Gamma-Ray Galactic Diffuse Emission and SNR Studies by AGILE

A. Giuliani [*], M. Tavani [†], G. Barbiellini [‖], A. Bulgarelli [¶] P. A. Caraveo [*], A. W. Chen [*], P. W. Cattaneo [††], E. Del Monte [†] Y. Evangelista [†], M. Feroci [†], P. Lipari [xi], F. Longo [‖], M. Marisaldi [¶], S. Mereghetti [*], A. Morselli [xii], A. Pellizzoni [xviii], G. Piano [†], M. Pilia [xviii], A. Rappoldi [††], S. Sabatini [‡], E. Striani [†], M. Trifoglio [¶], A. Trois [†], S. Vercellone [xvii], C. Pittori [xv], P. Santolamazza [xv] and F. Verrecchia [xv] (on behalf of the AGILE Team)

[*] *INAF/IASF–Milano, Via E. Bassini 15, I-20133 Milano, Italy*
[†] *INAF/IASF–Roma, Via Fosso del Cavaliere 100, I-00133 Roma, Italy*
[‡] *Dip. di Fisica, Univ. "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Roma, Italy*
[§] *CIFS–Torino, Viale Settimio Severo 3, I-10133, Torino, Italy*
[¶] *INAF/IASF–Bologna, Via Gobetti 101, I-40129 Bologna, Italy*
[‖] *Dip. di Fisica and INFN, Via Valerio 2, I-34127 Trieste, Italy*
[††] *INFN–Pavia, Via Bassi 6, I-27100 Pavia, Italy*
[xi] *INFN–Roma "La Sapienza", Piazzale A. Moro 2, I-00185 Roma, Italy*
[xii] *INFN–Roma "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Roma, Italy*
[xv] *ASI–ASDC, Via G. Galilei, I-00044 Frascati (Roma), Italy*
[xvii] *INAF-IASF Palermo, Via Ugo La Malfa 153, 90146 Palermo, Italy*
[xviii] *INAF-Osservatorio Astronomico di Cagliari, localita Poggio dei Pini, strada 54, I-09012 Capoterra, Italy*

***Abstract*. The AGILE gamma-ray satellite has been surveying the Galactic plane since mid-2007 with good exposure in the energy range 100 MeV -30 GeV and excellent spatial resolution. We present the results of our Galactic survey with emphasis on tests of the diffuse Galactic gamma-ray emission model. We also present results of high-resolution gamma-ray imaging of several Supernova Remnants. In particular, we focus on SNR IC443, SNR J1713.7-3946 and SNR W28 for which AGILE data provide crucial evidence for particle acceleration in SNR shocks.**

I. Diffuse Emission

In order to exploit the AGILE capabilities a very accurate model of the Galactic diffuse emission is required for the data analysis. 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 AGILE diffuse emission model [1] 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 available HI and CO radio surveys.

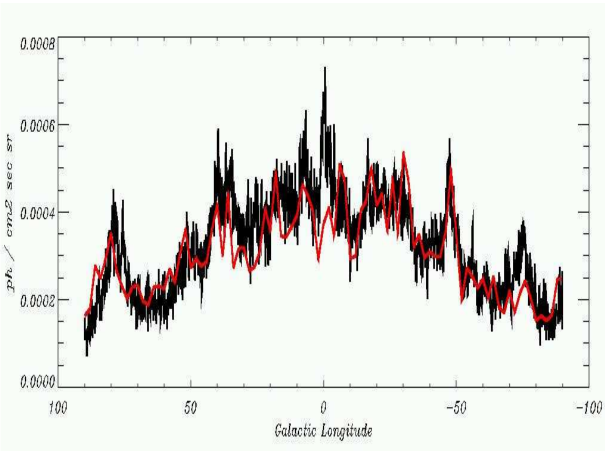

Fig. 1. Intensity of the gamma ray sky observed by AGILE as a function of Galactic longitude, averaged over the Galactic latitude from -5 to 5. The red line represents the model described here. This plot shows a good agreement between the model and the AGILE observations.

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.
In order to deproject the velocity-resolved radio data we used the Galactic rotation curve parameterized by Clemens (1985). Concerning the distribution of neutral hydrogen we used the Leiden-Argentine-Bonn (LAB) Survey of Galactic HI [3]. The LAB survey improves the previous results especially in terms of sensitivity (by an order of magnitude), velocity range and resolution.

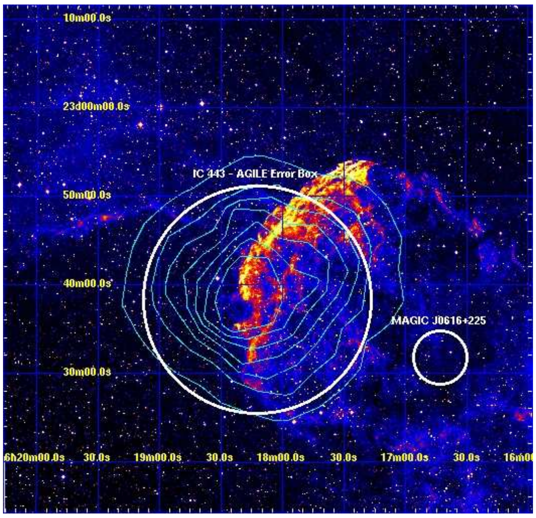

Fig. 2. An optical image of IC 443. The contours are the AGILE confidence levels. The 95 % c.l. error boxes of AGILE and MAGIC are also shown.

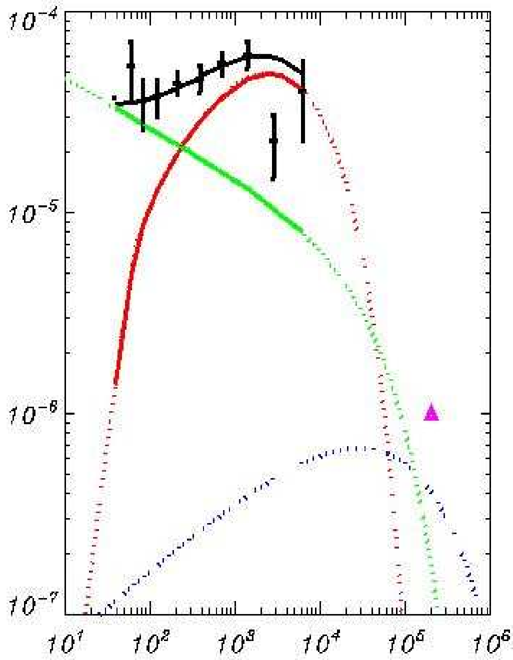

Fig. 3. The spectrum of IC 443 can be modeled by a pion-decay component (red) plus an electron bremsstrahlung component (green).

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 a known ratio between hydrogen density and CO radio emissivity.

Cosmic rays emit gamma radiation through the inverse Compton mechanism due to their interaction with photons of the cosmological background (CBR) 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 stellar emission).

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 here are obtained using the cosmic ray model given by the numerical code GALPROP [6].

II. SNR IC 443

IC 443 is a SNR lying at a distance of about 1.5 kpc in the Galactic anticenter direction. In radio, optical and X-rays there is clearly visible a shell structure, where the interaction of the SNR and the ISM creates a shock. A system of molecular clouds is also associated to the SNR, and an evidence of interaction is given by the observations of an high value of the ratio CO (J=2-1)/(J =1-0) [7].

EGRET observed a source in the direction of IC 443 in the 100 MeV-10 GeV energy range, suggesting the possibility that the enhanced cosmic ray flux produced by the shock interacts with the clouds and produces gamma-ray through pion decay and electron bremmstrahlung. A TeV source has been detected by MAGIC [8]. Due to the good angular resolution of the MAGIC telescope it was possible to locate the source in a small error box coincident with the direction of the most massive cloud. AGILE observed a gamma-ray source in this direction in the same energy range of EGRET, obtaining an error box which is not compatible with the MAGIC error box. The different position of the source in the TeV and gamma energy ranges implies a difference in the CR spectrum in the two emitting places or in the targets distributions. A possible interpretation can be given assuming a different distance of the emitting clouds [9] which can lead to a different spectrum of the accelerated protons seen by the near/far clouds [10].

III. SNR J1713.7-3946

A different beaviour is instead shown by young shell-type SNR J1713.7-3946. AGILE observed extensively, during the years 2007 and 2008, the field of this SNR. In figure 4 we show the gamma-ray intensity measured by AGILE above 400 MeV. For comparison in figure 5 is shown the CO distribution observed by the NANTEN telescope [11].

The intensity distribution along the shell of the SNR (indicated by the blue circle) shows a concentration in the north-west part of the rim, where most of the molecular gas is present (peaks A and C in [11]). Instead no obvious correlation is found between the TeV image of SNR J1713.7-3946 obtained by HESS and the gamma-ray emission observed by AGILE.

Figure 4 shows also the EGRET source 3EG J1714-3857

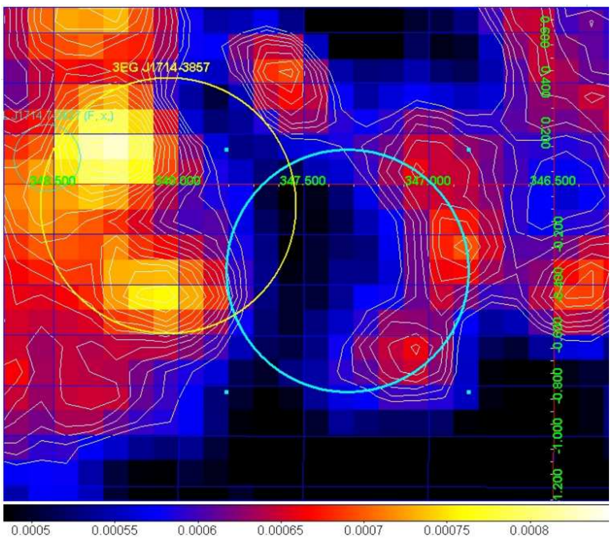

Fig. 4. Gamma-ray ($E > 400$ MeV) image for the field of SNR J1713.7-3946.

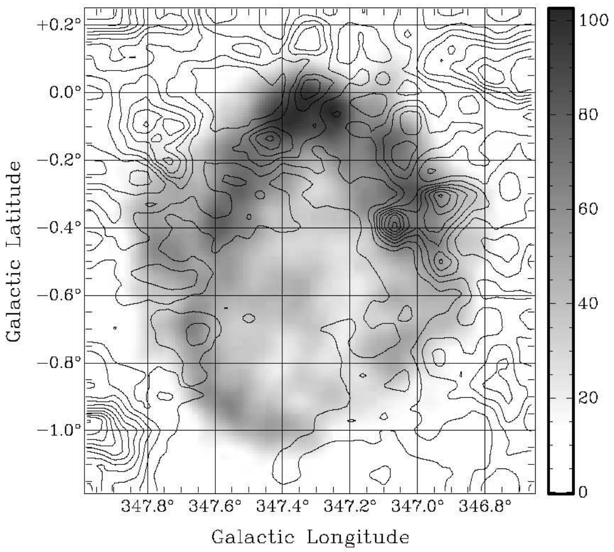

Fig. 5. Contours of the CO emission intesity observed by NANTEN derived by integrating the 12CO (J =1 0) spectra from 18 to 0 kms^1 . The TeV image of SNR J1713.7-3946 is also shown in gray scale. Adapted from [11]

which probably is not correlated to the SNR J1713.7-3946.

IV. SNR W 28

W28 is a quite old supernova remnants (with age more than 35000 years), located at an estimated distance between 1.8 and 3.3 kpc. It appears as a mixed-morphology SNR with large dimension (50'x54') In radio wavelength a shell structure where the interaction of the SNR and the ISM creates a shock is clearly visible.
The figure 6 shows the intensity map for the AGILE source associated to SNR W28 for energy greater than 400 MeV. At these energies the very good angular resolution of the GRID instrument allows to perform a morphological analysis of the source.
The figure 7 shows the TeV sky map of the W28 region obtained by HESS. For this object there is a very nice corrispondence between the MeV-GeV emission and the TeV emission.

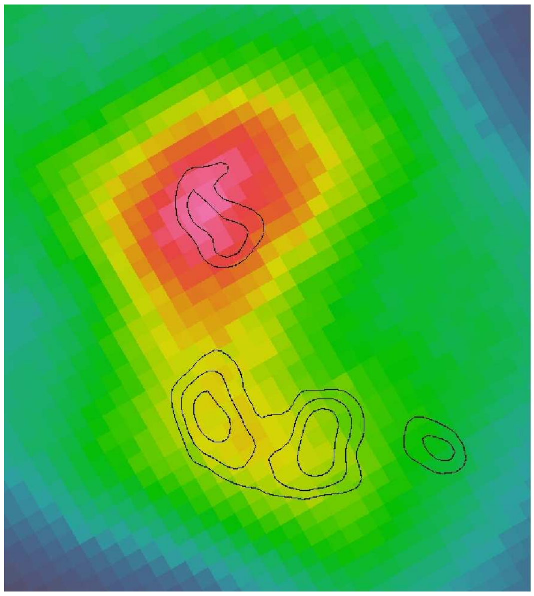

Fig. 6. Gaussian-smoothed counts map in Galactic coordinates for the W28 region over the observing period. Only photons with energy greater than 100 MeV have been folded. Contour lines show the 4, 5 and 6 sigma contours for the TeV signal.

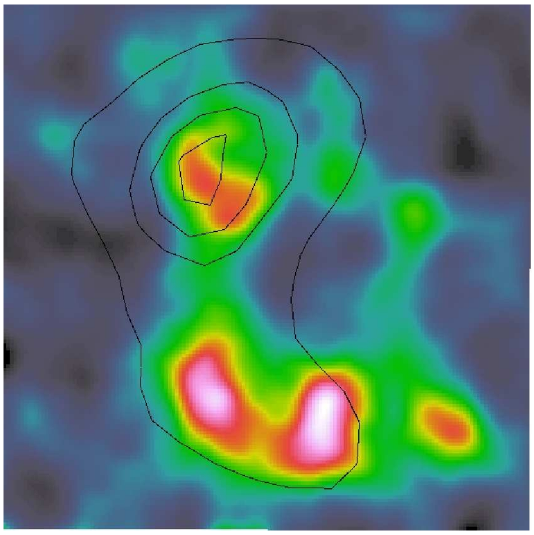

Fig. 7. H.E.S.S. gamma ray sky map of the W28 region. Black lines show the contours for the AGILE intensity map.

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