When unification freezes dark matter

Maíra Dutra [1], Yasaman Farzan [2], Yann Mambrini [1]

[1] Laboratoire de Physique Théorique d'Orsay (LPT-Orsay), Orsay, France.
[2] Institute for research in Fundamental Sciences (IPM),Tehran, Iran.

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Beyond the WIMP paradigm

WIMPs

Weakly Interactive Massive Particles

DM particles with:

* masses between 100s GeV - 10s TeV

* weak (but sizeable!) interactions with SM particles

* Initially **present** and in thermal equilibrium with SM particles } FREEZE-OUT

Many experiments, no signal yet...

FIMPs

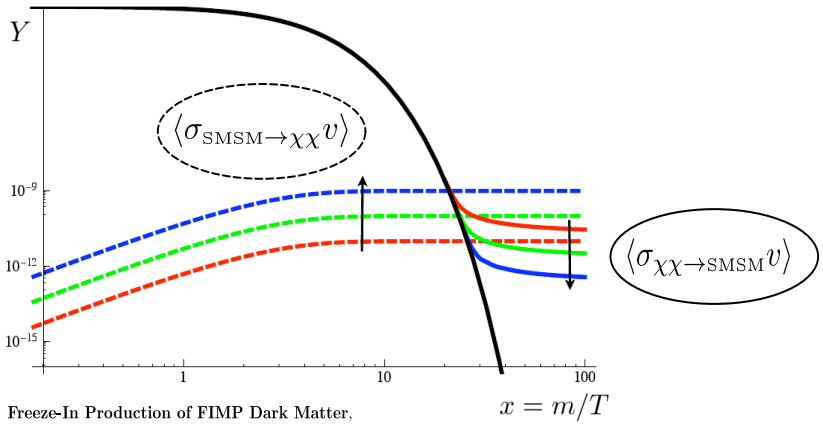
Feebly Interactive Massive Particles

DM particles with:

* "any" mass scale

* very weak interactions with SM particles

* Initially **absent** and not in thermal equilibrium with SM particles in the Early Universe } FREEZE-IN



Freeze-In Production of FIMP Dark Matter, Hall, L.J. et al, 10.1007/JHEP03(2010)080

A minimal model of FIMP dark matter

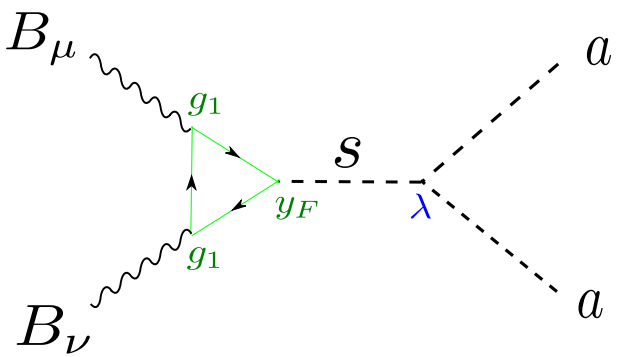
G_{SM}+ global $U(1)_X$

dark matter

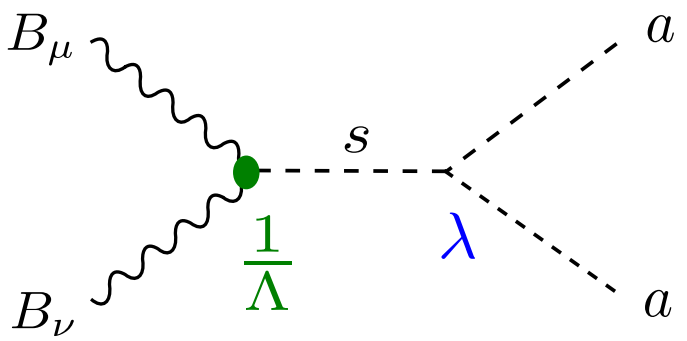
$$\mathcal{L}_\Phi \supset -\mu_\phi^2|\Phi|^2 - \lambda|\Phi|^4 + \frac{\epsilon_\Phi^2}{2}\left(\Phi^2 + \Phi^{\dagger 2}\right) \qquad \Phi = \frac{s+ia}{\sqrt{2}}$$

$$\mathcal{L}_F \supset -y_F(\Phi + \Phi^\dagger)\overline{F}F + ig_1\overline{F}\gamma^\mu B_\mu F$$

$$\Phi \to \frac{v_\Phi + s + ia}{\sqrt{2}} \qquad M_F = \frac{y_F}{\sqrt{2}}v_\Phi$$



$p_{B_\mu} \sim T \ll M_F$

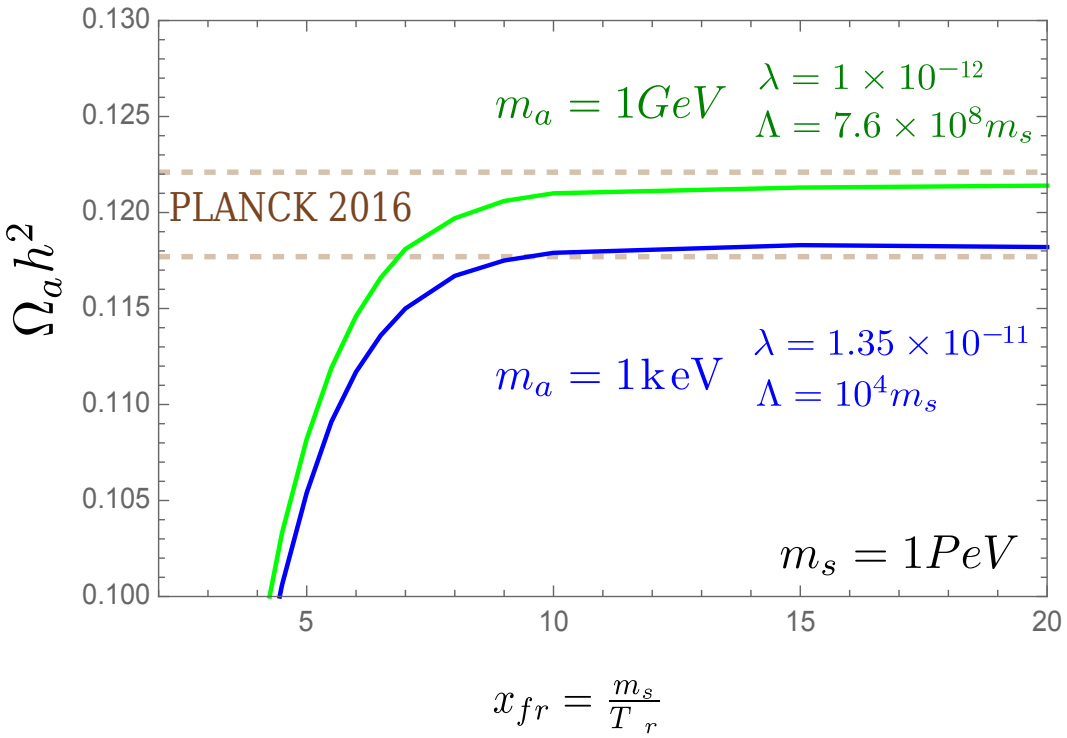


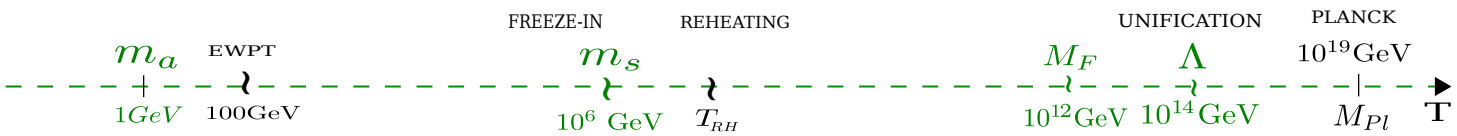
$$\frac{1}{\Lambda} \approx g_1^2 y_F \frac{Tr[Q_F^2]}{M_F} \qquad \lambda = \frac{y_F^2}{4}\frac{m_s^2}{m_F^2}$$

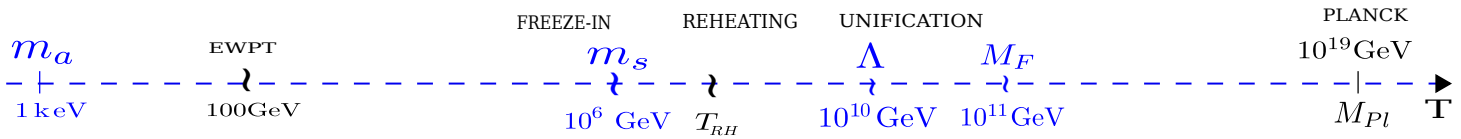
$$|\mathcal{M}|^2_{BB\to aa} = \frac{8\lambda}{\alpha^2}\frac{s^2}{(s-m_s^2)^2+m_s^2\Gamma_s^2}$$

$$\alpha = \frac{\Lambda}{m_s}$$

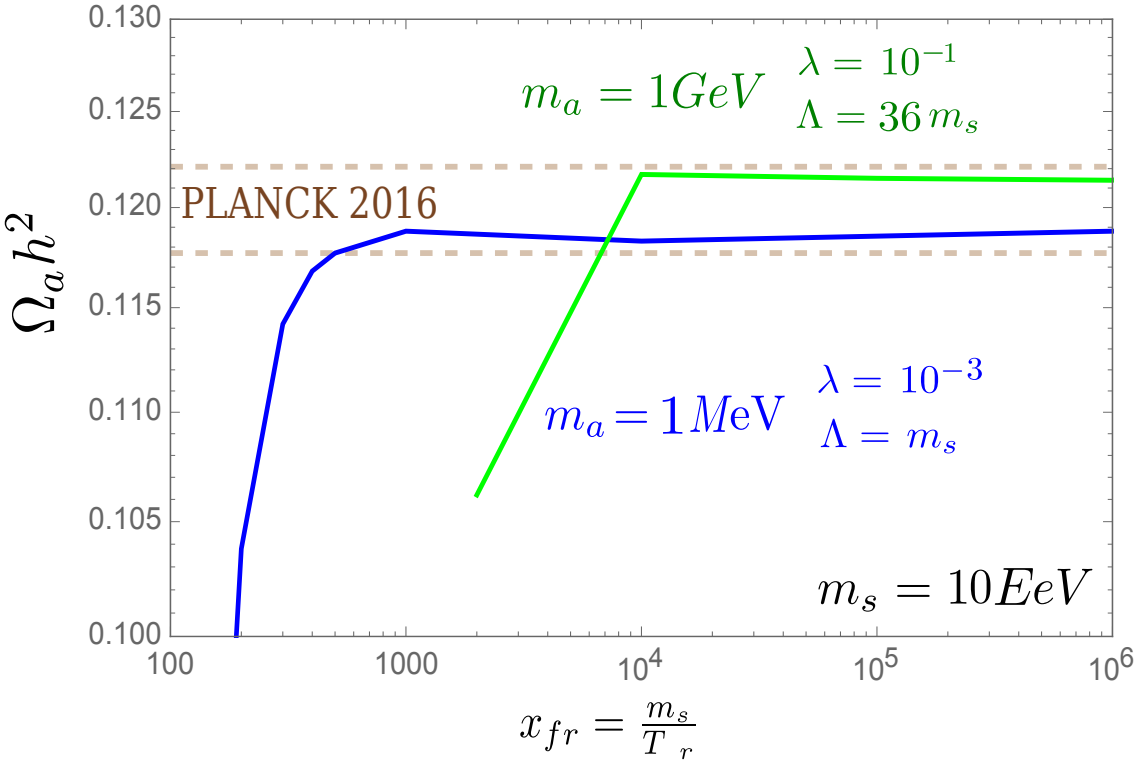
Light mediator: $m_s < T_{rh}$

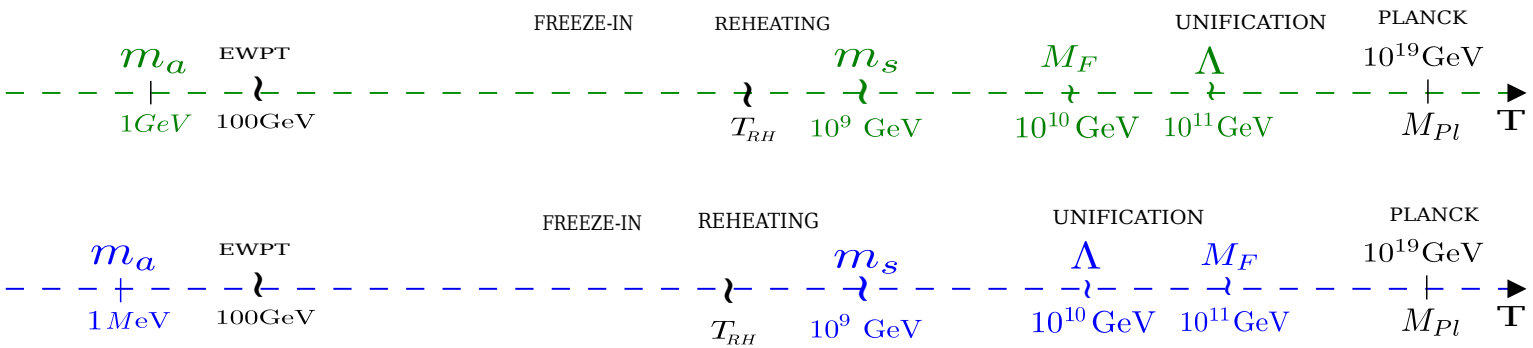






Heavy mediator: $m_s > T_{rh}$





Conclusions and perspectives

If DM and SM particles interact too weekly (so as to justify null results in dark matter searches), they would never have reached thermal equilibrium

→ If any mechanism suppressed the energy density of dark matter, its relic density may have been produced by the thermal bath (freeze-in mechanism)

We considered a minimal scenario where the smallness of the interaction between the dark and the visible sectors comes from a symmetry wich is broken at some high energy scale

We have found a wide range of dark matter mass which is sensitive to the high energy history of the universe

With free parameters providing a good relic density, we want to:

Imbed our minimal model in realistic GUT scenarios

Further constrain them by considering structure formation requirements and by looking for indirect detection signals