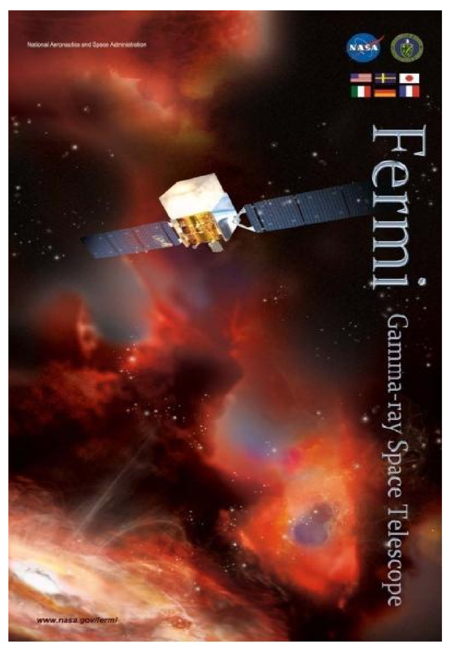

A tool for estimating the background of the LAT for transient events

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Abstract

The instantaneous rate of LAT background events from a source depends strongly on the geomagnetic coordinates at the location of the spacecraft and the off-axis angle of the source. These dependencies can cause short-term fluctuations of the background rate that can be as large as a factor of two. For long-term observations these fluctuations average out, however for short-term observations (seconds to ~several tens of minutes) they are important. A tool that takes into account these effects to accurately estimate the number of LAT background events for any kind of observational conditions has been developed and is presented here.

The Background Estimator

The background-estimation tool can estimate the background for observations of any duration and from any direction in the celestial sphere (including the galactic plane). It can provide estimates for both past and future observations and works with the S3, Transient and Diffuse LAT data classes. The estimates are provided versus the energy and have an accuracy of ~15%. The tool is currently available to only the members of the LAT collaboration, however it is planned to be included in the Science Tools and released to the public.

Background Estimation Method

The gamma-ray component of the background from some direction in the sky depends only on the exposure at that direction, while the Cosmic-Ray (CR) component of the background also depends on the geomagnetic coordinates of the spacecraft during that observation. For that reason, these two components are estimated separately using two different techniques.

Cosmic-Ray Background Estimation

At an instant of an observation, the CR-background rate from some direction in the sky (described by say its galactic coordinates L/B) is equal to the product of the all-sky CR-background rate ($R_{CR,allsky}$) times the probability that a generic CR-background event will be reconstructed at that specific direction P(L,B).

- $R_{CR,allsky}$ is calculated from its dependence on the geomagnetic coordinates at the location of the spacecraft (McIlwain's L parameter). See figure 1 for an example.
- P(L,B) is calculated from the probability of a generic CR-background event being reconstructed at some specific direction in instrument coordinates P(θ,φ) (where θ and φ are the off-axis and azimuthal angles respectively) and the pointing information of the spacecraft (to convert from instrument to galactic coordinates).

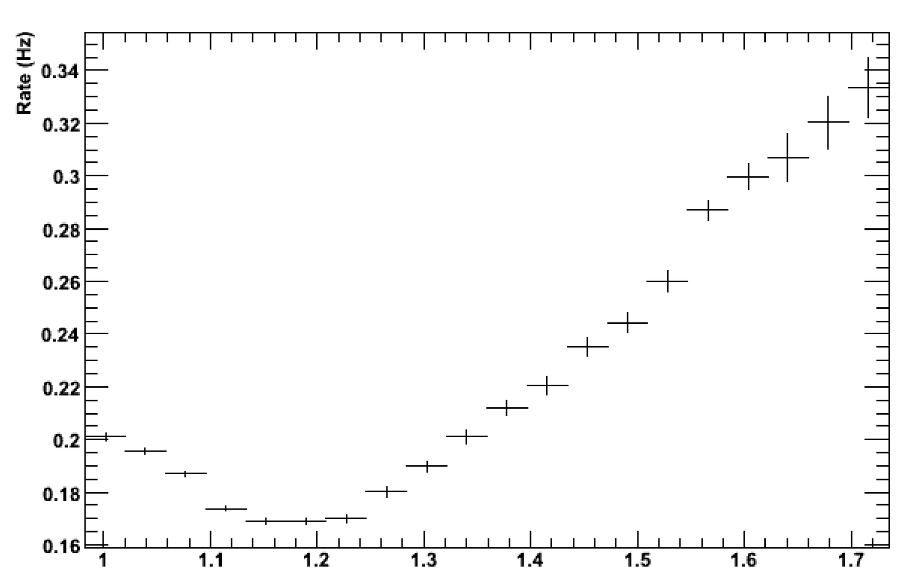

Figure 1: All-sky CR-background rate for transient-class events with energies ~1GeV versus the McIlwain L coordinate of the location of the spacecraft.

- Both $R_{CR,allsky}$(McIwalnL) and P(θ,φ) were extracted from a subset of an one-year actual LAT dataset, produced while the spacecraft was pointing at high galactic latitudes |B|>70°. For such a dataset, the fraction of gamma rays is minimized and the events can be approximated as being mostly cosmic rays (at least for the transient and S3 data classes).
- The background calculation is performed for different energy ranges, using a different $R_{CR,allsky}$(McIwalnL) and P(θ,φ) for each range.

Gamma-Ray Background Estimation

The amount of gamma-ray background from some direction in the sky depends only on the accumulated exposure in that particular direction. Therefore, this component is estimated by simply scaling the number of gamma rays detected in the one-year LAT dataset (with no galactic-latitude cuts applied this time) by the ratio of the exposure of the observation over the exposure of the one-year data set.

Applications

- **Estimation of the significance of the observation of a transient event.** Such events can be for example prompt GRB emissions, flares in GRB afterglows, flares from other sources such as SGRs or AGN.
- **Spectral analyses.** The tool can provide background templates for Fermi-LAT's standard likelihood-analysis tool gtlike.
- **Perform blind searches for transient emissions.** The tool can produce background-subtracted light curves that can be easily searched for evidence of transient emissions. Also, the future background maps produced by the tool can be compared with actual signal maps to search for flaring sources in real time.

Performance/Verification

The Tests

- The accuracy of the estimates has been tested against real LAT data by comparing the number of events that were actually detected from some direction in the sky during some time period to the background estimate corresponding to the same exact direction and time period.
- Multiple such comparisons have been performed for different directions in the sky, starting times, and LAT data classes (S3, Transient, and Diffuse).
- The background estimates of short-duration observations are sensitive to different types of systematics than the estimates of longer-duration observations. Unfortunately, the typical durations this tool is used for (seconds to tens of mins) correspond to few background events at best and are not long enough to provide enough statistics for comparison. To have enough statistics on the actually-detected number of events, observations of few tens of ks had to be used.
- To estimate the systematic error of the background estimate for some data class and some energy range, distributions of the ratio of the actually-detected over the estimated number of events were made, each for a different data class and energy range. The width of such distributions was a combination of the statistical error of the number of actually-detected events and of the systematic error of the background estimate. By properly subtracting the statistical error, the required systematic error of the background estimate was obtained.

Results

- For all tested data classes, the ratios of the actually detected over the estimated number of events were distributed on Gaussian distributions with average consistent with zero and standard deviations ~5-15% (depending on the duration and the data class). Figure 1 shows such a distribution, and figure 2 shows the systematic error of the background estimate versus the energy.
- The tests did not detect any systematic bias (over- or under-estimation of the background).
- The tests did not detect any dependence of the accuracy of the simulation on the location of the source (such as its galactic latitude).

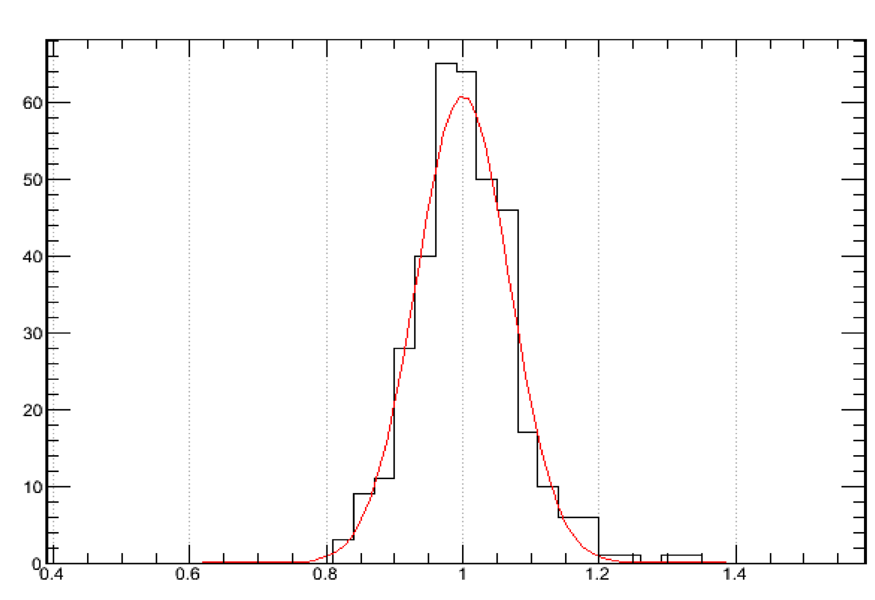

Figure 1: The distribution of the ratios of the estimated over the actually-detected events for transient-class events with energies about 100MeV. It follows a Gaussian distribution with average zero and width ~7%.

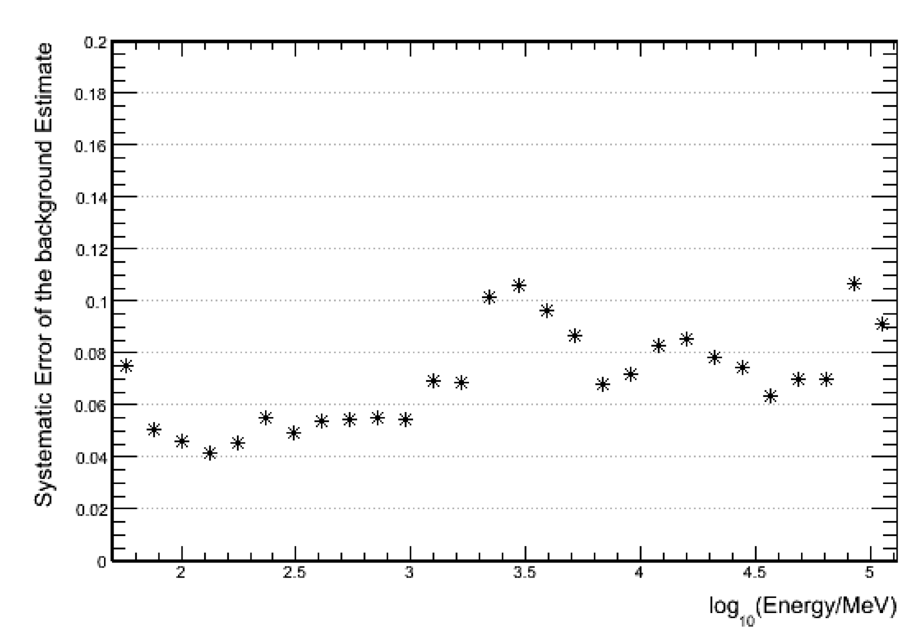

Figure 2: Systematic error of the transient-class background estimate versus the energy. These errors were calculated from the widths of the corresponding distributions (such as the one in the figure at the left) after subtraction of the statistical error in the number of actually detected events.