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Theoretical Implications of IceCube Neutrinos

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The IceCube Collaboration has recently found evidence for an astrophysical flux of neutrinos. The flux is consistent with an isotropic and equal-flavor E^{-2} power-law spectrum from 60 TeV to 2 PeV. There are also indications that the neutrino spectrum beyond 2 PeV requires a spectral break or cutoff. The origin of the IceCube excess is not known, but its multi-messenger context can already provide some theoretical orientation. For instance, the production of PeV neutrinos require hadronic interactions of cosmic rays (CRs) with energies of a few 10 PeV, extending into the poorly understood transition region between Galactic and extra-Galactic CRs. A local contribution to the neutrino flux from Galactic accelerators is hence feasible and could show up as arrival direction clustering towards Galactic structures. In this context, a possible association of the PeV neutrino sources with unidentified TeV gamma-ray sources, peculiar supernovae or the Fermi Bubbles has been speculated. In addition, a local hadronic neutrino production would predict an observable PeV gamma-ray flux. Spectral features of the neutrino flux, in particular a break or cutoff, serve as additional hints for candidate CR sources and astrophysical environments for neutrino production. Possible scenearios include starburst galaxies, low-luminosity gamma-ray bursts and the cores of active galactic nuclei. I will outline general theoretical implications of the IceCube excess and summarize various source candidates.