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High-Energy Neutrino and Gamma Ray Production in Clusters of Galaxies

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We estimated the contribution from clusters of galaxies to the diffuse neutrino and $\gamma-$ray background. Due to their unique magnetic-field configuration, CRs with energy $\leq 10^{17}$ eV can be confined within these structures over cosmological time scales, and generate secondary particles, including neutrinos and gamma-rays, through interactions with the background gas and photons. We used 3D-MHD simulations of galaxy formation to model the turbulent intergalactic and intracluster media. We propagate CRs in these environments using multi-dimensional Monte Carlo simulations across redshifts (from $z \sim 5$ to $z = 0$), considering all relevant photohadronic, photonuclear, and hadronuclear interactions. We find that for CRs injected with a spectral index $1.5 - 2.7$ and cutoff energy $E_{\rm max} = 10^{16} - 10^{17}$~eV, clusters contribute to a substantial fraction to the diffuse fluxes observed by the IceCube and Fermi-LAT, and most of the contribution comes from clusters with $M > 10^{14}\, M_{\odot}$ and redshift $z < 0.3$. We also estimated the contribution from Perseud-like clusters within a distance of about 75 Mpc.

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