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Neutrino predictions for 3HSP J095507.9+355101, an extreme X-ray flaring blazar

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Blazars whose low-energy spectral component peaks above ~ 0.4 keV are thought to be efficient particle accelerators and are known as extreme blazars. They are particularly interesting for high-energy astrophysics, as they may be the counterparts of very high-energy gamma-ray sources and high-energy astrophysical neutrinos. 3HSP J095507.9+355101 is the first extreme blazar to be possibly associated with a high-energy neutrino (IceCube-200107A) while undergoing a hard X-ray flare. Motivated by this observation, we perform detailed multi-messenger modeling of 3HSP J095507.9+355101 to assess the expected neutrino emission of the source during its recent X-ray flare and in the entire lifetime of IceCube operations. We focus on one-zone leptohadronic models, but we also explore alternative scenarios: (i) a blazar-core model, which considers neutrino production in the inner jet, close to the supermassive black hole; (ii) a hidden external-photon model, which considers neutrino production in the jet through interactions with photons from a weak broad line region; (iii) a proton synchrotron model, where high-energy protons in the jet produce gamma-rays via synchrotron; and (iv) an intergalactic cascade scenario, where neutrinos are produced in the intergalactic medium by interactions of a high-energy cosmic-ray beam escaping the jet. We find that the Poisson probability to detect one muon neutrino in ten years from 3HSP J095507.9+355101 with the real-time IceCube alert analysis is $\sim 1\%$ with our most optimistic leptohadronic scenario. Meanwhile, detection of one neutrino during the 44-day-long high X-ray flux-state period following the neutrino detection is only 0.06% . The most promising scenarios for neutrino production also predict strong intra-source gamma-ray attenuation above 100 GeV. If the association is real, then IceCube-Gen2 and other future detectors should be able to provide additional evidence for neutrino production in 3HSP J095507.9+355101 and other extreme blazars.

Collaboration name

Primary authors: OIKONOMOU, Foteini (ESO); Prof. MASTICHIADIS, Apostolos (National & Kapodistrian University of Athens); MURASE, Kohta; PADOVANI, Paolo (ESO); Dr VASILOPOULOS, Georgios (Yale University); GIOMMI, Paolo (Agenzia Spaziale Italiana)

Presenter: Dr PETROPOULOU, Maria Petropoulou (National and Kapodistrian University of Athens)

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