Searching for Gamma-Ray Emission from Rocky Bodies around Nearby Stars

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Abstract
Using the Fermi Large Area Telescope (LAT) we report on the utilization of the LAT to find evidence of particle cascades produced by cosmic ray interactions with surfaces of rocky bodies around nearby stars. In order to test the capabilities of Fermi as a tool to detect these bodies we pointed at α Lyr looking for signs of γ rays emitting off any asteroid-like bodies associated with the debris disk. Using an energy range of 100 MeV to 100 GeV the closest source to α Lyr’s coordinates, we found, is unsassociated with the star. Since no source was seen at these coordinates we concluded that the signal proposed to be there by these particle cascades is too faint to be detected by Fermi.

Introduction
The Fermi Large Area Telescope (LAT) is a space telescope conducting an all-sky gamma-ray survey. Below, Fig. 1, is the Fermi Gamma Ray picture of the sky. This photograph shows us what our sky looks like in gamma rays but also shows the innumerable amount of stellar objects to be studied in this spectrum.

Apart from being used for efforts towards finding potential dark matter candidates such as WIMPs and completing our picture of the night sky, the LAT has also been used for many other useful purposes one of which was to find the moon (A. A. Abdo et al. 2012), an object that initially one would think to be

References

Unbinned Analysis Results
After completing the previously described steps on the coordinates of α Lyr we present the following results. The primary result from our Likelihood analysis was the TS value we obtained from our unbinned analysis. We obtained a TS value of 0.875372. Typically a value of 25 or greater is necessary to claim a significant source exists at the coordinates.

Upper Limits
The idea of placing upper limits on the flux taken from a certain region helps us verify greater that we cannot see the debris disk surrounding α Lyr. By comparing the maximum flux as seen from our own moon to the maximum flux we can see from a particular region, if detectable, we can then put a limit on the amount of rocky bodies that have to be surrounding that source. However, in the case of Vega, simply not enough photons were detected to even reach a resulting upper limit for it’s region. This finding, accompanied by our unbinned analysis results, allows us to come to these conclusions.

Conclusions
After completing a Unbinned Likelihood and Upper Limit analysis on α Lyr we can conclude that with 6 months worth of photon collection data that if a gamma ray source is present from particle cascades off of any rocky asteroid-like bodies surrounding Vega exists it is too faint to be seen at the LAT. Within a 100 MeV to 100 GeV range we were unable to produce a sufficient TS value, 0.875372, at α Lyr’s coordinates, suggesting that to Fermi, nothing is there. The insufficient photon counts within our search area prohibited an Upper Limit analysis on the entire range, along with several energy bins, to be carried out.

Acknowledgments
Texas A&M University thanks Charles R. ’62 and Judith G. Murnerly, George P. ’40 and Cynthia Woods Mitchell, and their families for support of astronomical instrumentation activities in the Department of Physics and Astronomy.

Figure 1. Fermi two-year all-sky map depicting all sources and events collected by the Fermi LAT over the course of the first 2 years of its mission.

Figure 2. The red circles are the 24 month unbinned analysis made by Fermi LAT Spectra of the Moon by the LAT. A spectrum is comprised of two components. The short dashed line and long dashed lines show these components separately and the solid line shows the combined spectrum at a given energy range.

Figure 3. The center object is α Lyr and the red cloud surrounding it is the discovered debris disk. Hoping to offer another tool to find and study these debris disks we use the principles of particle cascades used to find the moon and apply them to these disks. Looking at a Lyr we ran an Unbinned Analysis using the Fermi Science Tools Package v10r0p5. Below is a summarized procedure, in order, of running an unbinned analysis of a particular source.

Obtain Data
The Fermi LAT Data can be requested by anonymous login in to analyze LAT data simply quoting the RA and DEC of your source, the number of energy bins, or time interval of interest, and energy range of observed photons.

glactic
First step in any analysis, glactic cuts the data specifically as on the user sees it. The greater use of these cuts are when many event files downloaded from the LAT Data Server and, as a last resort, calling them into one Binned File.

glatctos
The Fermi LAT team has included their event files when good-time intervals (GTIs) across ICTs are periods where fast imaging was done while collecting photons data. Periods common to these would be during certain months or software updates or position recalibration where photons were observed but could potentially be contaminated by these particular events, guideline can rule the data removing the poor time intervals allowing for more accurate analysis.

geocuts
Due to the LAT’s method of photons detections, incoming gamma-ray collisions causing electron-positron pairs that are then analyzed to determine origin and energy of the detected gamma-ray the angle from the LAT is recorded. Since both electrons and protons are detected the position where the primary photon was detected. Therefore, our analysis needs to know a specific time for each event recorded when the sky position and incident angle of the LAT event. This investment can be a three dimensional data set containing that information.

geomap
The exposure map created by this step is necessary to predict the number of photons contained and detected within the event set for XPL or any other components of our analysis.

makeOGLtest.py
This user contributed tool creates an input model that contains all sources from the XPL. The output is a file created from the Fermi LAT team at NASA that is within a certain number of degrees away from the XPL events. This model also allows the user to decide which source parameters they would like to freeze when optimizing the model flux. This file also contains the isotropic diffuse model and galactic diffuse model used to fix the background from a source.

medfilt
The LAT data unbinned analysis is based on expected values and probability. The expected photon distributions in components of the source model expectations and the instrument response functions compensating for extreme angles of the source results to the instruments is $\frac{\text{g}}{\text{c}}$. $\text{g}$ is the model of the diffuse and $\text{c}$ is the response function and adds the results to our event files in order to make sure component contributions $\text{c}$.

$\text{g}$ is the core of the unbinned analysis. Taking in the parameters from previously mentioned programs, $\text{g}$ creates a Tree Statistic (TS) depending on the type of analysis and the parameters that are included in the analysis. Since any of the parameters can be modified, the TS is able to include the TS depending on the parameters that are included. $\text{g}$ can modify the $\text{g}$ in which case the model vs. data becomes and if these increased or decreased the final parameters, until the best possible values for each parameter have been found. These parameters include things such as scale, index, and fluence.

Upper Limits
In the case that you wish to put upper limit values on the amount of flux that could be found in a given area, this python script takes a likelihood object, also created in python-similarly to $\text{g}$ and compares, based on TS values and the data from the event files, an upper limit for a given energy range or a given source.

Figure 4. This plot compares the total photon counts of Fermi LAT tool set the region of our analysis, with the individual counts of sources from the Fermi LAT tool set the region of our analysis. The black line represents the total photons or source attributed to the Galactic Diffuse background, the dotted red line represents the Isotrop Diffuse background, counts, and lastly the solid red line represents the counts at α Lyr. The dotted black line is to confirm the counts derived by the LAT data derived with the model name of our sources.

Fig. 4 shows how most, if not almost all, the photon counts in our total observed counts from LAT are contributed to the isotropic and galactic diffuse backgrounds. Very little, and sometimes no photons are contributed from Vega as a source.