What can we learn from and about the Large Magellanic Cloud with GLAST?

G. Weidenspointner[1], *V. Lonjou*[2], *and J. Knödlseder*[1]

[1] *CESR, Toulouse, France* [2] *CENBG, Bordeaux-Gradignan, France*

Abstract

The Large Magellanic Cloud (LMC) is one of our closest neighbouring galaxies. Its proximity, and the fact that we view it almost face-on, render it uniquely suited for studying with GLAST the content, distribution, and origin of cosmic rays in a galaxy other than the Milky Way. With EGRET, high-energy gamma rays above 100 MeV were already detected from the direction of the LMC, but this small galaxy could not yet be resolved. We performed detailed simulations using preliminary response functions for the Large Area Telescope on GLAST to assess whether this instrument will be able to resolve the LMC in high-energy gamma rays. Once the LMC is resolved, we will be able to study for example high-energy processes in the massive star-forming region 30 Doradus or high-energy emission associated with the prominent super-bubble LMC 2, a potential cosmic-ray acceleration site.

Please note...

The results presented here are work in progress.
All analyses have been performed using preliminary versions of the LAT Science Tools and preliminary response functions.
The results presented here pertain to an observation time of 1 year.
It is a pleasure to acknowledge indispensable advice on how to best use the LAT Science Tools by S. Digel and J. Chiang (SLAC).

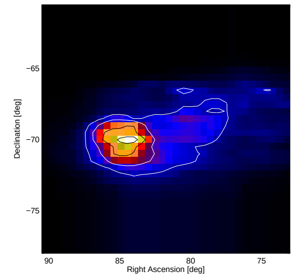
Conclusions and Further Work

We conclude that LAT will allow us to study the origin of cosmic rays in the LMC. Depending on how structured the emission is, we can hope to identify the most prominent emission regions as early as after 1 year of observations. Once the spatial distribution is determined, a spectral analysis, revealing the physical origin of the emission, can be performed.
The next step in our study will be to characterize extent and centroid of extended emission by fitting families of simple shapes (e.g. Gaussians) on a grid of positions to the data. We will also explore atomic and molecular gas distributions as tracers of high-energy emission from the LMC.

Simulated Sky Components

Our simulated sky consisted of three components: the LMC (either an extended source or a point source), the Galactic diffuse emission, and the extragalactic diffuse emission.

- LMC models: the spectrum was assumed to be a power law with a spectral index of −2 and an integrated flux above 100 MeV of 1.42×10^{-7} ph cm^{-2} s^{-2} (3rd EGRET catalog, Hartman *et al.*, 1999, ApJS, 123, 79).



∗ Extended source: model developed by Sreekumar (priv. comm.), shown to the right (contour levels correspond to intensities of 1, 2, 4, and 6 × 10^{-5} ph cm^{-2} s^{-1} sr^{-1}). The emission is extended over several square degrees with very little structure. We expect the LMC emission not be more diffuse, and consider this model a "worst case" in terms of the emission extent. The brightest emission is found close to the 30 Doradus complex (at $\alpha \sim 85°$ and $\delta \sim -69°$) with a FWHM of about 3°.

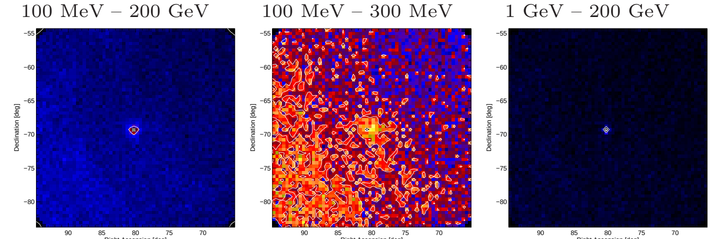
∗ Point source: at $l = 280°$ and $b = 33°$, corresponding to $\alpha = 80.78°$ and $\delta = -69.35°$. We expect the LMC emission to be more extended; this model serves mainly to study the impact of the source extent on the analysis.

- Galactic diffuse emission: simulated using the current LAT model, which is built using the "optimized" distributions of cosmic rays in `GALPROP` (see P17.9). The all-sky flux was set to 18.595 ph m^{-2} s^{-1} in the energy range 10 MeV to 655.36 GeV.
- Extragalactic diffuse emission: modelled as an isotropic distribution. Its spectrum was assumed to be a power law with spectral index −2.1 and an integrated intensity above 100 MeV of 1.45×10^{-5} ph cm^{-2} s^{-1} sr^{-1} (Sreekumar, *et al.*, 1998, ApJ, 494, 523) .

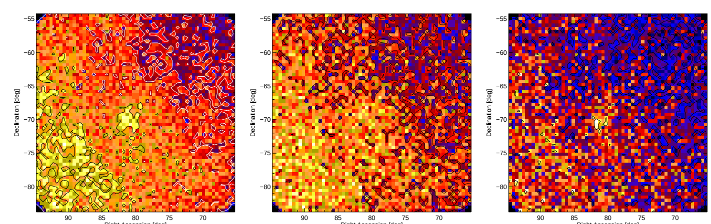
Examples of simulated skies after 1 year of observations are given below for three energy ranges. The gradient in the count maps are due to the Galactic diffuse emission. By definition, the counts due to a point source are more concentrated than the counts due to extended emission. The PSF of the LAT decreases with increasing energy, from ∼ 5° at 100 MeV to ∼ 0.2° at 10 GeV. The emission from the LMC is most easily discerned from the underlying diffuse emission components at the highest energies.

100 MeV – 200 GeV | 100 MeV – 300 MeV | 1 GeV – 200 GeV

- LMC (point source) with Galactic diffuse emission and extragalactic diffuse emission.



- LMC (Sreekumar model) with Galactic diffuse emission and extragalactic diffuse emission.



Constraining the Spectral Shape

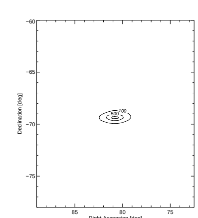
As a first step, we fitted the simulated sky components to the simulated data in order to assess the significance of the source detection and the constraints that can be put on the spectral shape. In the Table below, λ (2 times the log-likelihood ratio) and the the power-law index are summarized for the point source model and the Sreekumar model.

Energy Range	Point Source		Sreekumar Model	
	λ	Index	λ	Index
30 MeV – 200 GeV	2873.03	-2.28 ± 0.04	444.02	-2.29 ± 0.08
100 MeV – 200 GeV	2645.85	-2.07 ± 0.03	428.50	-2.01 ± 0.04
30 MeV – 100 MeV	590.94	-5.00 ± 0.01	284.28	-7.50 ± 0.39
100 MeV – 300 MeV	319.60	-2.10 ± 0.22	69.796	-3.62 ± 13.60
300 MeV – 1 GeV	900.118	-2.06 ± 0.15	163.96	-2.44 ± 0.26
1 GeV – 200 GeV	1425.88	-2.00 ± 0.06	179.87	-2.14 ± 0.09

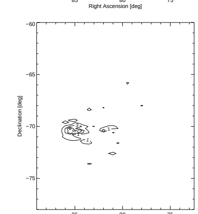
The LMC is clearly detected in all energy intervals (for 1 degree of freedom, the source significance is equal to $\sqrt{\lambda}$). As expected, although their fluxes are equal the point source is always more significantly detected than the extended emission; this trend increases with increasing energy because the LAT PSF becomes smaller.
For the point source model, the spectral shape can be well contrained above 100 MeV (the input spectrum has a slope of −2). For the much more extended Sreekumar model, the spectral shape is reasonably well constrained above 300 MeV. Below 100 MeV, the LAT response is not yet well defined. These results indicate that once the spatial distribution of the emission is determined (see "Constraining the Spatial Distribution" to the right), a spectral analysis to determine the physical origin of the LMC emission is feasible.

Constraining the Spatial Distribution

We began to explore how well the spatial distribution of the LMC emission can be constrained by fitting on a grid of positions (step size 0.5° in α and 0.2° in δ) a point source on top of the Galactic and extragalactic diffuse emissions using the LAT likelihood analysis tool. A first set of fits was performed in the 1-200 GeV interval, where the LAT PSF is smallest (see also count maps above).



- The top figure to the right depicts the λ (2 times the log-likelihood ratio) map obtained for a simulated sky in which the LMC emission is represented by a point source at $\alpha = 80.78°$ and $\delta = -69.35°$. The point source can easily be located. Although the grid is not optimized for this purpose, the best position is at $\alpha = 80.95°$ and $\delta = -69.35°$ – within 0.2° of the true position.



- The bottom figure to the right depicts the λ map obtained for a simulated sky in which the LMC emission is represented by the Sreekumar model. The distribution of λ values resembles the simulated emission model, despite the fact that the extended LMC model was fitted by point source PSFs (a rather poor approximation). Formally, the centroid of the emission is located at $\alpha \sim 85.5°$ and $\delta \sim -70.2°$, with an error of about 1°, in good agreement with the input model. However, although this method indicates the presence of extended emission and approximates its distribution, the low significance at each grid point (the maximum value is only about 8) renders this method not well suited for obtaining accurate constraints on the spatial distribution of the LMC emission.

As a next step, we will explore fitting models of extended emission (e.g. Gaussians) on a grid (see "Conclusions and Further Work").