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Prospecting a scalar Singlet-Triplet two component Dark Matter model with Gravitational Waves

We investigate gravitational wave (GW) production from a first-order electroweak phase transition (FOEWPT) in a two-component dark matter (DM) scenario. The Higgs sector of the Standard Model (SM) is extended by a complex scalar singlet and a hyperchargeless ($Y = 0$) scalar triplet. In this setup, the neutral component of the triplet serves as a DM candidate under a $\mathbb{Z}_2$ symmetry. Meanwhile, the pseudo-scalar part of the complex scalar, charged under a global $U(1)$ symmetry, which is explicitly broken by a $\mathbb{Z}_3$-symmetric term in the scalar potential, acts as the second DM candidate. The triplet scalar DM typically contributes only 10–20% to the relic density in the sub-TeV region and remains underabundant up to ~ 1.9 TeV due to strong $SU(2)_L$ gauge interactions. However, in our two-component setup, DM-DM conversion enhances the triplet contribution up to 50–60% in the sub-TeV range. The pseudo-scalar DM, on the other hand, benefits from a suppressed spin-independent direct detection cross-section, allowing a larger viable parameter space consistent with current bounds. We highlight the interplay between cosmological and collider constraints, the correlations among model parameters, and identify regions that evade current limits but are within the sensitivity range of future and current detectors, such as XENON1T, LZ-2024, and DARWIN. Next, we study the FOPT dynamics and emphasize its connection with DM phenomenology. The resulting GW spectrum is estimated and analyzed for detectability using both the conventional power-law integrated (PLI) sensitivity and the recently proposed peak-integrated sensitivity curves (PISC). Our analysis reveals that a novel region of the model's parameter space, compatible with DM observables, can produce a detectable GW signal. These signals are within reach of future space-based GW detectors such as LISA, BBO, DECIGO, and DECIGOcorr. Our investigation complements the collider searches for BSM new physics at the DM and GW detector frontiers.

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