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$U(1)$-charged Dark Matter in three-Higgs-doublet models

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We explore three-Higgs-doublet models that may accommodate scalar Dark Matter where the stability is based on an unbroken $U(1)$-based symmetry, rather than the familiar $\mathbb{Z}_2$ symmetry. We try to classify all possible ways of embedding a $U(1)$ symmetry in a three-Higgs-doublet model. The class of such models is presented and models are compared. These models all contain mass-degenerate pairs of Dark Matter candidates, due to the $U(1)$ symmetry unbroken (conserved) by the vacuum. The pairs can be seen as one even and one odd, under CP, or, in a different basis, as having opposite charges under $U(1)$. Most of these models preserve CP. Three of the discussed models have not been considered before in the literature, which reminds us that there are still many aspects to consider in the three-Higgs-doublet models. Such classification and identification of models is useful for model builders interested in the three-Higgs-doublet models stabilised by continuous symmetries. Apart from classifying the Dark Matter candidates, we perform a numerical check of the $U(1) \otimes U(1)$-symmetric 3HDM, which is the most general phase-invariant three-Higgs-doublet model.

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