The TeV Diffuse Gamma-Ray Emission: Time Variability and Prospects for Future Detection

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December 2022

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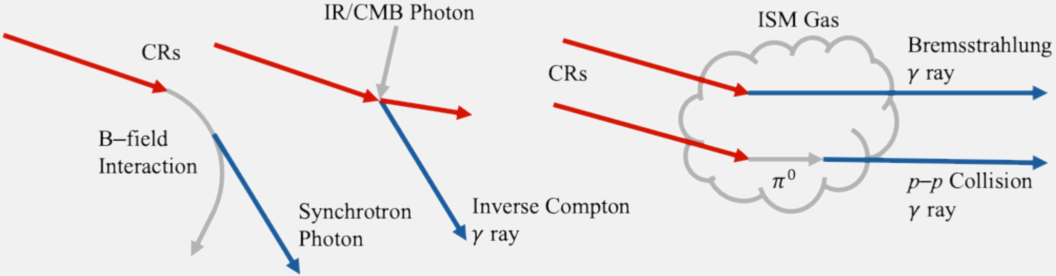
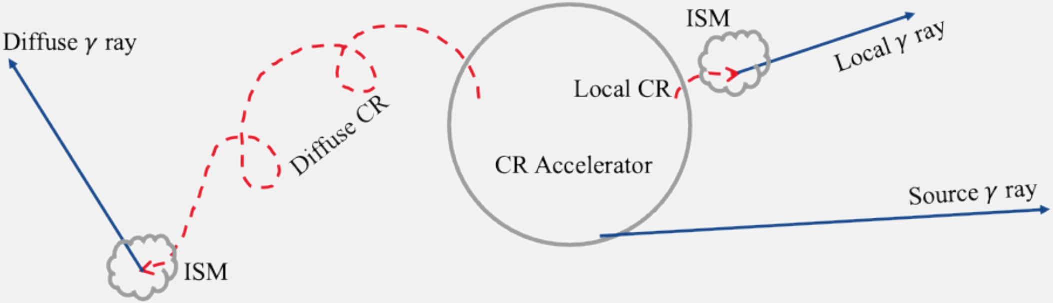
How γ–ray Emission is Produced

- CRs (electrons, protons, or other nuclei) can interact with the Galactic $\vec{B}$–field to create Synchrotron photons
- ... or with low-energy photons to create inverse Compton γ rays
- ... or with the ISM gas to create Bremsstrahlung or p–p collision γ rays



Diffuse vs Local γ–ray Emission

- The TeV diffuse γ–ray emission is caused by diffuse CRs interacting with the ISM
- Is the diffuse emission caused by CR protons and either nuclei (hadronic emission) or CR electrons (leptonic emission)?



Diffuse Emission at TeV Energies

- The diffuse γ–ray emission has been observed at GeV energies by *Fermi*–LAT (Ackermann et al. 2012)
- Observations of the diffuse γ–ray emission now extend to the TeV regime with H.E.S.S. (Abdalla et al. 2018) and the PeV regime with Tibet AS_γ (Amenomori et al. 2021)
- Galaxy-wide CR transport simulations can be used to model the GeV diffuse γ–ray emission
- For our modelling we use Galprop, which has been shown to accurately model the GeV diffuse γ–ray emission (e.g. Abdo et al. 2010; Ackermann et al. 2015; Acero et al. 2016a)

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The steady-state multi-TeV diffuse γ-ray emission predicted with GALPROP and prospects for the Cherenkov Telescope Array

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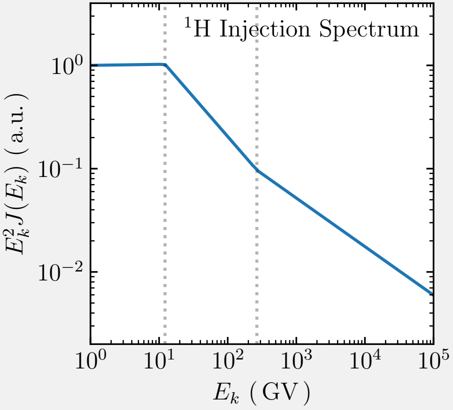
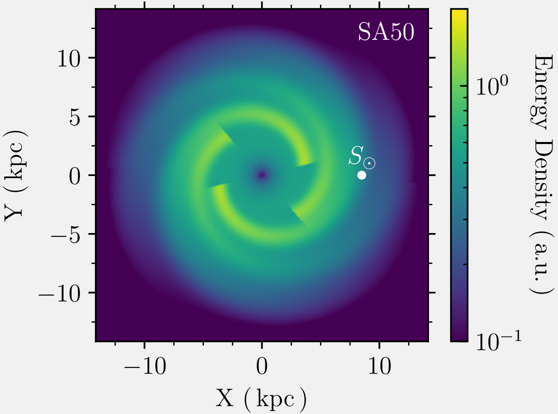
Accepted 2022 November 3. Received 2022 November 3; in original form 2022 May 6

ABSTRACT

Cosmic rays (CRs) interact with the diffuse gas, radiation, and magnetic fields in the interstellar medium (ISM) to produce electromagnetic emissions that are a significant component of the all-sky flux across a broad wavelength range. The *Fermi*–Large Area Telescope (LAT) has measured these emissions at GeV γ-ray energies with high statistics. Meanwhile, the high-energy stereoscopic system (H.E.S.S.) telescope array has observed large-scale Galactic diffuse emission in the TeV γ-ray energy range. The emissions observed at GeV and TeV energies are connected by the common origin of the CR particles injected by the sources, but the energy dependence of the mixture from the general ISM (true 'diffuse'), those emanating from the relatively nearby interstellar space about the sources, and the sources themselves, is not well understood. In this paper, we investigate predictions of the broad-band emissions using the GALPROP code over a grid of steady-state 3D models that include variations over CR sources, and other ISM target distributions. We compare, in particular, the model predictions in the very-high energy (VHE; $\gtrsim$100 GeV) γ-ray range with the H.E.S.S. Galactic plane survey (HGPS) after carefully subtracting emission from catalogued γ-ray sources. Accounting for the unresolved source contribution, and the systematic uncertainty of the HGPS, we find that the GALPROP model predictions agree with lower estimates for the HGPS source-subtracted diffuse flux. We discuss the implications of the modelling results for interpretation of data from the next generation Cherenkov Telescope Array (CTA).

Time-Independent Solution

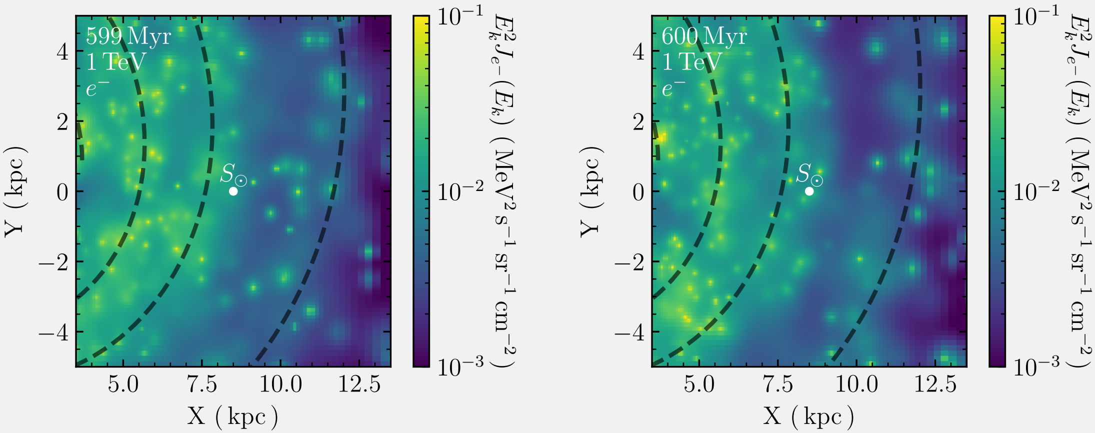




LEFT: Proton Injection Spectrum

RIGHT: Source Distribution

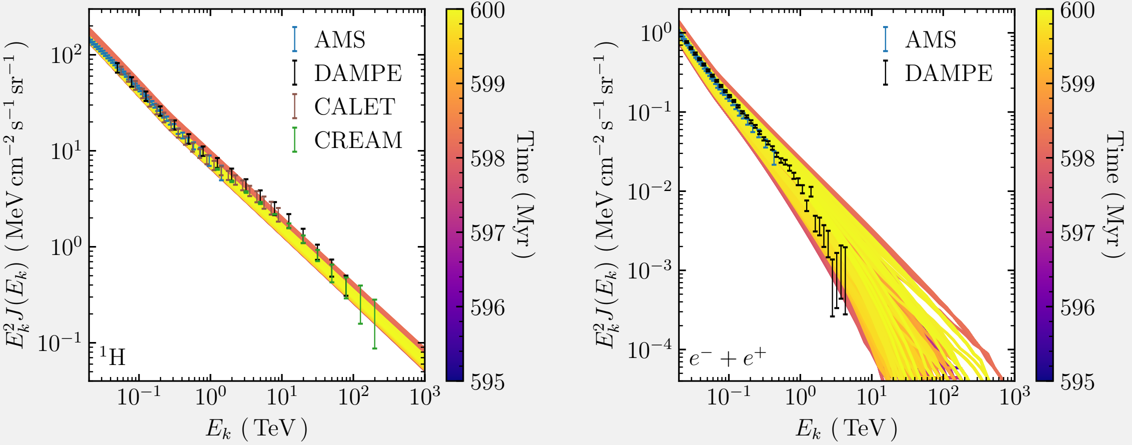
Time-Dependent Solution



LEFT: Electron Flux at $t = 599\,\mathrm{Myr}$, $E = 1\,\mathrm{TeV}$

RIGHT: Electron Flux at $t = 600\,\mathrm{Myr}$, $E = 1\,\mathrm{TeV}$

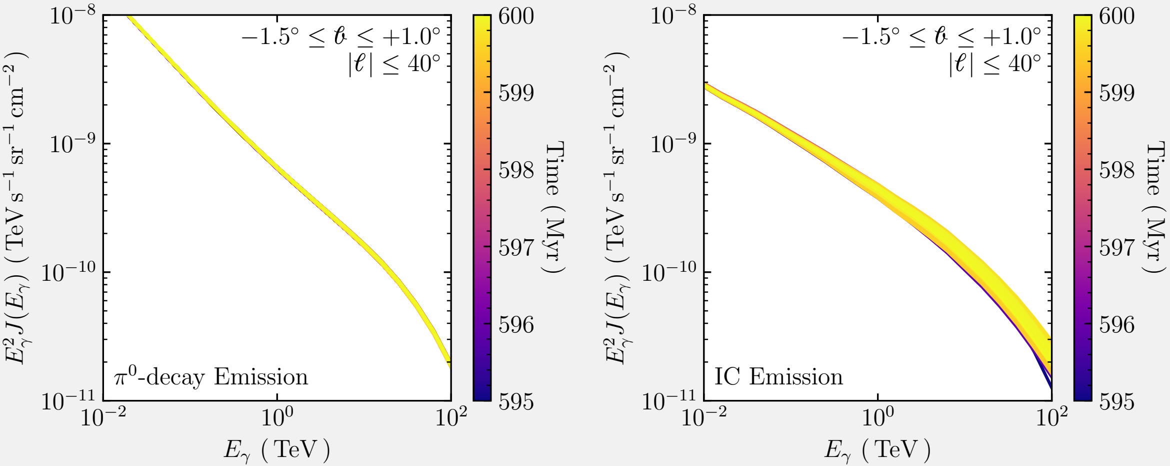
Time-Dependent CR Spectra



LEFT: Proton Spectrum

RIGHT: Total Electron and Positron Spectrum

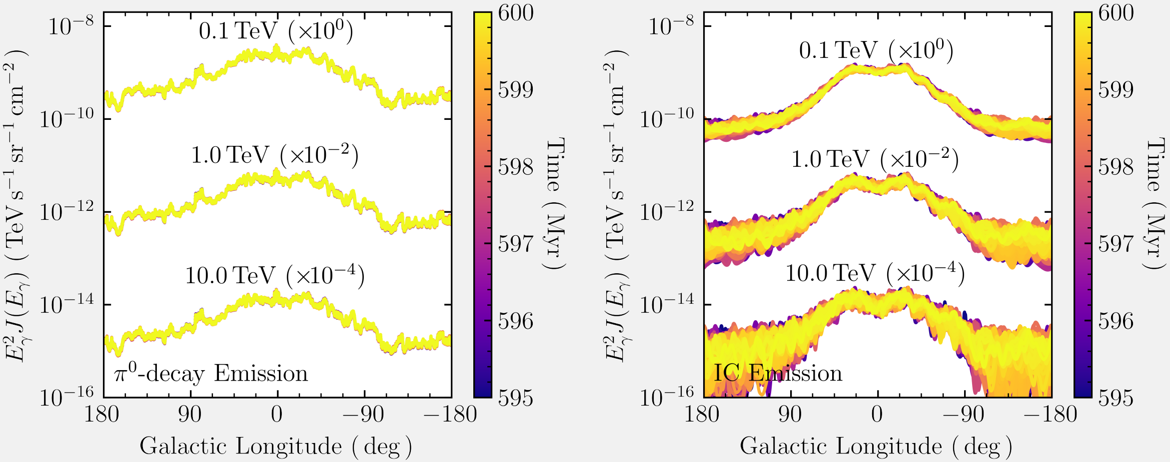
γ–ray Spectra Along the Galactic Plane



LEFT: Pion-Decay Emission

RIGHT: Inverse Compton Emission

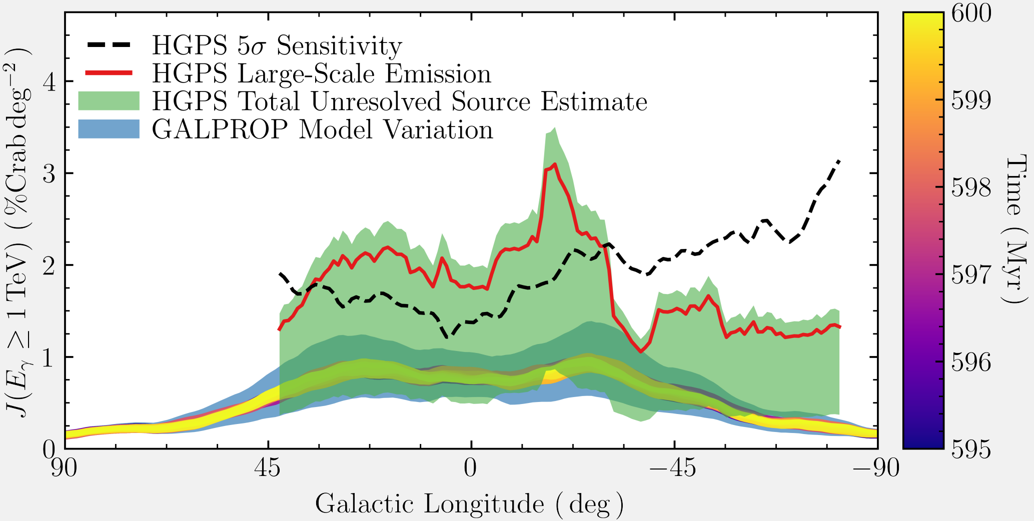
γ–ray Longitudinal Profile



LEFT: Pion-Decay Emission

RIGHT: Inverse Compton Emission

Comparison to Observations



Summary

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- We have previously used GALPROP to model the diffuse emission via a time-independent solution. We are now extending our models to utilise time-dependence
- Potential steepening in the local CR electron spectrum is naturally explained by the time-dependent solution. No nearby CR electron accelerators leads to a reduced electron flux above 1 TeV
- The local CR electron flux can vary by a factor of ± 15 at 20 TeV over a period of 5 Myr. Hadronic CRs are less variable, only varying by a factor of ± 1.5 at 1 PeV
- The large-scale IC emission in Galactic regions far from the GC vary by a factor of ± 5 at 1 TeV. Low amount of variability in the pion-decay

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