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High-energy neutrinos from multi-body decaying dark matter

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Since the report of the PeV-TeV neutrinos by the IceCube Collaboration, various particle physics models have been proposed to explain the neutrino spectrum by dark matter particles decaying into neutrinos and other Standard Model particles. In such scenarios, simultaneous gamma-ray emission is commonly expected. Therefore, multi-messenger connections are generally important for the indirect searches of dark matters. The recent development of gamma-ray astronomy puts stringent constraints on the properties of dark matter, especially by observations with the Fermi gamma-ray satellite in the last several years. Motivated by the lack of gamma-ray as well as the shape of the neutrino spectrum observed by IceCube, we discuss a scenario in which the DM is a PeV scale particle which couples strongly to other invisible particles and its decay products do not contain a charged particle. As an example to realize such possibilities, we consider a model of fermionic dark matter that decays into a neutrino and many invisible fermions. The dark matter decay is secluded in the sense that the emitted products are mostly neutrinos and dark fermions. One remarkable feature of this model is the resulting broadband neutrino spectra around the energy scale of the dark matter. We apply this model to multi-PeV dark matter, and discuss possible observable consequences in light of the IceCube data. In particular, this model could account for the large flux at medium energies of 10 to 100 TeV, possibly as well as the second peak at PeV, without violating the stringent gamma-ray constraints from Fermi and air-shower experiments such as CASA-MIA.

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