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VHE gamma-ray and hard X-ray followup studies of IceCube astrophysical neutrinos with VERITAS and NuSTAR

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IceCube has reported evidence for neutrino emission from the nearby active galaxy NGC 1068 and the gamma-ray blazar TXS 0506+056. A search for electromagnetic radiation temporally and spatially-correlated with high-energy IceCube neutrino events is an important strategy for exploring the connection between neutrinos and high-energy blazars. Here we report on the very-high-energy gamma-ray and hard X-ray follow up studies of IceCube astrophysical neutrinos with VERITAS and NuSTAR. In particular, we report on multiwavelength target-of-opportunity observations of the blazar PKS 0735+178, located 2.2 degrees away from the best-fit position of the IceCube neutrino event 211208A, detected by IceCube as a track-like event with an energy of about 171 TeV. Hard X-ray observations from NuSTAR, as well as gamma-ray observations at TeV energies, have provided some of the strongest constraints on the hadronic emission from blazars. In the spectral energy distribution for PKS 0735+178, we find that the X-ray data characterizes the transition in the spectrum from the low-energy to the high-energy component. The gamma-ray data show a spectral cut-off near 100 GeV, suggesting the existence of an external photon field in the source. We discuss implications for leptonic and hadronic models of emission in blazars based on these measurements. In addition, we report on other target-of-opportunity observations of IceCube alerts with VERITAS and NuSTAR in the last two years and ask the question whether the observed multi-wavelength spectra are consistent with the neutrino events.

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