Doublet Singlet Dark Matter

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Why a simplified model?

1. In this proposal, our focus is a simplified DM model.
2. Multiple complete theories could lead to the same simplified model.
3. Allows the possibility to encode the full model parameter space of a typical UV complete model containing multiple degrees of freedom in terms of a few parameters $\rightarrow$ making the analysis tractable.
4. The results from one simplified analysis could be translated to various models, while also giving considerably appropriate results $\rightarrow$ gives a seemingly good amount of flexibility.
5. The simplified model which we intend to explore will contain one weak doublet and one weak singlet, and additional pseudoscalar and scalar states.[1]

[1] Higher $SU(n)$ $(n > 2)$ representations have been widely covered in the literature; see for example Low et al. (2014), Cirelli et al. (2014), Chiang et al. (2020).

The simplified model

- We intend to consider a minimal dark matter model with one fermion doublet (χ_D) and a fermion singlet (χ_S):

The new terms in the lagrangian:

$$\frac{M_s}{2}\bar{\chi_s}\chi_s + M_D\bar{\chi_D}\chi_D + (y_1 H\chi_S\chi_D + y_2 H^\dagger\chi_S\bar{\chi_D}) + h.c.$$

- Describes a particular limit of the MSSM/NMSSM in the decoupling limit.
- $y_{1,2}$ can be generic parameters and need not be dependent on the gauge couplings as in MSSM.
- Relevant for recasting the current limits and future projections on the neutralino DM sector of various well-motivated SUSY scenarios, *viz*. `pure-higgsino MSSM`[2], `the higgsino-bino MSSM`[3], `the higgsino-singlino NMSSM` [4].

[2] Han et al. (2018), Baer et al. (2020)
[3] Liu et. al. (2006), Abdughani et al. (2017), Barman et al. (2017)
[4] Xiang et al. (2016), Ellwanger et al. (2016), Barman et al. (2020)

The simplified model

- Extend the scenario with a pseudoscalar:

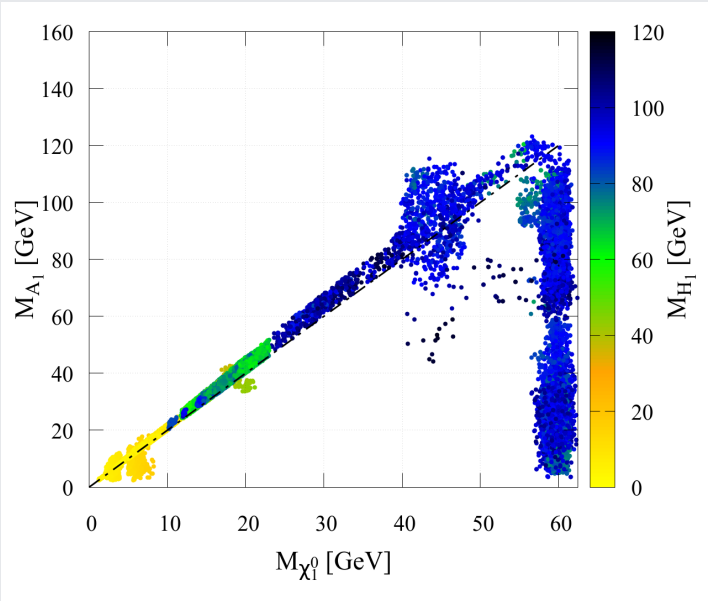
$$\frac{1}{2}m_a^2 a^2 + \lambda_H a^2 |H|^2 + (i\lambda_S a\bar{\chi}_S\gamma_5\chi_S + i\lambda_D a\bar{\chi}_D\gamma_5\chi_D + h.c) \quad (1)$$

$$+\frac{1}{\Lambda}\left(iy_U aHQU + iy_D aH^\dagger QD + iy_L aH^\dagger LE + h.c.\right) \quad (2)$$

- Only the lowest order operators in the Higgs and DM sector are written $\rightarrow$ encodes the phenomenology relevant for the intended study.
- At a later stage, we also plan to include an additional scalar within the framework.

The simplified model

- The inclusion of a weakly coupled light scalar would be a more appropriate proxy model to study the phenomenological implications of beyond-the-MSSM, *viz*. the NMSSM.



Ref. [Barman et al. (2020)]

- Previous studies have obtained allowed NMSSM points with thermal $\widetilde{\chi}_1^0$ DM with a mass between 0-62.5 GeV.
- These points are compatible with the PLANCK constraints through resonant annihilation via singlet scalar or pseudoscalar.
- Such points can have scalar and pseudoscalar mass of similar magnitude.

Implications

- Light scalar and pseudoscalar Higgses with roughly similar masses can have important implications for direct and indirect detection.
- The complex nature of the NMSSM parameter space makes it extremely difficult to fully exhaust all such possibilities and the identification of blind spots.
- The simplified scenario (a decoupling limit of the NMSSM) can help in shedding more light on the underlying dynamics and future possibilities.

The aim of this proposal

- Perform an exhaustive study of the DM sector within the purview of the simplified framework which can be later translated onto the parameter space of various relevant models, *viz*. MSSM, NMSSM.
- Analyze the coverage and complimentarity between different future colliders, while also investigating the relevance of various target parameters, *viz*. collision energy, luminosity, detector layout, efficiency.
- Collect the results from existing studies [1-5] and recast the projection reach of future colliders, direct and indirect detection.
- The simplified framework also encapsulates both prompt and long-lived searches for DM[5]. We intend to study its future prospects as well.

[5] Mahbubani et al. (2017)

Thank you.

References


Lorenzo Calibbi, Alberto Mariotti, and Pantelis Tziveloglou.
Singlet-Doublet Model: Dark matter searches and LHC constraints.
JHEP, 10:116, 2015.


Howard Baer, Vernon Barger, Shadman Salam, Dibyashree Sengupta, and Xerxes Tata.
The LHC higgsino discovery plane for present and future SUSY searches.
7 2020.


Rakhi Mahbubani, Pedro Schwaller, and Jose Zurita.
Closing the window for compressed Dark Sectors with disappearing charged tracks.
JHEP, 06:119, 2017.
[Erratum: JHEP 10, 061 (2017)].


Chengcheng Han, Ruibo Li, Ren-Qi Pan, and Kai Wang.
Searching for the light Higgsinos in the MSSM at future e-p colliders.
Phys. Rev. D, 98(11):115003, 2018.


Qian-Fei Xiang, Xiao-Jun Bi, Peng-Fei Yin, and Zhao-Huan Yu.
Searching for Singlino-Higgsino Dark Matter in the NMSSM.
Phys. Rev. D, 94(5):055031, 2016.