, we can not time-resolve the gamma-rays over $< 1$ day; however, our future work will check for general consistency with these
models. The relatively low amplitude and long duration of the flares in this study (as compared to, say, 1622-297 and 3C 279) favor external scattering models [8].

CONCLUSION

We have shown that three blazars undergo factors of 2–3 variability on time-scales $\sim 1$ week. This variability is consistent with inverse Compton processes from a shock in a jet. The high amplitude variability seen within one week for 2EG J0220+4228 suggests that this source is much more likely to be related to the blazar 0219+428 than to the pulsar PSR J0218+4232 [11] at energies $> 100$ MeV. 2EG J1835+5919 shows only marginal short time-scale variability, and varies by less than a factor of two over longer time-scales [9]. There are no compelling radio counterparts to this source [5]. These results suggest that the source 2EG J1835+5919 is unlikely to be a blazar.

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FIGURE 1. Short-term flux history for blazar PKS 0208-512

FIGURE 2. Short-term flux history for 2EG J1835+592
FIGURE 3. Short-term flux history for 2EG J0220+4228

\[ \chi^2 = 21 \text{ for 6 d.o.f.} \]

FIGURE 4. Short-term flux history for blazar 0446+112