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Dark matter in three-Higgs-doublet models with S_3 symmetry

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Models with two or more scalar doublets with discrete or global symmetries can have vacua with vanishing vacuum expectation values in the bases where symmetries are imposed. If a suitable symmetry stabilises such vacua, these models may lead to interesting dark matter (DM) candidates, provided that the symmetry prevents couplings among the DM candidates and the fermions. We analyse three-Higgs-doublet models with an underlying S_3 symmetry. These models have many distinct vacua with one or two vanishing vacuum expectation values (1) which can be stabilised by a remnant of the S_3 symmetry which survived spontaneous symmetry breaking. In our framework the stability of the DM sector results from a $\mathbb{Z}_2$ symmetry. We identify all possible DM models based on vacua in the context of S_3-symmetric three-Higgs-doublet models, allowing also for softly broken S_3 scalar potential.

We focus on two specific models R-II-1a (2) and C-III-a. In these cases one of the scalar doublets provides the DM sector, while the other two are active. The way the fermions couple to the scalar sector is constrained by the S_3 symmetry and is such that the flavour structure of the model is solely governed by the V_{CKM} matrix which, in our framework, is not constrained by the S_3 symmetry. The main difference between the models is that there is no CP violation in R-II-1a, while in C-III-a there is an irremovable phase present. We explore models numerically, based on theoretical and experimental constraints. After applying a number of successive checks over the parameter space we found a viable DM mass region to be [52.5, 89] GeV for R-II-1a and [6.5, 44.5] GeV for C-III-a.

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