

Probing circumgalactic cosmic rays around the Milky Way via GeV-PeV gamma rays and neutrinos

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Cosmic rays (CRs) in the GeV-PeV range are believed to originate mainly from sources in the Milky Way (MW) disk, propagate diffusively in the interstellar medium, and eventually escape into the circumgalactic medium (CGM) that permeates the MW halo. Circumgalactic CRs (CGCRs) may play important thermal and dynamical roles for the formation and evolution of the MW, but observational evidence for them is very scarce to date. We discuss constraints on CGCRs from available gamma-ray observations and our current knowledge of the MW CGM. Particularly emphasized is the PeV band, with various advantages over the GeV-TeV bands in probing spatially extended emission from the MW CGM, by virtue of gamma-gamma absorption effects with the cosmic microwave background. Using data from Tibet ASgamma, we search for signals associated with intermediate velocity clouds (IVCs) and high velocity clouds (HVCs) seen in HI, and find no clear evidence so far. For IVCs, previous GeV detections combined with our PeV upper limits provide valuable constraints on the propagation of CRs at Galactic heights $z \sim$ a few kpc, and possibly on their relation to Galactic winds. For HVCs that can probe more distant CGCRs at $z \sim 10$ kpc, our limits are relatively weaker, but nevertheless offer unique constraints on some non-conventional scenarios for the origin and propagation of PeV CRs. We also touch on the relevance of IceCube neutrino observations for probing CRs in the outer CGM at $z \sim 100$ kpc. Prospects are discussed for significant advances with LHAASO, SWGO and Mega ALPACA, complementary constraints from CTA and ASTRI, as well as improved knowledge of the MW CGM from future radio, UV and X-ray observations.

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