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Simulation of Gamma Rays from Proton Interaction in Local Galaxies

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Abstract. The GLAST Large Area Telescope will provide unprecedented opportunities to detect cosmic GeV gamma rays, thanks to its large effective area, field of view and angular resolution compared with earlier telescopes. We present here the possibility of detecting GeV gamma rays produced by interactions of accelerated protons (or hadrons) with surrounding ambient material. Sources where such detection could be made include local galaxies, such as the Large Magellanic Cloud (LMC), molecular clouds and other extended sources. We have calculated the expected gamma-ray spectrum for an isotropic distribution of protons in the LMC and simulated a one-year GLAST-LAT observation.

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INTRODUCTION

It is widely accepted that the diffuse Galactic gamma-ray emission in the GeV range is dominated by decays of neutral pions produced in interactions of cosmic rays with interstellar matter [1, 2, 3, 4, 5]. With the sensitivity of the GLAST-LAT it is very likely that regions of enhanced density of gas or cosmic rays in the Galaxy as well as local external galaxies will be detected as extended sources. The proximity of the Large Magellanic Cloud (LMC) makes it a good candidate. The Energetic Gamma Ray Experiment Telescope (EGRET) measured an integrated gamma-ray flux above 100 MeV of $(1.9 \pm 0.4) \times 10^{-7}$ photons cm^{-2} s^{-1} [6] and a photon spectral index of 2.20 ± 0.20 [7].

SIMULATING GAMMA RAYS FROM THE LMC

We have simulated the gamma-ray emission due to protons interacting with atomic hydrogen (HI) in the LMC. We take the HI column density, shown in Figure 1a, from the ATCA/Parkes[1] 21 cm survey [8] and used our parameterization of the inclusive gamma-ray cross section [9] to calculate the expected gamma-ray spectrum and flux. Assuming a cosmic-ray spectrum the same as the local interstellar spectrum, $J_p(E) = 1.27 \times E^{-2.75}$ (m^2 GeV sr s)$^{-1}$ [10], we get a total gamma-ray flux above 100 MeV in the LMC region ($274^\circ < l < 284^\circ$, $-38^\circ < b < -28^\circ$) of 2.0×10^{-7} photons cm^{-2} s^{-1} and a photon spectral index of about 2.7. The spectrum is shown in Figure 1b. A count map for a one-year observation simulation of gamma rays from cosmic-ray interactions in the LMC over the Galactic diffuse and extragalactic background is shown in Figure 2.

CONCLUSIONS AND FUTURE WORK

As expected, the LMC will be easily detected with the GLAST-LAT. The LAT should be able to study the spectral shape of the gamma-ray emission from the LMC between about 80 MeV and 10 GeV. However, the calculated photon

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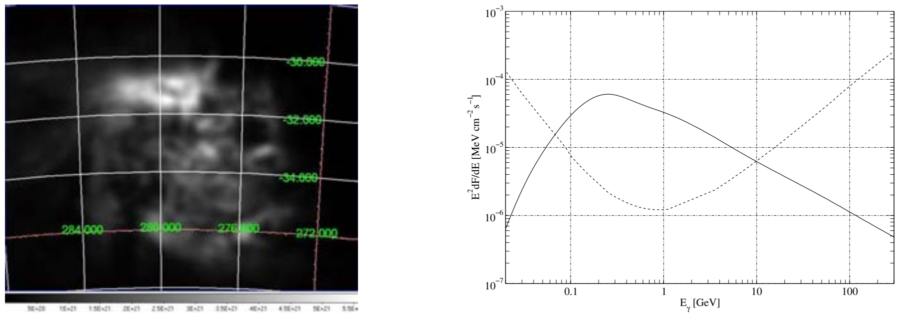

FIGURE 1. a) Column density of atomic hydrogen in the LMC [8]. The intensity range is from 0 to 6×10^{21} atoms cm^{-2} and the angular resolution is about $4'$. b) Predicted gamma-ray spectrum in the GLAST-LAT range assuming a proton spectrum equal to the local interstellar spectrum, $J_p(E) \propto E^{-2.75}$. The dashed line is the GLAST-LAT differential sensitivity for a one-year observation.

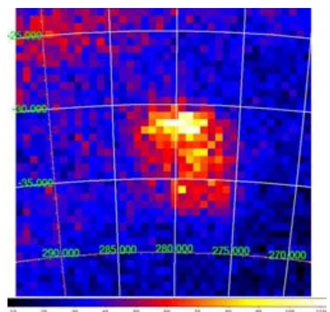

FIGURE 2. Gamma-ray count map (background not subtracted) from a one-year simulation of the LMC with both Galactic diffuse and extragalactic background. The count map covers $20^\circ \times 20^\circ$ centered at $l = 281^\circ$, $b = -33^\circ$ in 0.5° bins.

spectral index is much softer than that measured with EGRET, indicating that the cosmic-ray spectrum in the LMC is quite different from the local interstellar spectrum.

Future work will include estimates of the H_2 density from recent CO surveys (NANTEN) and simulations of other local galaxies, such as the Small Magellanic Cloud and M31, and dark clouds within the Galaxy. We will also utilize the deconvolution technique developed by H. Tajima [11] on EGRET data to constrain modeling.

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