Draft version July 2, 2021
Typeset using LaTeX default style in AASTeX63

The role of Galactic unresolved PWNe to the gamma-ray diffuse emission

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1. SUMMARY

The TeV Galactic sky is dominated by a population of bright sources powered by pulsar activity, such as pulsar wind nebulae (PWNe). The properties of this population can be effectively constrained by observations at TeV energy. In particular, the Galactic Plane Survey (HGPS) data allow us to estimate the total γ-ray flux due to PWNe above 1 TeV.

In this work, we discuss the implications of the TeV galactic PWNe population observed by HESS for the interpretation of Fermi-LAT data in the GeV domain. We show that consistency among HGPS and 3FGL catalogs requires that the average ratio $R_\Phi = \Phi_{\rm GeV}/\Phi_{\rm TeV}$, where $\Phi_{\rm GeV}$ ($\Phi_{\rm TeV}$) is the integrated gamma-ray flux emitted by sources in the range 1-100 GeV (1-100 TeV) probed by Fermi-LAT (HESS), is $R_\Phi = 500 - 1000$.

Considering that the average spectral index of observed sources at TeV energies is $\beta_{\rm TeV} = 2.3$, the required range of values for R_Φ can be only obtained by assuming that sources have spectral breaks below 1 TeV and a harder emission spectrum with $\beta_{\rm GeV} < 2$ in the GeV domain. We take this into account by parameterizing the source emission with a broken power-law with different spectral indexes $\beta_{\rm GeV}$ and $\beta_{\rm TeV}$ in the GeV and TeV energy domain and with transition energy $E_0 = 0.3\,{\rm TeV}$ located between the ranges probed by Fermi-LAT and HESS. Such spectral shapes are well compatible with the expected gamma-ray emission in young PWNe due to Inverse Compton scattering of high-energy electrons on background radiation fields.

Adopting the previous phenomenological prescription for the average PWN source spectrum, we estimate the fraction of sources that cannot be resolved by Fermi-LAT with a detection threshold $\Phi_{th} = 10^{-9}\,{\rm cm^{-2}\,s^{-1}}$. We show that this fraction is relevant and could be as large as 46% of the total flux due to PWNe in the GeV energy range. We suggest that unresolved sources provide a not negligible contribution to the large-scale diffuse emission observed by Fermi-LAT that adds up to the truly diffuse emission due to cosmic ray (CR) interactions with the interstellar medium. This additional diffuse component due to PWNe is characterized by peculiar spatial and energy distributions shaping the total diffuse emission observed by Fermi-LAT.

In particular, we estimate the unresolved PWNe component by considering different Galactocentric rings. The flux produced by unresolved TeV PWNe in each ring is compared with the Fermi-LAT diffuse emission from the same region. We find that the unresolved contribution becomes more relevant in the central rings, since the source density (and the average distance from the Sun position) is larger. In the most internal region ($1.7 \leq r \leq 4.5$kpc), unresolved sources account for about $\sim 20\%$ ($\sim 30\%$) of the Fermi-LAT diffuse emission for $R_\Phi = 500$ ($R_\Phi = 1000$). Finally, we fit the Fermi-LAT data with the additional contribution due to unresolved PWNe. The truly diffuse gamma-ray flux due to CR interactions is always parameterized as a single power-law (the number of degrees of freedom in the fit is not changed) but the total flux is obtained as the sum of CR diffuse emission plus the unresolved PWNe contribution. We find that the reconstructed spectral properties of the cosmic ray diffuse emission are strongly affected by the inclusion of the unresolved PWNe and the evidence of CR spectral hardening toward the galactic center reported by previous analyses is quantitatively reduced.