Multicomponent Dark Matter and the Inert Doublet Model

Amalia Betancur

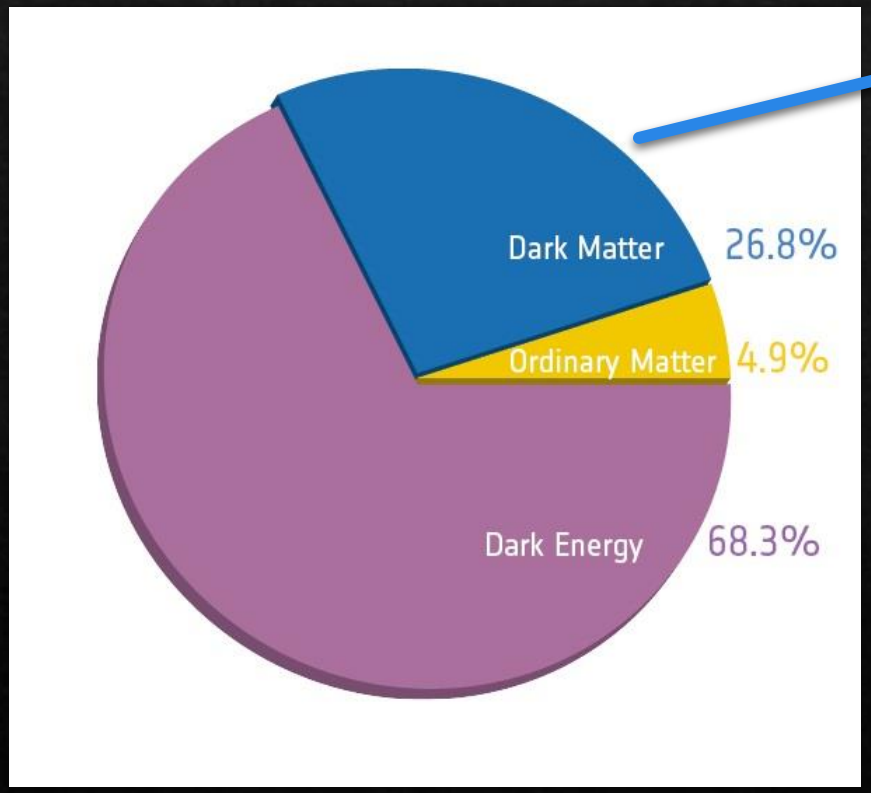
In collaboration with: Andrés Rivera and Guillermo Palacio

MOCA 2019

Oultine

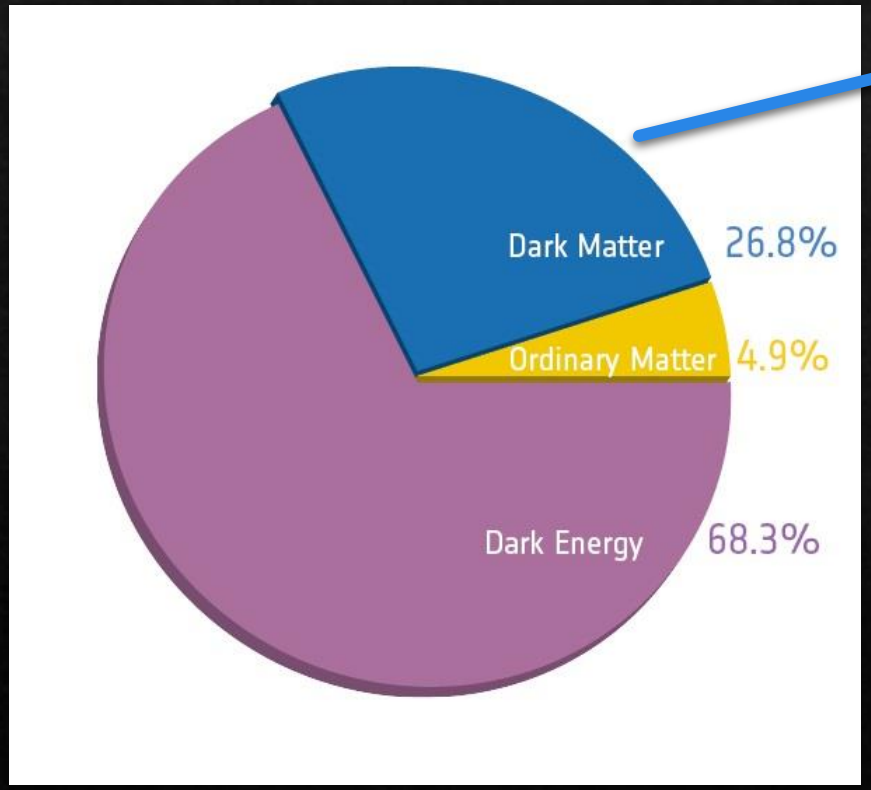
- Motivation
- The models
- Phenomenology
- Relic density
- Direct detection
- Indirect detection
- Conclusions

Motivation for Multicomponent Dark Matter



χ_1^0

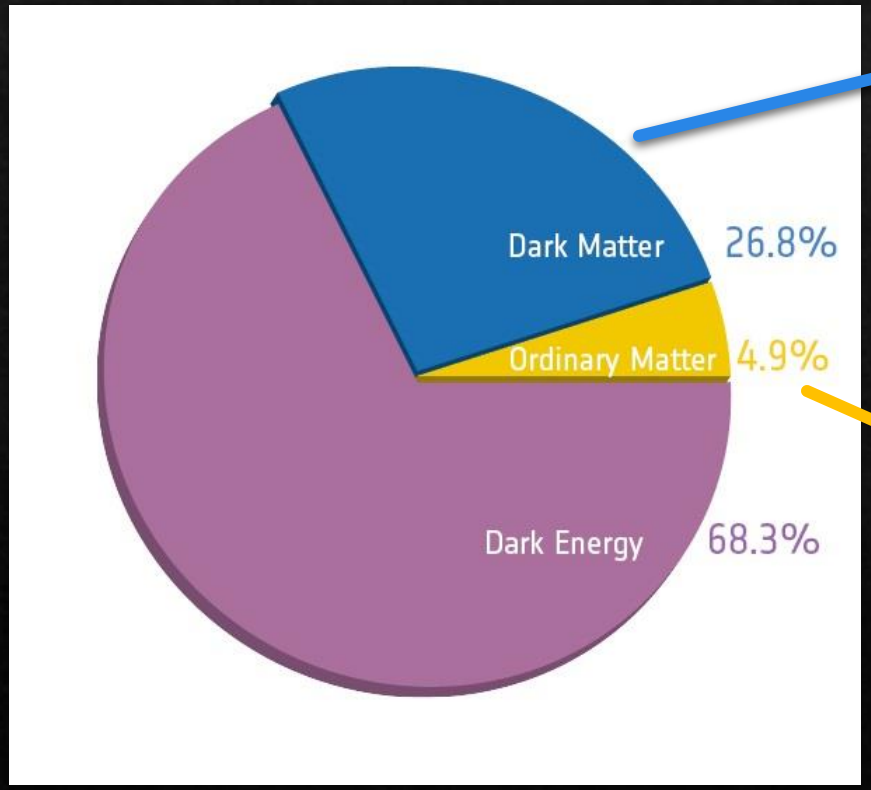
Motivation for Multicomponent Dark Matter



$$\chi_1^0$$

$$\nu_e \ \nu_\mu \ \nu_\tau$$

Motivation for Multicomponent Dark Matter



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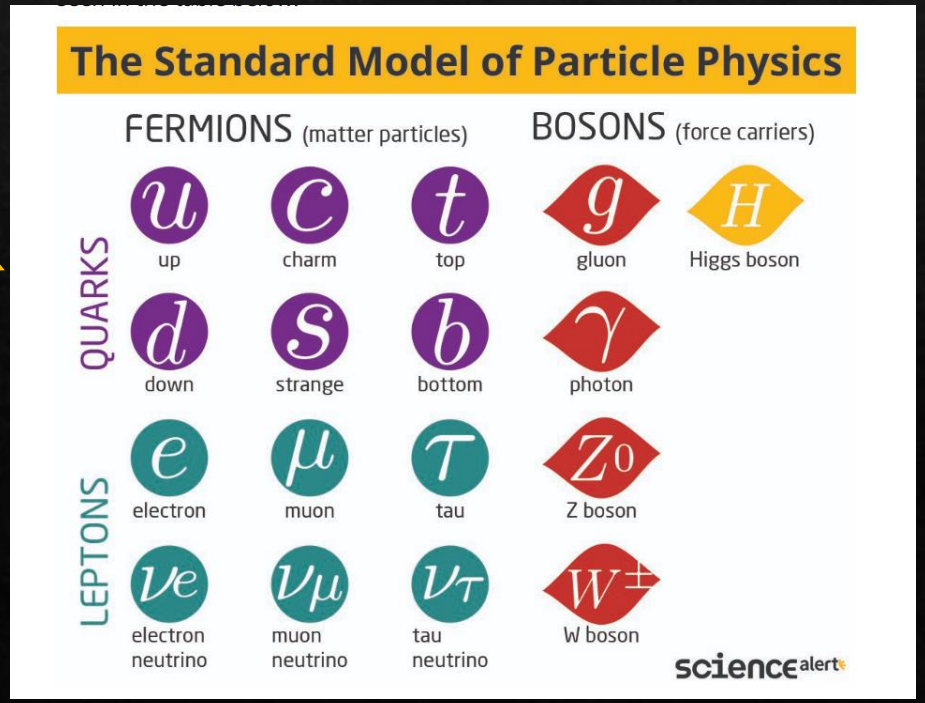

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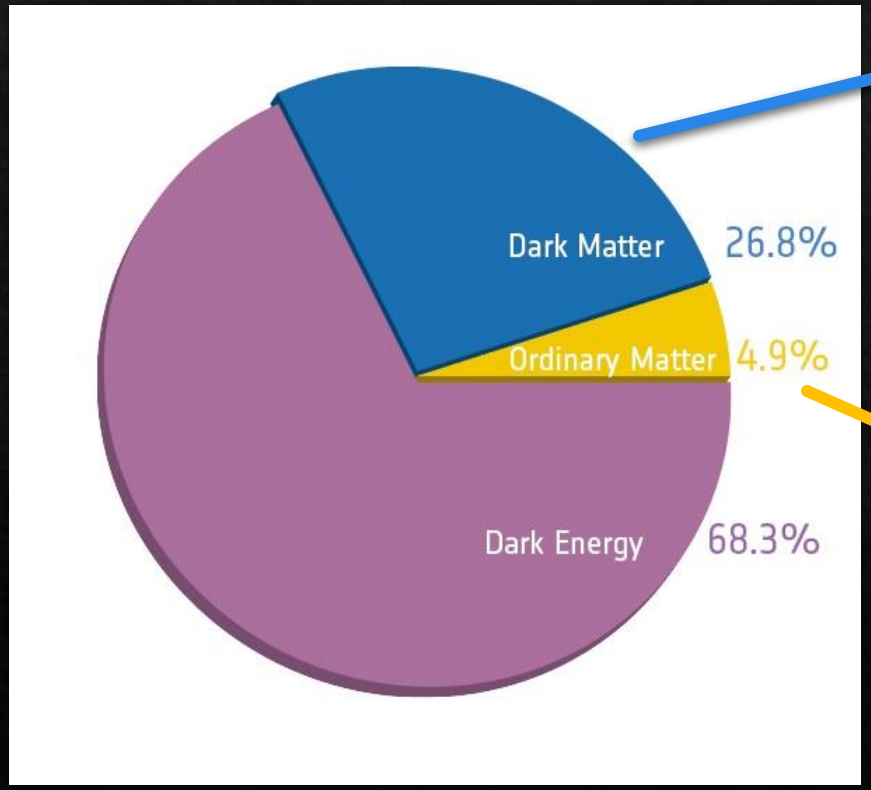

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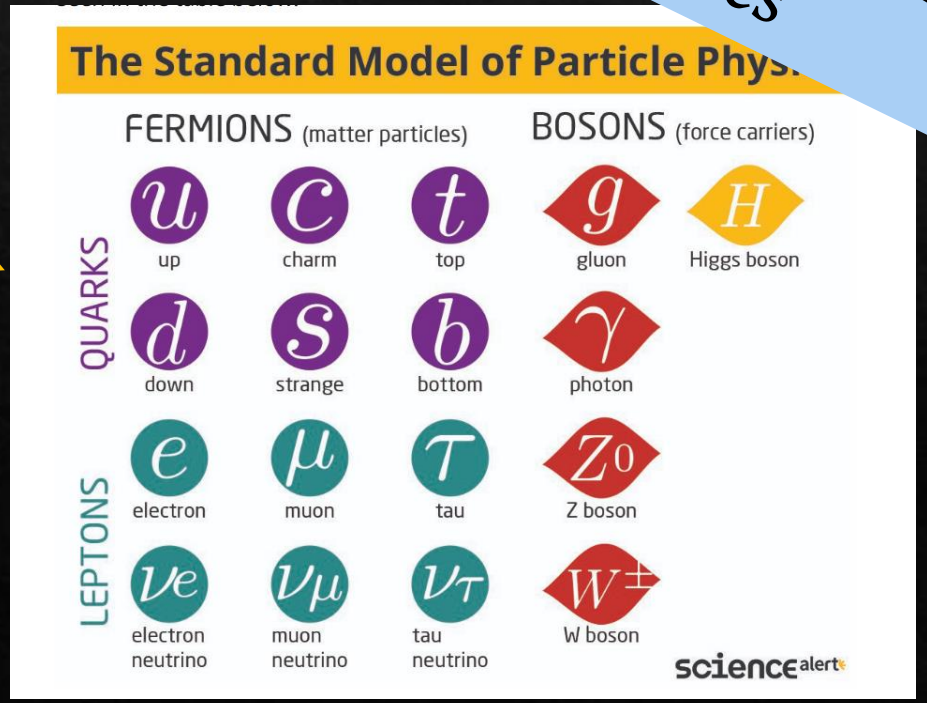
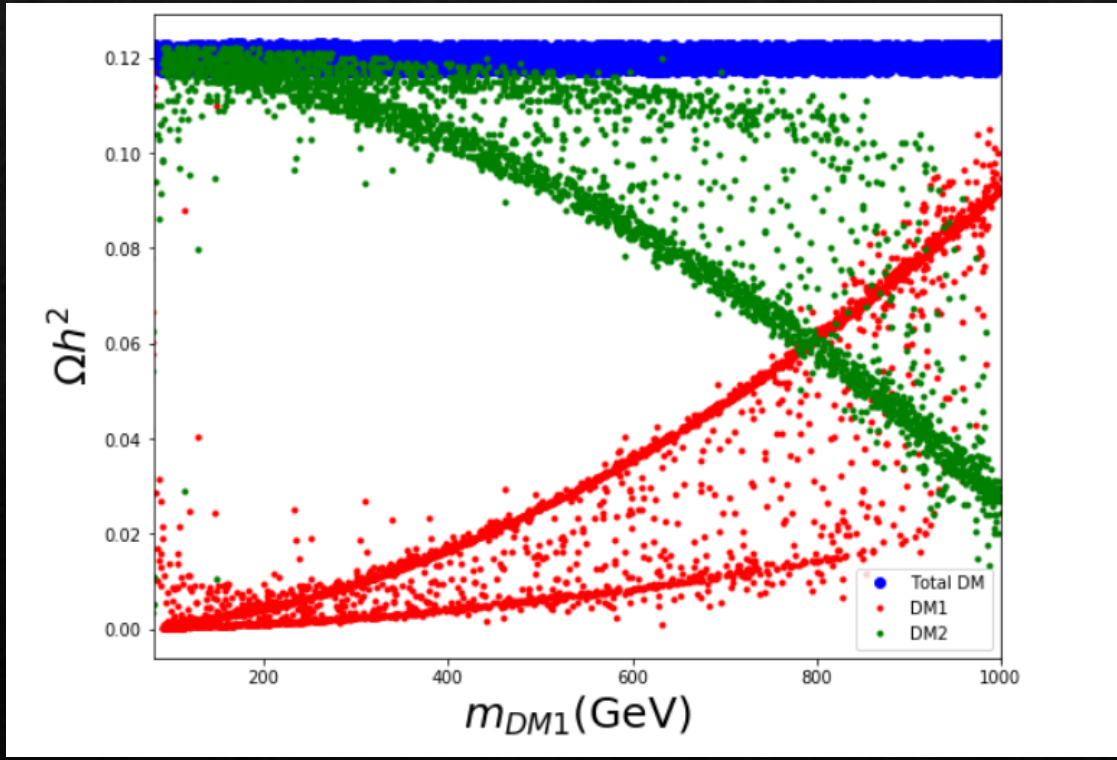
DM could be made up of a myriad of particles

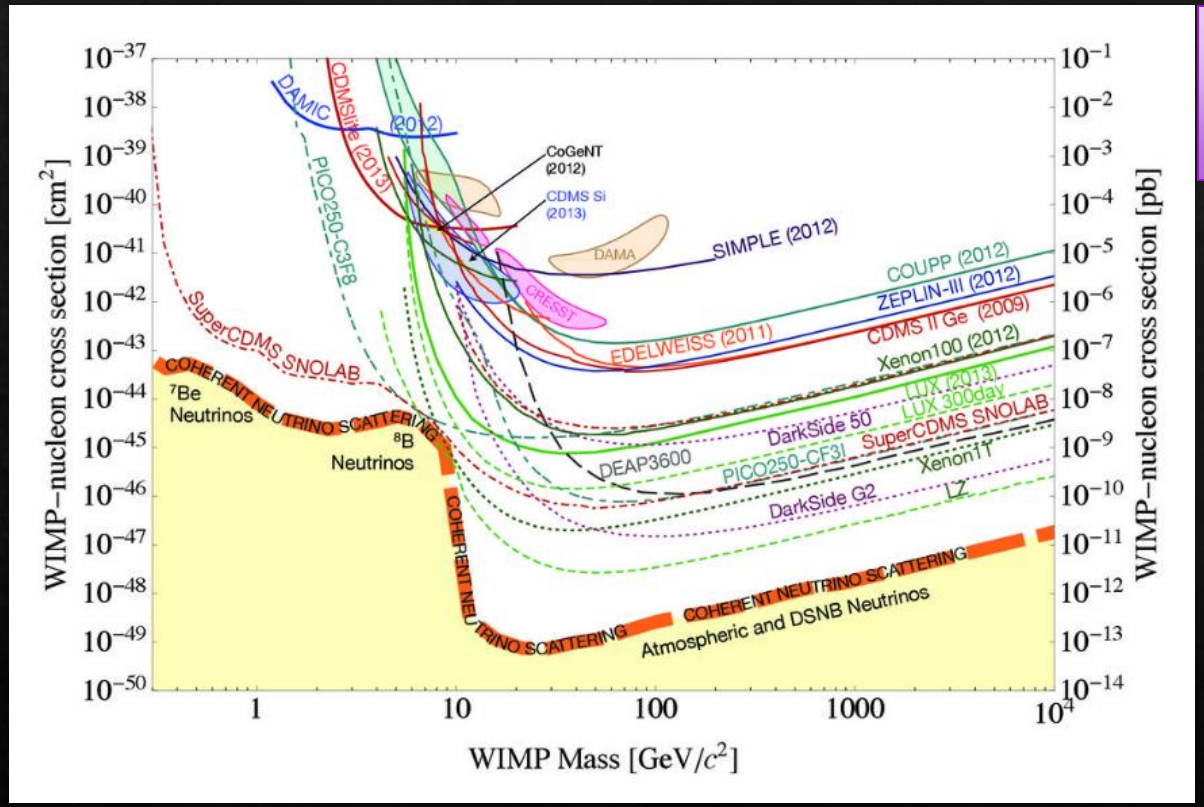


Advantages of Multicomponent dark sectors: Relic density

- Easier to saturate the relic density



Advantages of Multicomponent dark sectors: Direct detection constraints



WIMP direct detection cross section is getting more constrained

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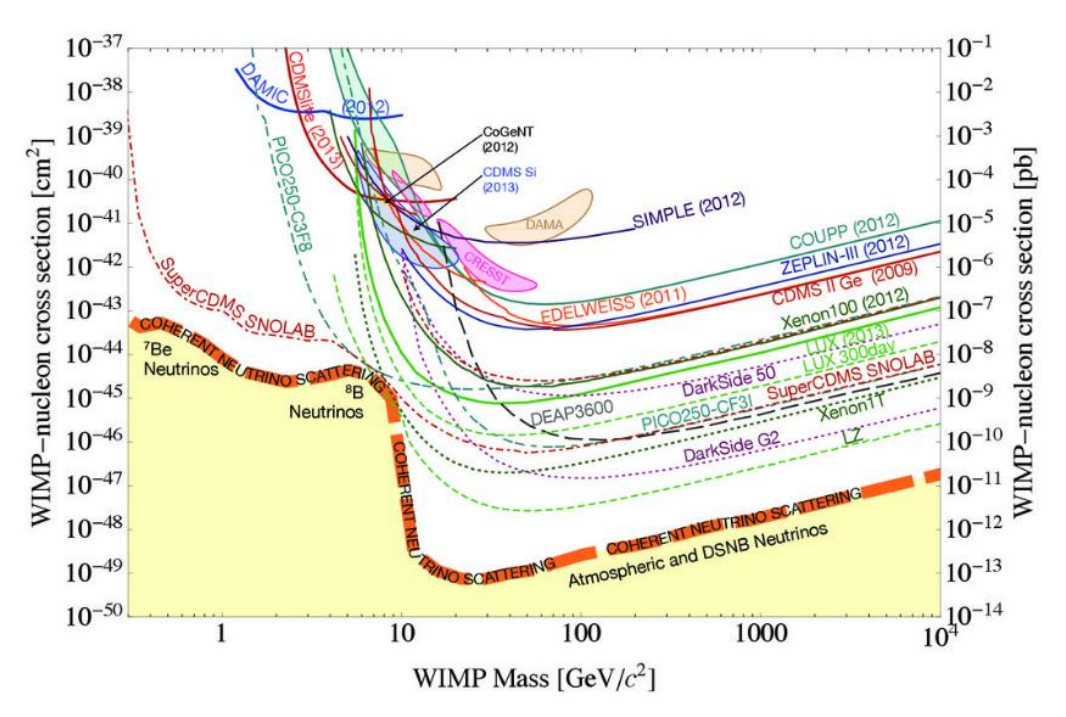
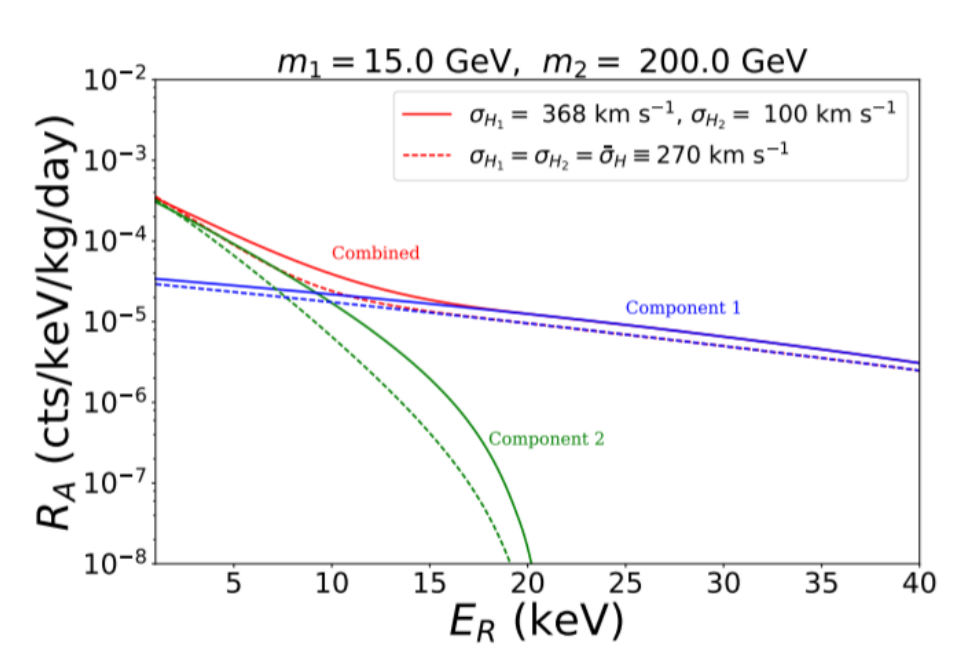


WIMP direct detection cross section is getting more constrained

Multicomponent dark matter is less constrained because the restrictions depend on the local dark matter abundance.

Advantages of Multicomponent dark sectors: Direct detection constraints



It is even possible to differentiate between the dark matter candidates

Herrero García, et. Al 2018

The Inert Doublet Model

- Extend the scalar sector with a new doublet and a new Z_2 symmetry:

New gauge interactions

New Higgs interactions

$$\mathcal{V}_{\rm I} = \lambda_3 |H_1|^2 |H_2|^2 + \lambda_4 |H_1^\dagger H_2|^2 + \frac{\lambda_5}{2}\left[(H_1^\dagger H_2)^2 + \text{h.c.}\right]$$

$$H_2 = \begin{pmatrix} H^+ \\ \frac{H^0 + iA^0}{\sqrt{2}} \end{pmatrix}$$

DM candidate

$$m^2_{H^0} = \mu_2^2 + \lambda_L v^2$$

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Interesting phenomenology but hard to probe around the electroweak scale!

Fermion sector, the recipe

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- Singlet-doublet
- Doublet-triplet
- Singlet-triplet

The fermion sector

Singlet-Doublet

Ψ , N

Doublet-Triplet

Ψ , Σ

Singlet-Triplet

N , Σ

The fermion sector

Singlet-Doublet

Ψ , N

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Ψ , Σ

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N , Σ, Ω

New scalar that mixes with the Higgs, not scalar DM

The fermion sector

Singlet-Doublet

Ψ , N

Doublet-Triplet

Ψ , Σ

Singlet-Triplet

N , Σ, Ω

New scalar that mixes with the Higgs, not scalar DM

Fermion Mixing

χ_1^0 → Dark matter candidate plus other fermionic guys

Phenomenology

- Check theoretical constraints for all models.
- In particular for the Inert Doublet Model, vacuum stability, pertubativity.

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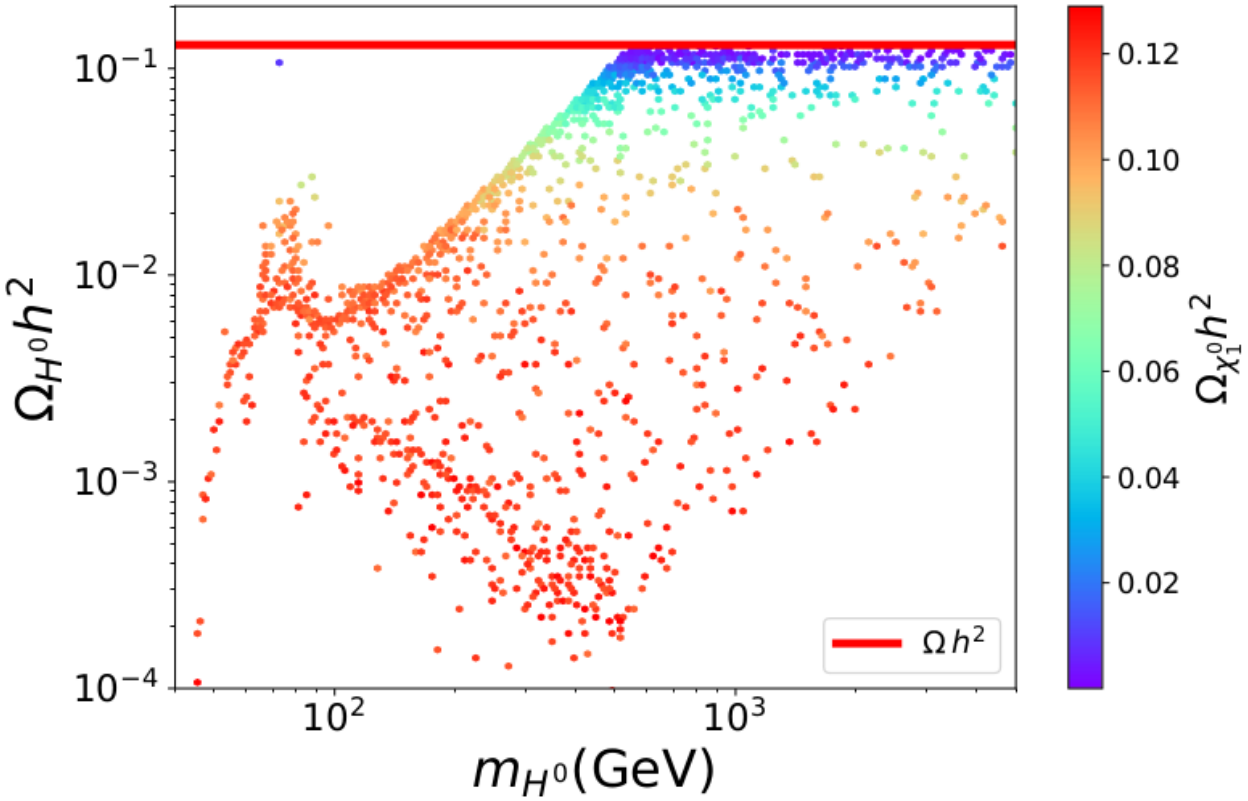
- Check theoretical constraints for all models.
- In particular for the Inert Doublet Model, vacuum stability, pertubativity.
- Check Higgs diphoton decay
- Check oblique parameters such as S, T and U

Implement all models in SARAH and use SPheno.
Perform checks!

Relic density
Singlet
Doublet

All points yield the correct relic abundance (amount of dark matter)



Relic density Doublet Triplet

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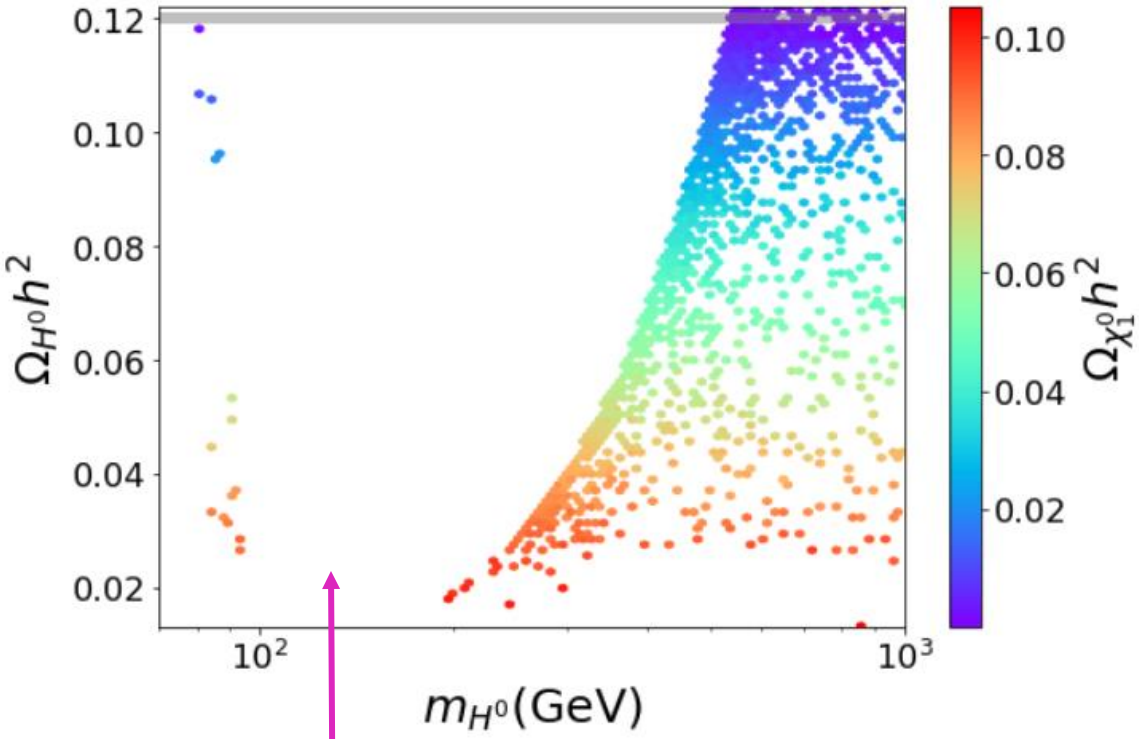

Due to large gauge interactions from the fermion sector and scalar sector it is not possible to recover this region

Relic density Singlet Triplet

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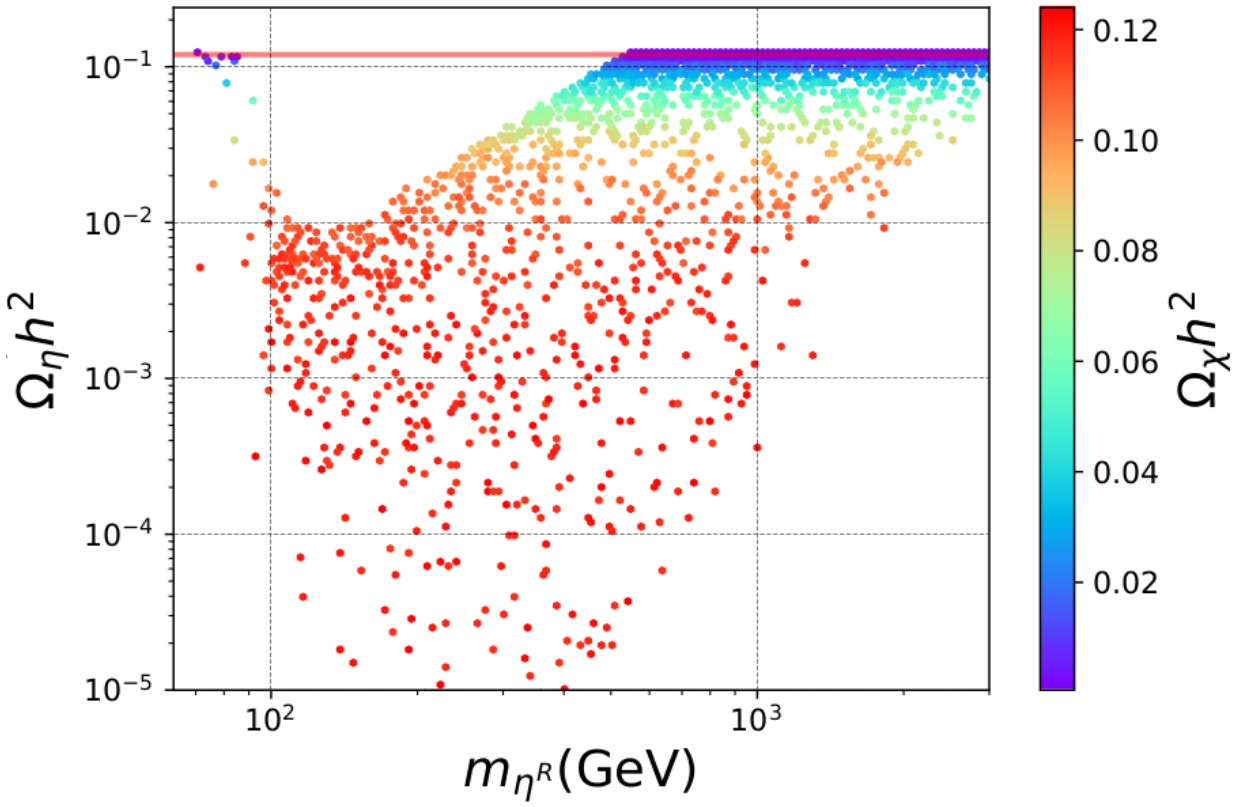


Relic density

DM1 scalar

DM2 fermion

Relic density

Can they communicate?

DM1 scalar

DM2 fermion

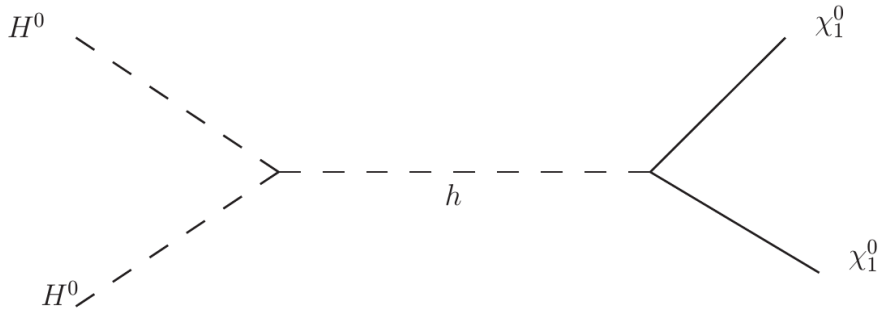
Relic density
Dark Matter
conversion

Can they communicate?

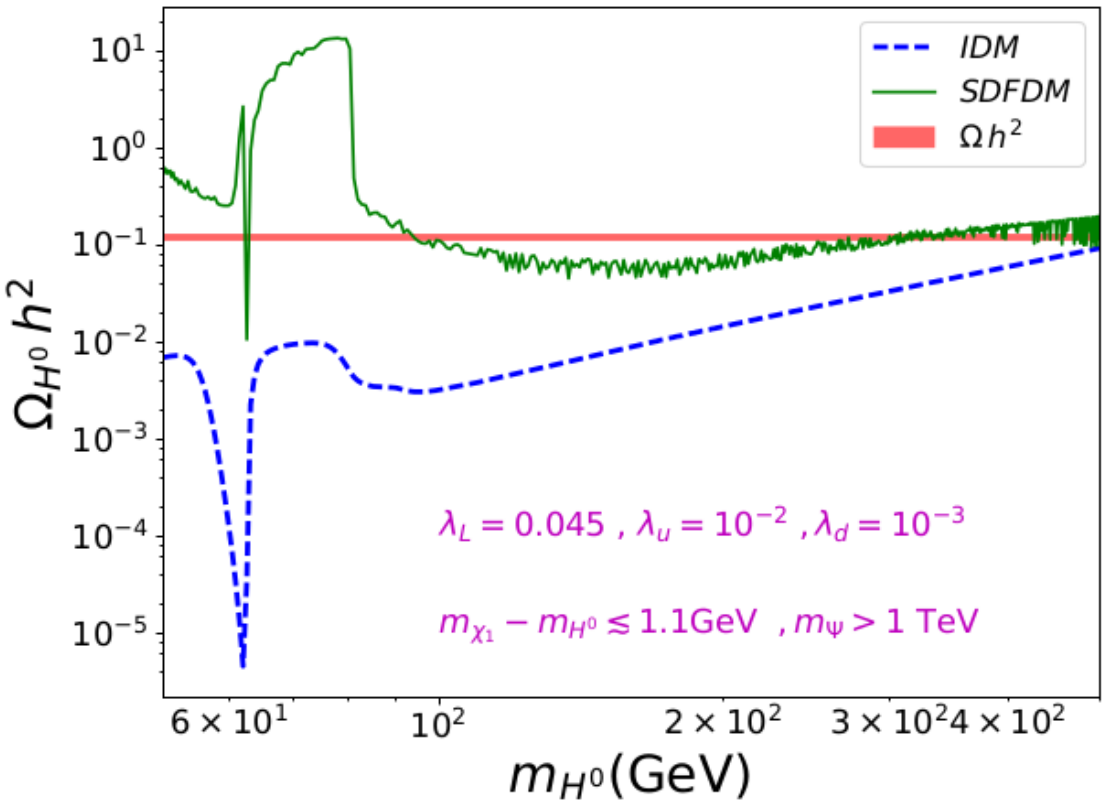
DM1 scalar

Higgs Boson

DM2 fermion

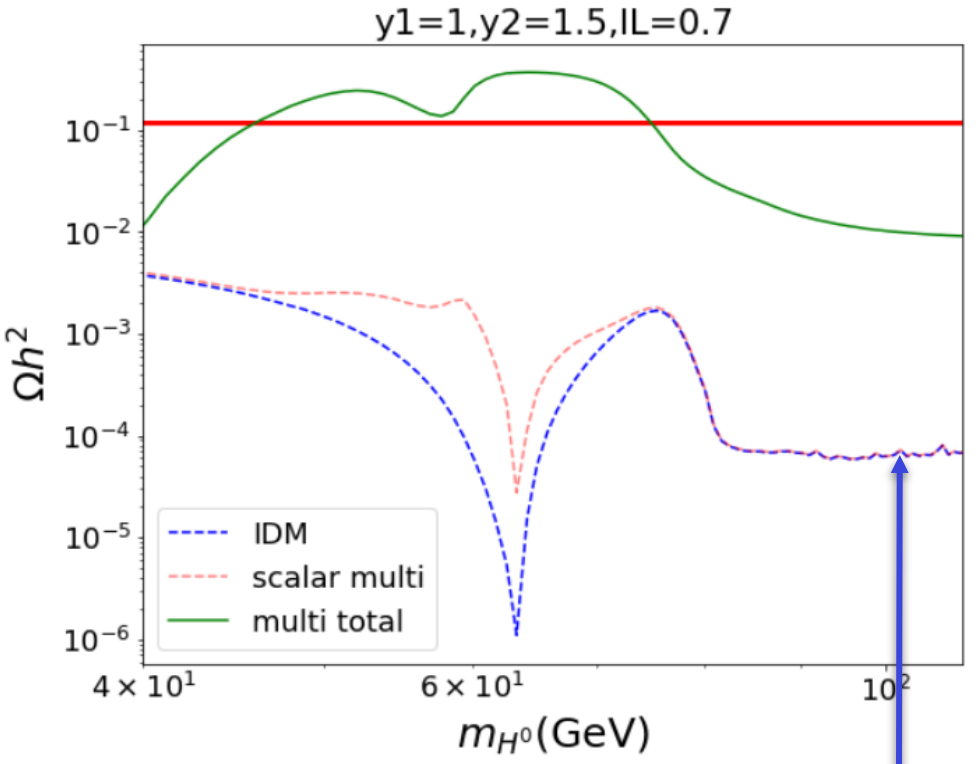


Dark matter conversion singlet-doublet



Similar to the Singlet-Triplet

Dark matter conversion singlet-doublet



Gauge interactions dominate over the Higgs

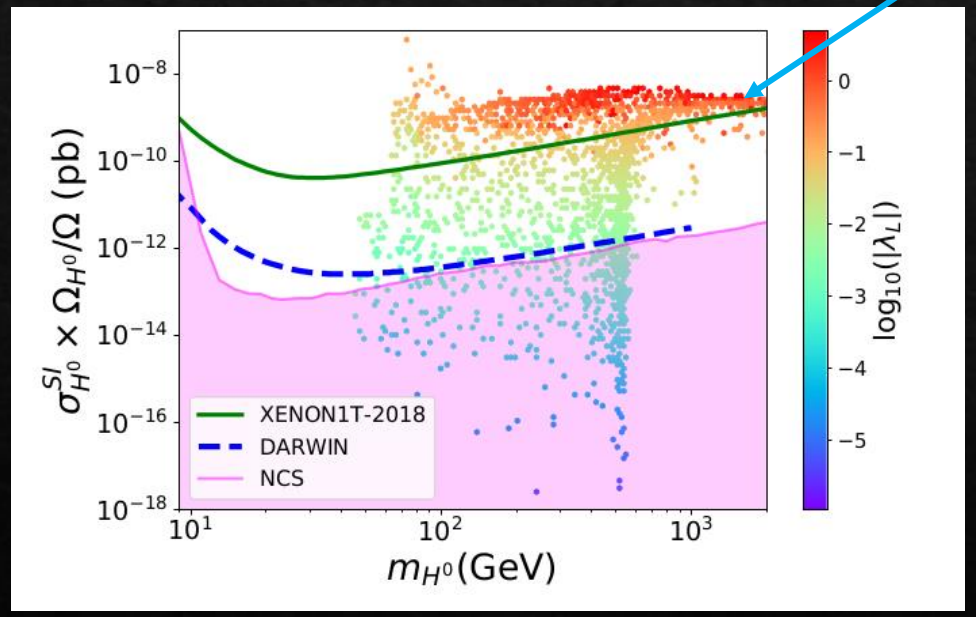
Direct Detection

- In multi-component dark sectors, direct detection is suppressed because it depends on the local relic abundance of the dark matter candidate

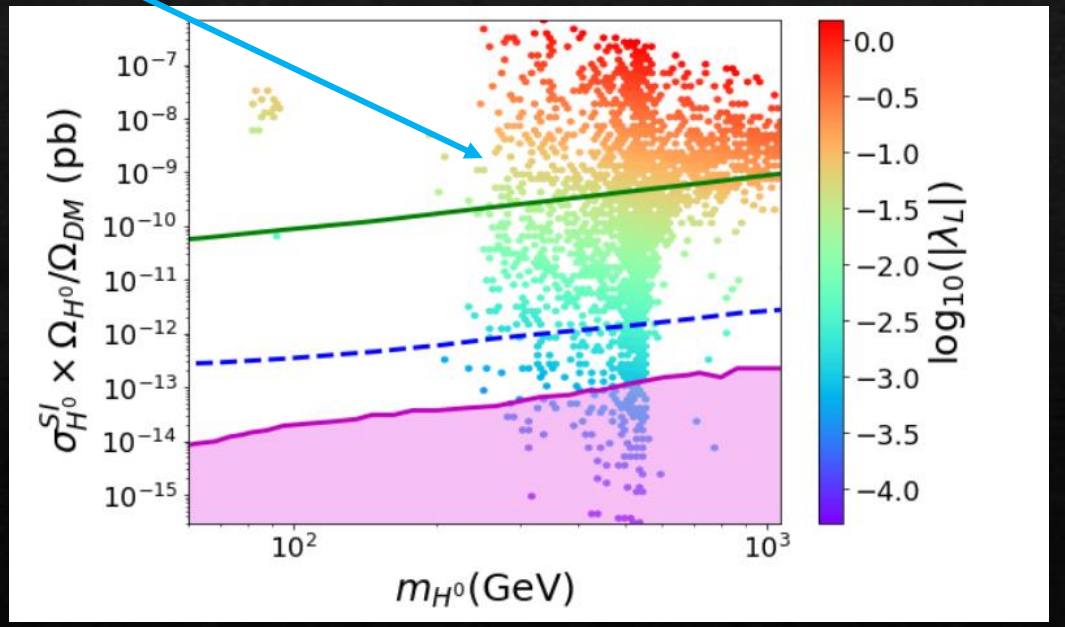
Direct Detection

XENON1T excludes $|\lambda_L| > 0.1$

Singlet-Doublet



Doublet-Triplet



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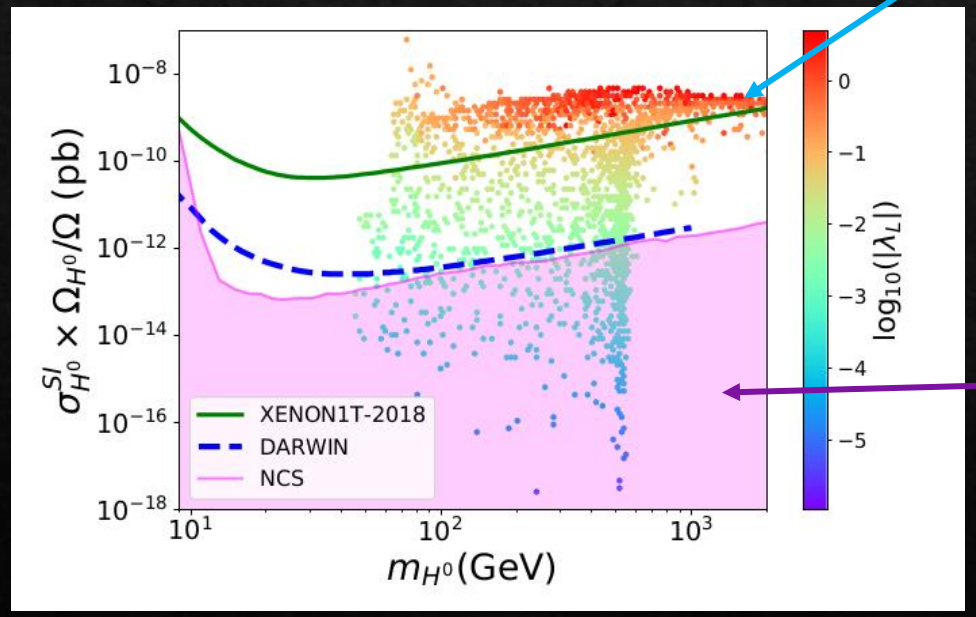
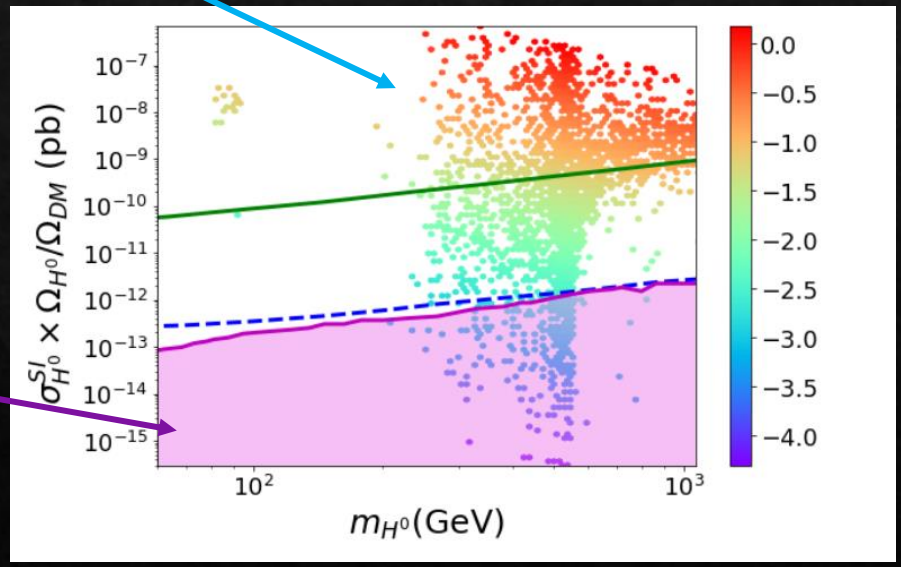


Neutrino floor
Let's hope the experimentalists come up with something

Doublet-Triplet

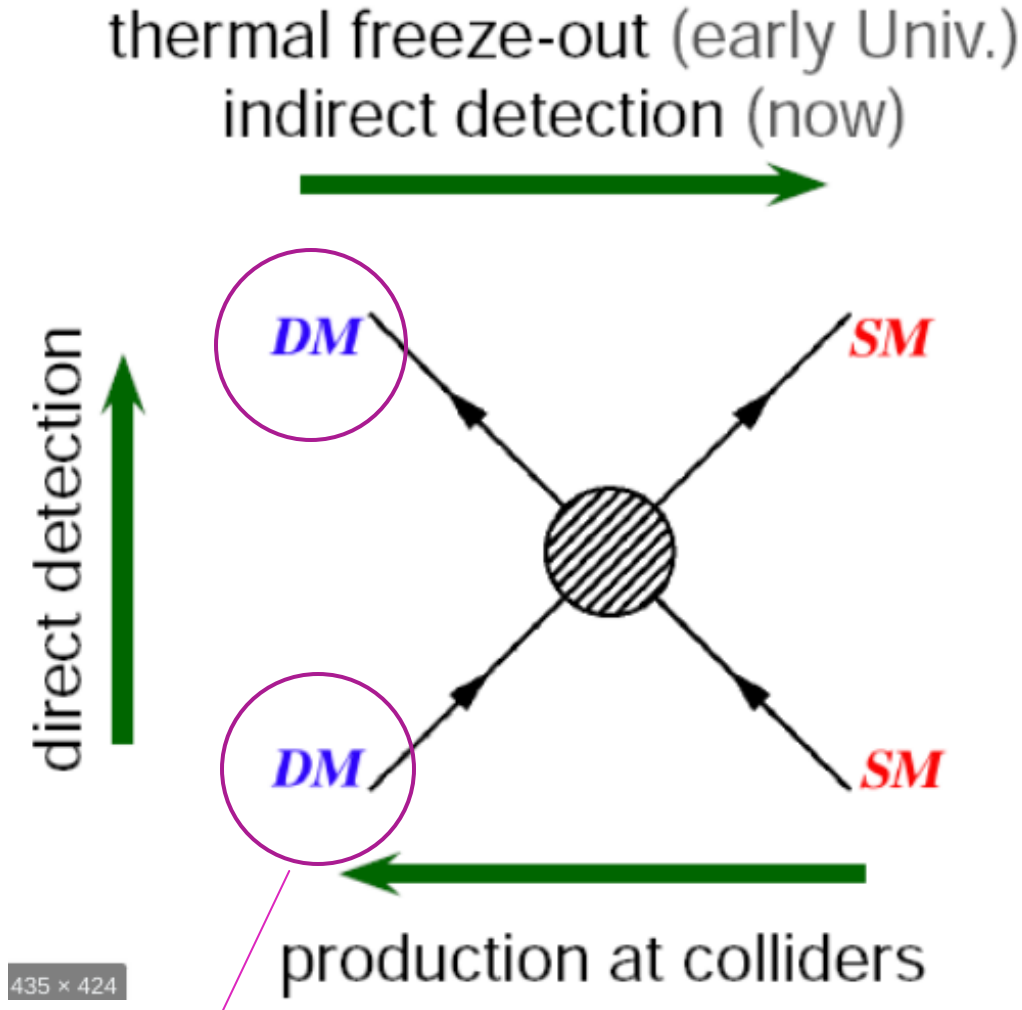


Direct Detection

No additional restrictions for λ_L in the Singlet-Triplet fermion

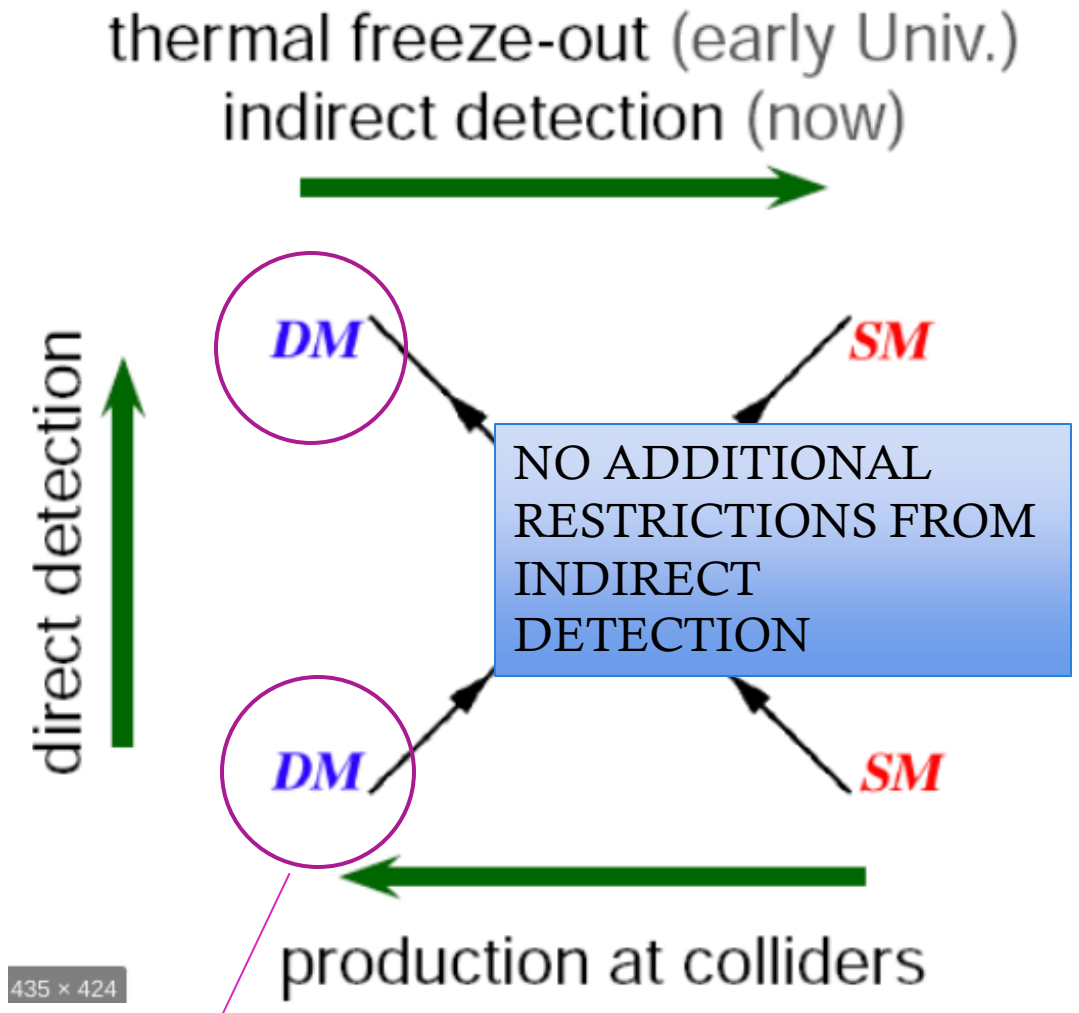
For the singlet-doublet and doublet-triplet the restrictions in $c_{h\chi_1^0\chi_1^0}$ yield similar results as those in λ_L

Indirect detection



Double suppression from smaller density of each species

Indirect detection



Double suppression from smaller density of each species

Conclusions

- Multicomponent dark sectors are interesting scenarios of Dark Matter.
- For the Inert Doublet Model it is possible to recover the intermediate regime when another stable fermionic Dark Matter candidate is included.
- It is possible for the two DM candidates to communicate through the Higgs portal, thus altering each other's relic density
- Direct detection places constraints in the Higgs coupling to both scalars and fermions while the thermally averaged cross sections of the models are out of bounds of current experiments.

Bibliography

[1] On the direct detection of multi-component dark matter implications of the relic abundance, JCAP, Herrero-Garcia, Juan and Scaffidi, Andre and White, Martin and Williams, Anthony G.

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[3] Exploring new models in all detail with SARAH, F. Staub

[4] SPheno 3.1: extensions including flavour, CP-phases and models beyond the MSSM, W. Porod, F. Staub.