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Stochastic modelling of cosmic ray sources for diffuse high-energy gamma-rays and neutrinos

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Cosmic rays of energies up to a few PeV are believed to be of Galactic origin, yet individual sources have still not been firmly identified. Due to inelastic collisions with the interstellar gas, cosmic-ray nuclei produce a diffuse flux of high-energy gamma-rays and neutrinos. Fermi-LAT has provided maps of galactic gamma-rays at GeV energies which can be produced by both hadronic and leptonic processes. Neutrinos, on the other hand, are exclusively produced by the sought-after hadronic processes, yet they can be detected above backgrounds only at hundreds of TeV. Oftentimes, diffuse emission maps are extrapolated from GeV to PeV energies, but the sources contributing at either energies likely differ. We have modelled the production of diffuse emission from GeV through PeV energies in a Monte Carlo approach, taking into consideration the discrete nature of sources. We can generate realisations of the diffuse sky in a matter of seconds, thus allowing for characterising correlations in direction and energy. At hundreds of TeV, relevant for observations with LHAASO, Tibet AS-gamma, IceCube and the upcoming SWGO, variations between different realisations are sizeable. Specifically, we show that extrapolations of diffuse emission from GeV to PeV energies must fail and apply our results on the recent experimental findings.

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