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Robustly Dissecting the Gamma-Ray Sky at High Latitudes with Simulation-Based Inference

Over the past 16 years, the *Fermi* Large Area Telescope (LAT) has significantly advanced our view of the GeV gamma-ray sky, yet several key questions remain - such as the nature of the isotropic diffuse background, the properties of the Galactic pulsar population, and the origin of the GeV excess towards the Galactic Centre. Addressing these challenges requires sophisticated astrophysical modelling and robust statistical methods capable of handling high-dimensional parameter spaces.

In this work, we analyse 14 years of high-latitude ($|b| > 30°$) *Fermi*-LAT data in the 1–10 GeV range using simulation-based inference (SBI) via neural ratio estimation. This approach allows us to detect individual gamma-ray sources and derive a source catalogue with estimated positions and fluxes that are consistent with the bright portion of the *Fermi*-LAT collaboration's 4FGL catalogue. Additionally, we reconstruct the source-count distribution $\mathrm{d}N/\mathrm{d}S$ in both parametric and non-parametric forms, achieving good agreement with previous literature results and detected sources. We also quantitatively validate our gamma-ray emission simulator via an anomaly detection technique demonstrating that the synthetic data closely reproduces the complexity of the real observations.

This study highlights the practical utility of SBI for complex, high-dimensional problems in gamma-ray astronomy and lays the groundwork for its application to more challenging sky regions or data from next-generation facilities such as the Cherenkov Telescope Array Observatory.

AI keywords

simulation-based inference; neural ratio estimation; uncertainty quantification; anomaly detection

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