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Cosmic-Ray Anisotropy and Extended Gamma-Ray Emissions as Probes of Cosmic-Ray Transport

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We calculate the shape of the anisotropy of TeV-PeV cosmic-rays (CR) in different models of the interstellar turbulence. In general, the large-scale CR anisotropy (CRA) is not a dipole, and its shape can be used as a probe of the turbulence and CR transport properties. The 400 TeV and 2 PeV data sets of IceTop can be fitted with Goldreich-Sridhar turbulence and a broad resonance function, but other possibilities are not excluded. We then present our first numerical calculations of the CRA down to 3 TeV energies in 3D Kolmogorov turbulence. At these low energies, the large-scale CRA aligns well with the direction of local magnetic field lines around the observer. In this type of turbulence, the CR intensity is flat in a broad region perpendicular to field lines. Even though the CRA is quite gyrotropic, we show that the local configuration of the turbulence around the observer does result in the appearance of weak, "non-gyrotropic" small-scale anisotropies, which contain information on the local turbulence level.
Finally, we show how extended gamma-ray emissions around CR sources can be used to extract information on the interstellar turbulence and CR transport properties. As an example, we use HAWC measurements to place constraints on the properties of the magnetic fields within $\simeq 25$ pc from Geminga pulsar. We also study the impact of CR-driven instabilities on the turbulence around CR sources, and show how one could use gamma-ray emissions to study these instabilities.

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