Mem. S.A.It. Suppl. Vol. 5, 135

Memorie della
Supplementi

Gamma-Ray emission from the Galaxy: a new model for AGILE

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

Key words. Gamma Rays – ISM – Cosmic Rays

1. Introduction

The study of galactic diffuse gamma emission will be one of the main scientific objectives of AGILE (Astro rivelatore Gamma a Immagini LEggero), the Italian Space Agency (ASI) satellite for gamma-ray astronomy that will be launched in 2005. 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 (Energetic Gamma Ray Experiment Telescope). Thus AGILE will collect, in the same observing time, twice the number of diffuse photons. AGILE will also be the gamma-ray imager with the highest angular resolution achieved so far. This amounts to about a factor of two the one of EGRET, for photons with energy larger than 400 MeV, with a point spread function depending weakly on off-axis angle.

In order to exploit these capabilities to their best a very accurate model of the Galactic diffuse emission is required for the analysis of AGILE data.
The gamma ray emissivity is supposed to be produced by the interaction of cosmic rays with the interstellar medium through three physical process: proton-proton collisions, bremsstrahlung and inverse compton scattering. Therefore, to build a gamma ray emmissivity map of the galaxy it is necessary to know the 3-D distributions of cosmic rays and of cosmic-ray targets (interstellar matter, mainly constitued of atomic hydrogen and molecular clouds), and the interstellar radiation field. The method we used to derive the gamma-ray emissivity is similar to the one developed for EGRET (Hunter et al. 1997). The

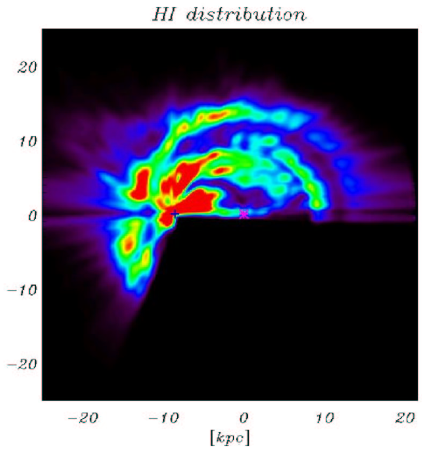

Fig. 1. Atomic hydrogen surface density derived from the Leiden-Dwingeloo survey. The south celestial pole is not covered by this survey.

AGILE model, however, uses a 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 3-D grid of gamma-ray emissivity of our galaxy, centered on the Sun and with coordinates given by galactic longitude and latitude, and distance along the line of sight. The minimum bin of this matrix is 0.5 degree for longitude and latitude and 0.5 kpc for the 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 everywhere equal to the local value. The atomic hydrogen distribution is derived mainly from the 21 cm survey of Weaver & Williams (1973), and from the Maryland-Parkes southern survey (Kerr et al. 1986), while the molecular clouds distribution is obtained from the CfA "superbeam" survey (Dame et al. 1987). These data were the best ones available at the time the EGRET model was made.

3. The AGILE model

The AGILE diffuse emission model is based on a 3-D 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 matter distribution in the galaxy we use the HI and CO radio survey completed recently, which are more accurate than the previous ones. Finally, in our model we are experimenting the cosmic ray models developed in the last few 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 et al. (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 (see Fig. 1) improves the previous results especially in terms of sensitivity (by an order of magnitude), 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).

As described below, 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, through the ratio X between hydrogen density and CO radio emissivity (see Figs. 2, 3) At the moment we assume a constant value for X, but one of the future improvements of our model is to make it a function of position.

3.2. Interstellar Radiation Field

Cosmic rays produce gamma rays through the inverse compton mechanism interacting with photons of the cosmological background (CBR) and of the interstellar radiation field

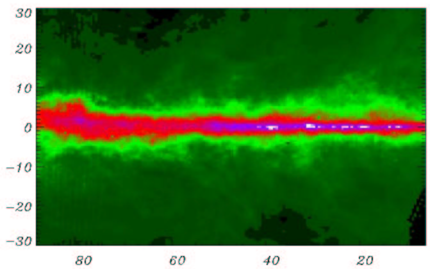

Fig. 2. Contribution of HI region to the AGILE model.

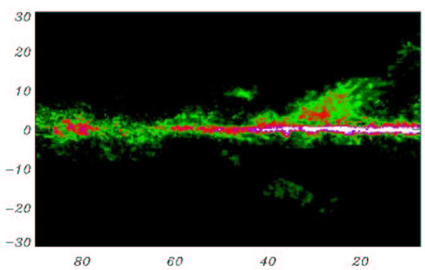

Fig. 3. Contribution of molecular clouds to AGILE model.

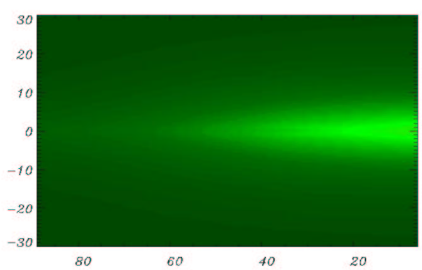

Fig. 4. Contribution of inverse compton scattering (on CBR and ISRF) to the AGILE model

(ISRF). In order to account for this component we use the analytical model proposed by Chi & Wolfendale (1991), giving rise to Fig. 4. It describes the ISRF as the result of three main contributions: far infrared (due to dust emis-

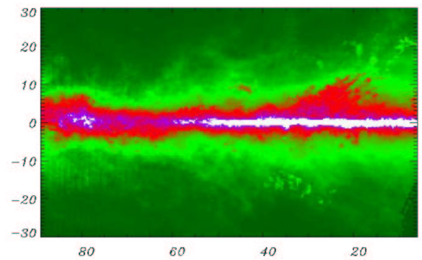

Fig. 5. The AGILE emission model for the first galactic quadrant. Full resolution images are available at the web site: http://www.mi.iasf.cnr.it/~giuliani/galaxy

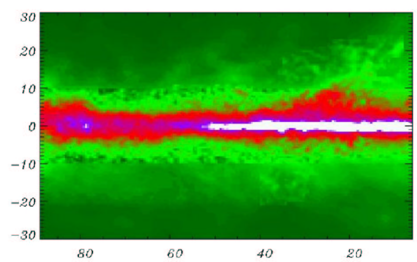

Fig. 6. The EGRET emission model for the first galactic quadrant.

sion), near infrared and optical/UV (due to stellar emission).

3.3. Cosmic Rays

One of the aims of the 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 the last few years. The results presented in these proceedings are obtained using the cosmic ray model given by the numerical code GALPROP (Strong & Moskalenko 1998), which derives the cosmic ray distribution from calculations that account for physical processes like diffusion and energy losses.

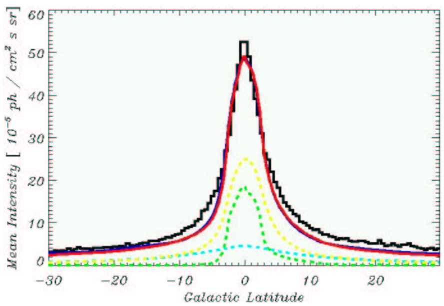

Fig. 7. Diffuse emission intensity observed by EGRET as a function of galactic latitude averaged in longitude from 10 to 90 degrees (binned black line). The red and the blue lines represent the AGILE and EGRET models respectively. The figure shows also the contributes due to HI emission regions (yellow line), molecular clouds (green) and inverse compton (light blue).

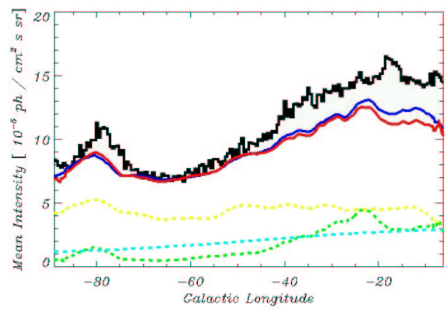

Fig. 8. Same as figure 7 but averaging over latitude.

4. First galactic quadrant

Figures 5 and 6 show the AGILE and EGRET models computed for the first galactic quadrant.

The AGILE map has higher angular resolution than the EGRET one. Full resolutions images are available at the web site: `www.mi.iasf.cnr.it/` ~ `giuliani/galaxy`. Figure 7 shows the intensity of the gamma ray sky observed by EGRET as a function of galactic latitude, averaged in longitude from 10° to 90°. The red and the blue lines represent the AGILE and EGRET models respectively.

Figure 8 is a plot analogous to Fig. 7, but this time averaging over the galactic latitude from -30° to 30°. These plots show a good agreement among the two models and with the EGRET observations.

5. Conclusion

A new galactic diffuse emission model is under development. The model follows the EGRET approach but it is based on up-to-date matter and cosmic ray distributions. The resulting model has a higher spatial resolution, as required by the narrower AGILE point spread function.
The comparison with EGRET observations shows a good agreement.

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