Effects of the gas content on the Gamma-ray emission from the Galactic bulge

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Abstract. We use the recent model for the distribution of interstellar gas in the Galactic bulge developed by Ferrière et al. (2007) [1] together with the Galprop numerical code to compute the Galactic diffuse gamma-ray emission due to cosmic rays. We then compare our computed Galactic diffuse gamma-ray sky with the previous results obtained with Galprop. Based on the differences between the models of gas of [1] and that commonly employed in Galprop, we investigate what observational constraints GLAST/LAT could provide by simulating one year of GLAST/LAT sky survey.

Keywords: Gamma-ray: Diffuse emission - Galaxy : Cosmic ray

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INTRODUCTION

The spatial and spectral characteristics of γ-ray emission in the Galactic bulge (GB) depend not only on the intensity and propagation of high-energy particles, but also on the spatial distribution of the interstellar medium (ISM) in this region. The models for the gas spatial distribution that have been used so far to calculate this γ-ray emission are roughly representative of the gas content observed at other wavelengths. Recently, Ferrière et al. [1] constructed a model for the gas spatial distribution in the GB. In the present paper we are interested in the effects of this model on the Galactic γ-ray emission and also in the constraints that could be provided by the upcoming GLAST/LAT observations.

GAS CONTENT OF THE GALACTIC BULGE

Based on the observational studies of the ISM content of the inner part (|l| ≲ 20°) of the Galaxy performed over the last two decades at various wavelengths (dust thermal emission, CO line emission, HI 21-cm line emission and absorption, pulsar dispersion measures), together with recent theoretical analyses of gas dynamics close to the Galactic center, Ferrière et al. [1] built a model to describe the spatial distribution of the interstellar gas in the GB. According to [1], the ionized gas, which has a total mass \(M(H^+) \approx 7.1 \times 10^7 \, M_\odot\), appears to fill the entire GB, whereas both the HI and the \(H_2\) gas distributions can be divided into two different features:

a- The central molecular zone (CMZ), which has a disk-like shape with a major axis \(\sim 0.5\) kpc and a minor axis \(\sim 0.2\) kpc. In the CMZ, the HI gas with a Gaussian scale height \(\sim 54\) pc has a total mass \(M(HI) \approx 1.7 \times 10^6 \, M_\odot\) and the \(H_2\) gas has a Gaussian scale height \(\sim 18\) pc and has a total mass \(M(H_2) \approx 1.9 \times 10^7 \, M_\odot\).

b- A "holed" disk with a major axis \(\approx 3.2\) kpc and a minor axis \(\approx 1.0\) kpc in which the HI gas has a Gaussian scale height \(\sim 120\) pc and a total mass \(M(HI) \approx 3.5 \times 10^6 \, M_\odot\), whereas the \(H_2\) gas has a Gaussian scale height \(\sim 42\) pc and a total mass \(M(H_2) \approx 3.5 \times 10^7 \, M_\odot\).

MODEL OF THE GALACTIC DIFFUSE GAMMA-RAY SKY

Using the Galprop numerical code [2, 3] for Galactic CR propagation, we simulate the Galactic diffuse γ-ray emission resulting from CR interactions with the interstellar gas. We then use the CR source density as described in [4] and the Galprop parameters given in [5] to estimate the CR propagation for (a) the combined models of HI, \(H_2\) and...
FIGURE 1. Midplane profile averaged over 5° in Galactic latitude of the one-year GLAST/LAT simulation related to the Galactic diffuse $\gamma$-ray emission obtained with Galprop. The light line is related to the emission simulated using "standard" Galprop gas model complemented with the GB distribution made by [1], the dark line is related to the emission obtained with Galprop using the "standard" gas model. The dots are related to the one-year GLAST/LAT simulation of galactic diffuse emission modeled with the latest model at which we added the contribution of the central excess measured by EGRET [13].

H$^+$ distributions [6, 7, 8, 9, 10, 11] that are taken in Galprop and (b) for these models complemented with the GB distributions modeled by [1]. Using the GLAST Science Tools [12] and preliminary LAT instrument response together with the $\gamma$-ray sky modeled by Galprop, we simulate one year of GLAST/LAT survey of the Galactic diffuse emission for the two different ISM models. Figure 1 shows the midplane profile of the simulation of one-year GLAST/LAT observations of the Galactic diffuse emission in the photon energy range $300 – 1000 \text{ MeV}$.

CONCLUSION

Figure 1 shows that GLAST/LAT would be able to distinguish between both models after one year of sky survey. The diffuse $\gamma$-ray emission simulated in the disk by Galprop, using the gas model of [1], still consistent with the "standard" Galprop model which reproduces the EGRET measurements [5]. The main difference between both models reside in the presence of bright emission in the central 5° due to the high density of gas pervading the CMZ in the model of [1]. A longer GLAST observation time would enable one to study more accurately the spatial distribution of the $\gamma$-ray emission, and to obtain more constraints on the interstellar-gas distribution in the GB. We also show that the central excess measured by EGRET, with a total flux $\sim 9 \times 10^{-3}\text{ }\gamma\text{ cm}^{-2}\text{ s}^{-1}$ [13], could actually be induced by the CMZ emissivity under CR interactions. Here again, GLAST/LAT would enable one to determine whether the observed excess in $\gamma$-ray emissivity in the Galactic center is due to a compact source or to a diffuse medium.

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