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Prospects for detecting quark star features with IceCube

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This Master's Thesis explores the prospects of detecting the neutrino signal associated with a hadron-to-quark matter phase transition during core-collapse supernovae (CCSNe), a process that may lead to the formation of quark stars—compact and exotic objects composed of deconfined quark matter. By using state-of-the-art CCSN simulations that incorporate this first-order phase transition in the equation of state, the resulting neutrino emission was modelled. A particular focus is placed on the secondary burst of electron antineutrinos triggered by the transition that leads to a second collapse of the proto-neutron star into a quark star. A newly developed analysis framework is applied to assess the detectability of this feature using the IceCube Neutrino Observatory and its Gen-2 upgrade. Preliminary results, obtained using the ASTERIA simulation tool, show that this neutrino signal could be distinguished from background noise with high confidence, up to 5σ, for CCSNe occurring within the Milky Way and nearby galaxies such as the Large and Small Magellanic Clouds. These findings suggest that future neutrino observations could offer valuable insights into the QCD phase diagram and the internal composition of compact stellar remnants.

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