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Probing Pair-Instability Supernovae via 56Ni Decay Signatures

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Pair-instability supernovae (PISNe) are theorized thermonuclear explosions of extremely massive stars, predicted to occur when the helium core mass exceeds ~65M⊠. The large amounts of radioactive 56 Ni synthesized in such events (~60M⊠ in extreme cases) can power extraordinarily luminous optical light curves, but to date no supernova has been definitively confirmed as a PISN. Direct detections of high-energy emission from the decay chain 56Ni ⟶ 56Co ⟶ 56Fe would provide unambiguous evidence for these explosions. In this work, we investigate the detectability of gamma-ray and hard X-ray signals from a suite of PISN models and compare them with the capabilities of current and near-future observatories. We find that for a PISN model with a helium core mass of MHe =130M⊠, the dominant 56Co-decay lines at 847 and 1238 keV would be detectable out to distances of about 300 Mpc by upcoming gamma-ray missions with improved sensitivity. Furthermore, it is known that the 12C(a, g)16O nuclear reaction has a significant effect on PISN nucleosynthesis. We will also discuss observational constraints on this nuclear reaction using the gamma-ray emission of this model. These results strongly motivate targeted high-energy campaigns to confirm—or rule out—the long-sought phenomenon of PISNe.

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