Gamma Emission from the Galaxy: a New Model for AGILE

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ABSTRACT. We present the AGILE model of galactic gamma diffuse emission. The method used to derive gamma-ray emissivity is similar to that developed for the EGRET model (Hunter et al. 1997), but uses matter distribution derived from more recent observations and a different cosmic-ray model. The resulting model has a finer angular resolution, as required by the AGILE better performances. The model is in good agreement with EGRET observations.

1. Introduction

The study of galactic diffuse gamma emission will be one of the main scientific objectives of AGILE, the ASI satellite for gamma-ray astronomy that will be launched in 2005 (Tavani et al. 2004). The AGILE solid-state tracker (the GRID instrument) will have a field of view many times larger than previous gamma imagers. It will be able to cover π sr with one single pointing with an effective area about one half of that of EGRET. This means that AGILE will collect, for the same observing time, a number of diffuse photons larger by a factor of two. AGILE will also be the gamma-ray imager with the better angular resolution of ever, about a factor two with respect to EGRET for photons with energy larger than 400 MeV, with a point spread function depending weakly on off-axis angle. In order to better exploit these capabilities, a very accurate model of the Galactic diffuse emission is required for the analysis of AGILE data.
The gamma emissivity is supposed, as in the EGRET model, to be produced by the interaction of cosmic rays with the interstellar medium through three physical process: proton-proton collision, bremsstrahlung and inverse compton. Therefore, to build a gamma ray emmissivity map of the galaxy it is necessary to know the 3D distributions of cosmic rays and of cosmic-ray targets, namely interstellar matter, given mainly by atomic hydrogen and molecular clouds, and interstellar radiation field. The method used to derive gamma-ray emissivity is similar to that developed for the EGRET model (Hunter et al. 1997), but uses matter distribution derived from more recent radio observations and a different cosmic-ray model.

2. The EGRET model

The EGRET galactic diffuse emission model (Hunter et al. 1997) is a 3D grid of gamma-ray emissivity of our galaxy, centered on the Sun and with coordinates given by galactic longitude, galactic latitude and distance on the line of sight. The bin of this matrix is 0.5 degree for longitude and latitude and 0.5 kpc for radial distance. The cosmic ray model assumes that cosmic rays have throughout the galaxy the same spectral shape as measured near the Sun and a normalization correlated to the matter surface density. Also the ratio between protons and electrons fluxes is assumed to be equal to the local value. The atomic hydrogen distribution is derived mainly from the 21 cm survey of Weaver and Williams (1973) and the Maryland-Parkes southern survey (1986), while the molecular clouds distribution is obtained from the "superbeam" survey of Dame et al. (1987). These data were the best ones available when the EGRET model was made.

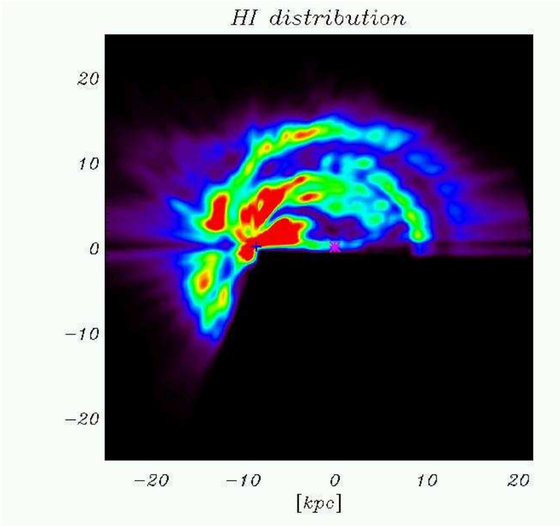

Fig. 1. Atomic hydrogen surface density derived from Leiden-Dwingeloo survey. The south celestial pole is not covered by this survey.

3. The AGILE model

The AGILE diffuse emission model is a 3D grid with bin of 0.25 degree in galactic longitude and latitude and 0.2 kpc in distance along the line of sight. In order to model the galaxy matter distribution we use the HI and CO radio survey recently terminated which are more accurate than the previous ones. Finally, in our model we are experimenting the cosmic ray models developed in the last years, which can differ from the locally observed cosmic ray spectrum.

3.1. Atomic and molecular hydrogen distribution

In order to deproject the velocity-resolved radio data we used the galactic rotation curve parameterized by Clemens (1985). Concerning the distribution of HI hydrogen we used the Leiden-Dwingeloo 21 cm survey (Hartmann & Burton 1997). This survey covers the sky north of declination −30°. The Leiden-Dwingeloo survey improves the previous results especially in terms of sensitivity (an order of magnitude better), velocity range and resolution. For the region around the south celestial pole, which is not covered by this survey, we used other observations, such as those from the Maryland-Parkes survey (Kerr et al. 1986).
In order to obtain the distribution of molecular hydrogen we use the CO observations described in Dame et al. (2001). The CO is assumed to be a tracer of molecular hydrogen with a ratio between hydrogen density and CO radio emissivity given by the factor X. At the moment we assume a constant X value, but one of the future improvements of our model is to make it a function of position.

3.2. Cosmic Rays

One of the aims of observation of gamma ray diffuse emission is to discriminate between cosmic ray models. For this reason our gamma ray emissivity model can include different analytical and numerical cosmic ray models which have been developed in last years.

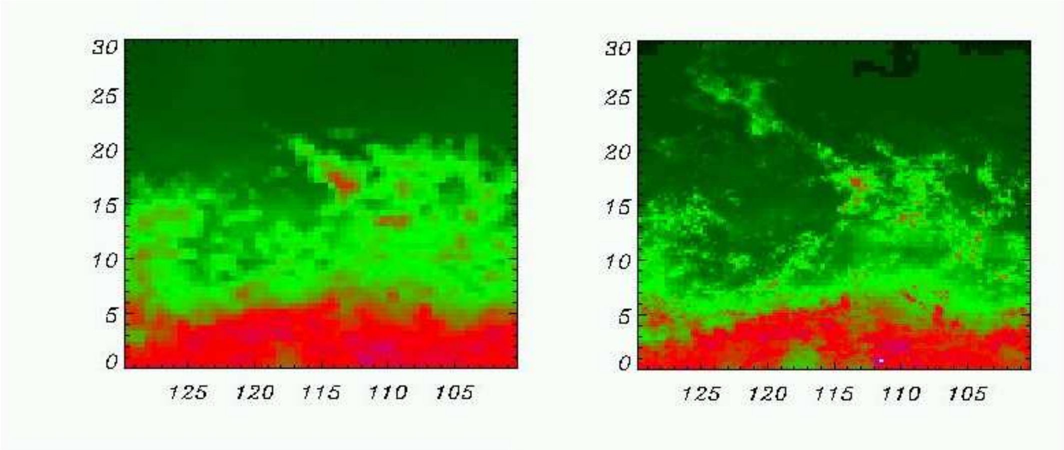

Fig. 2. The EGRET (left) and AGILE (right) diffuse emssion model for the Cepheus and Polaris flare region. Full resolutions images are available at the web site: `www.mi.iasf.cnr.it/` $\sim$ `giuliani/galaxy`

The results presented in these proceedings are obtained by using the cosmic ray model given by the numerical code GALPROP (Strong & Moskalenko 1998) which derives the cosmic ray distribution accounting for physical processes like diffusion and energy losses.

3.3. Interstellar Radiation Field

Cosmic rays produce gamma ray through the inverse compton mechanism interacting with photons of the cosmological background and of the interstellar radiation field (ISRF). In order to account for this component we use the analytical model proposed by Chi & Wolfendale (1991). It describes the ISRF as the result of three main contributions: far infrared (due to dust emission), near infrared and optical/UV (due to stars emission).

4. Second galactic quadrant

Figures 2 show the AGILE and EGRET models computed for the second galactic quadrant. The AGILE map appears to be more resolved than the other. Full resolutions images are available at the web site: `www.mi.iasf.cnr.it/` $\sim$ `giuliani/galaxy`.
Figure 3 shows the intensity of the gamma ray sky observed by EGRET as a function of galactic latitude, averaged in longitude from 90° to 160°. The red and the blue lines represent the AGILE and EGRET model respectively. Figure 4 is the analogous plot but averaged over latitude from -30° to 30°. These plots show a good agreement among the two models and the EGRET observations.

5. Test on simulations

A good knowledge of the diffuse emission model is important also for source analysis. In order to test the performances of our model from this point of view, we have simulated a set of 10 AGILE observations, at energy above 100 MeV, of the second quadrant sky region for a total observing time of about 5 months. In these simulations we have included the diffuse emission model, the point sources from third EGRET catalog and a component of noise due to particle background. As a test source for our analysis we have considered the source 2CG 135+01, with an assumed flux of $10^{-6} photons\ cm^{-2} s^{-1}$

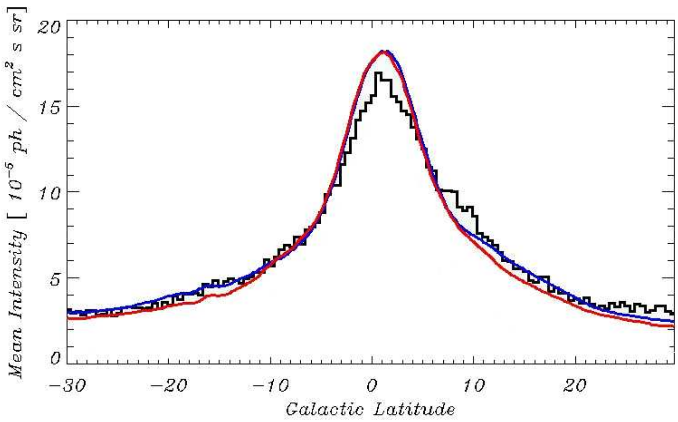

Fig. 3. Diffuse emission intensity observed by EGRET as a function of galactic latitude averaged in longitude from 90 to 160 degrees (binned line). The red and the blue lines rapresent the AGILE and EGRET model respectively.

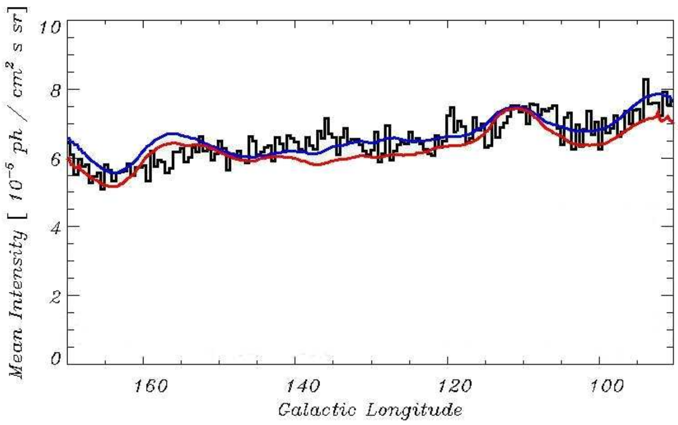

Fig. 4. As figure 3 but averaged over latitude.

above 100 MeV.
We performed two maximum likelihood analysis (Chen et al. 2004) on the test source using the AGILE and the EGRET models. Table I summarizes the results of the analy-

TABLE I
Results of ALIKE analysis for the two models

2GC 135+01	Flux ($10^{-8} ph/cm^2 s$)	G mult	G bias
EGRET model	179±5	0.271	11.1
AGILE model	149±5	0.789	7.85

sis. The second column presents the estimated flux of the test source. We found a better

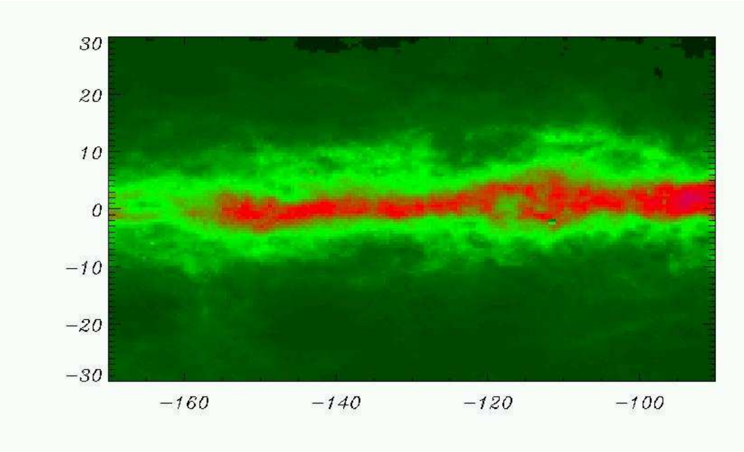

Fig. 5. Contribution of HI region to AGILE model.

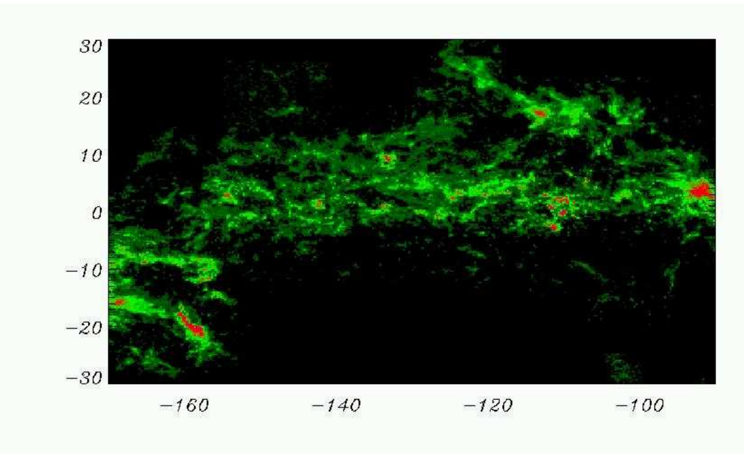

Fig. 6. Contribution of molecular clouds to AGILE model.

agreement with the simulated value using the AGILE model. Two more parameters are provided by the maximum likelihood method, the multiplicative (G mult) and additive (G bias) terms which allow the diffuse emission model used to better fit the simulated data. Also in this case we can notice that a smaller correction is needed for the AGILE model.

6. Conclusion

A new galactic diffuse emission model is under development. The model follows the EGRET approach but is bases on more updated matter and cosmic ray distributions. The resulting model has a higher resolution, as required by better AGILE point spread function.

The comparison with EGRET observations gives good agreement. The model gives better results also in term of source analysis.

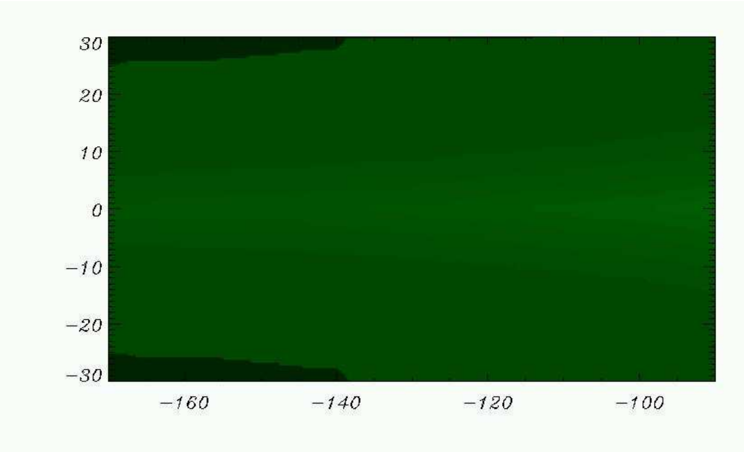

Fig. 7. Contribution of inverse compton (on CBR and ISRF) to AGILE model.

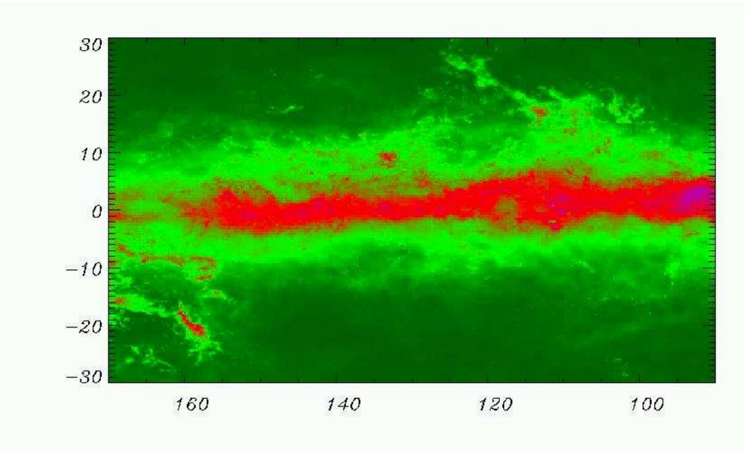

Fig. 8. The AGILE emission model for second quadrant. Full resolutions images are available at the web site: `www.mi.iasf.cnr.it/` $\sim$ `giuliani/galaxy`

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