The *Inflaton portal* to PeV-EeV dark matter

In collaboration with **Fei Huang**, *1806.XXXX*

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Its production mechanism remains unknown

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A large class of models requires unnatural choices of parameters

(small kinetic mixings, tiny portal interactions…)

Primordial production of the dark matter bath is barely discussed

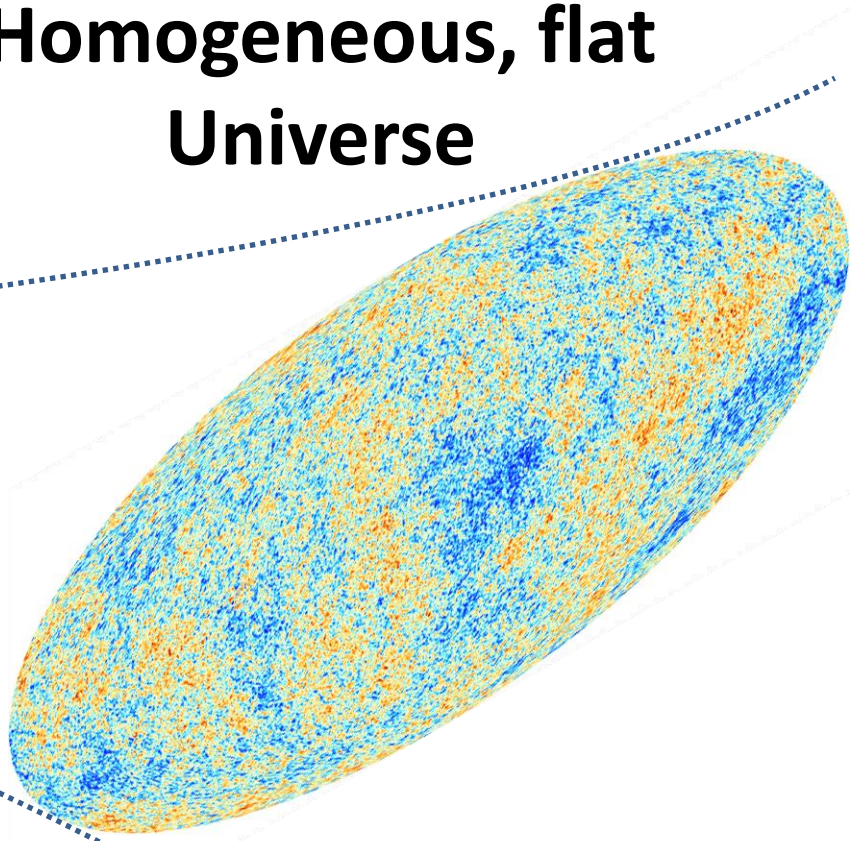
…

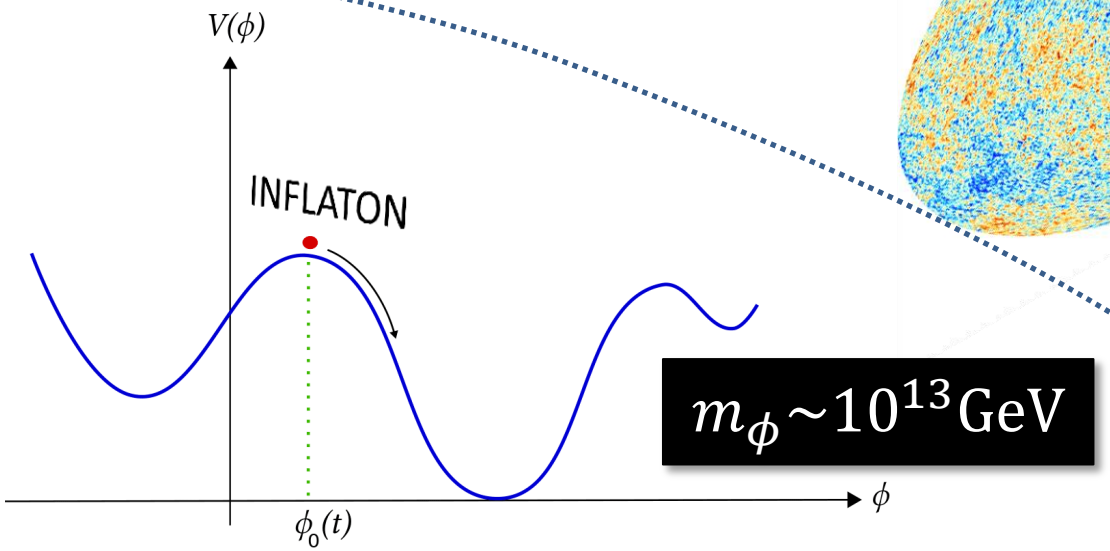
The standard cosmological History

Primordial Universe

Homogeneous, flat Universe

INFLATION

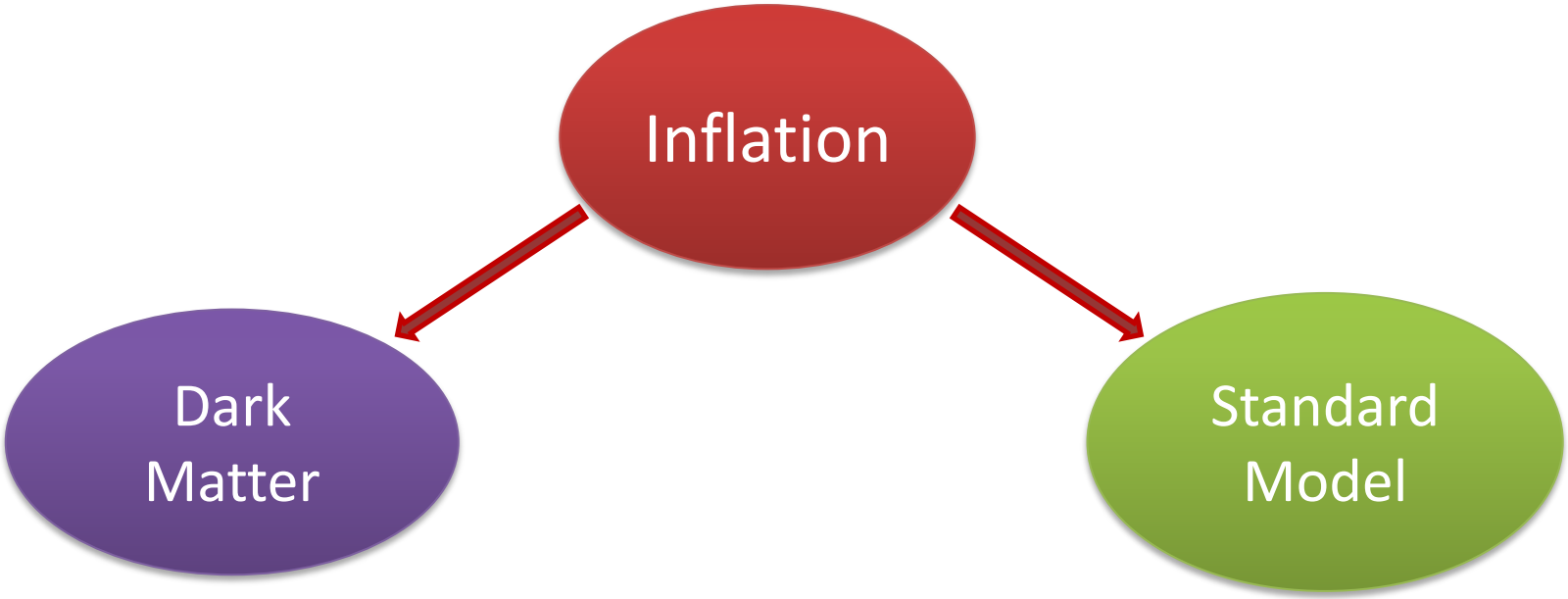




$m_\phi \sim 10^{13}\,\mathrm{GeV}$

The standard cosmological History

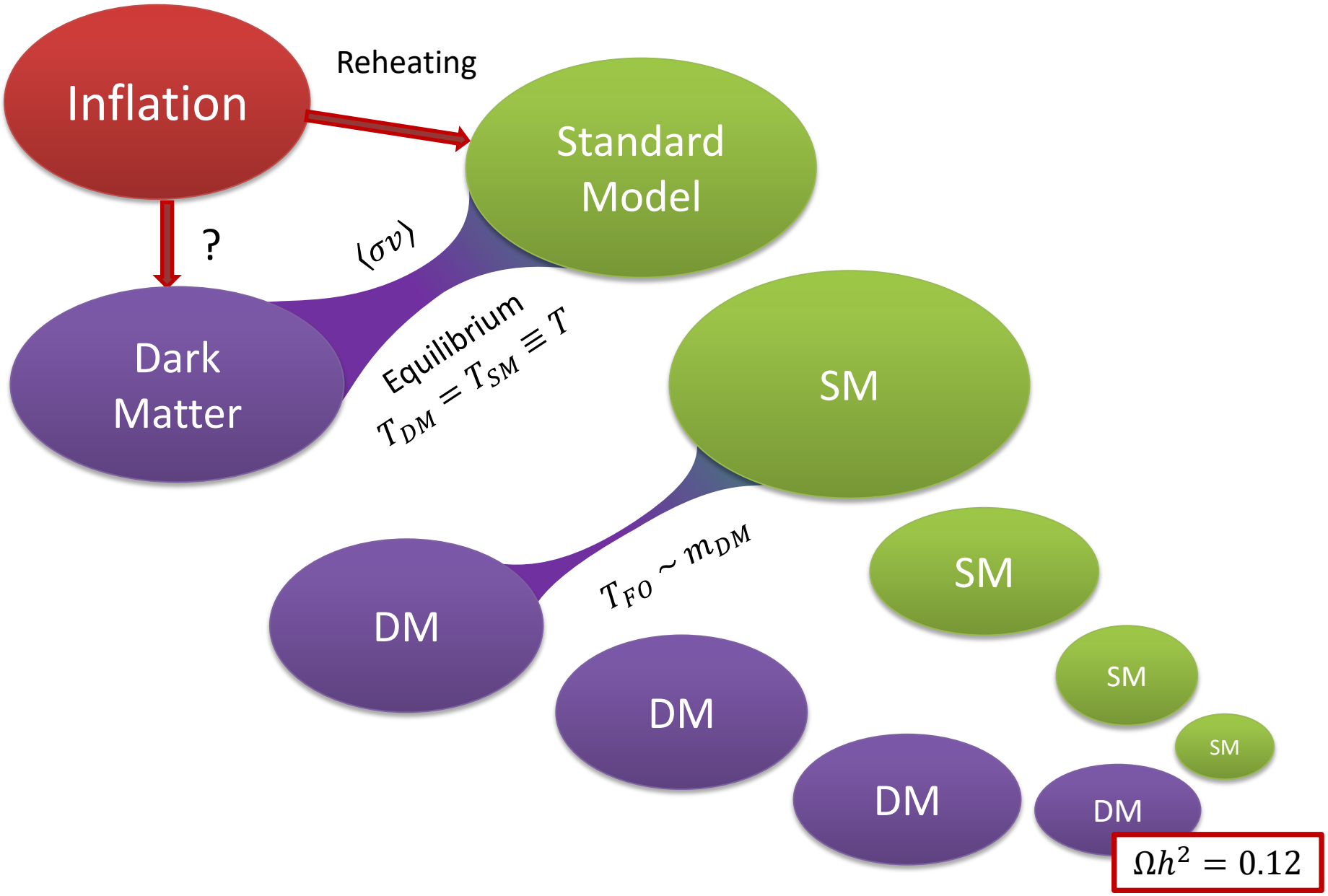
Inflaton Decay : Reheating



Being explicit about the reheating lagrangian fixes initial conditions for dark matter production …

When is it relevant to DM production ?

Thermal scenario of Dark matter production :



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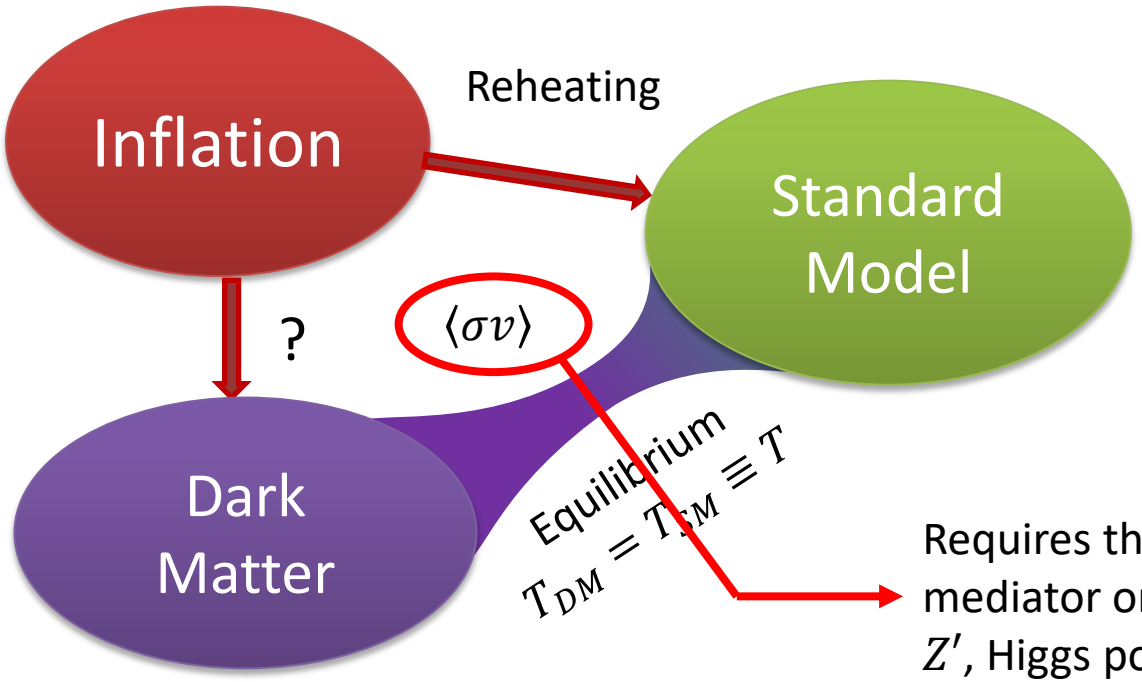

Requires the presence of a mediator or small coupling : Z', Higgs portal, etc.

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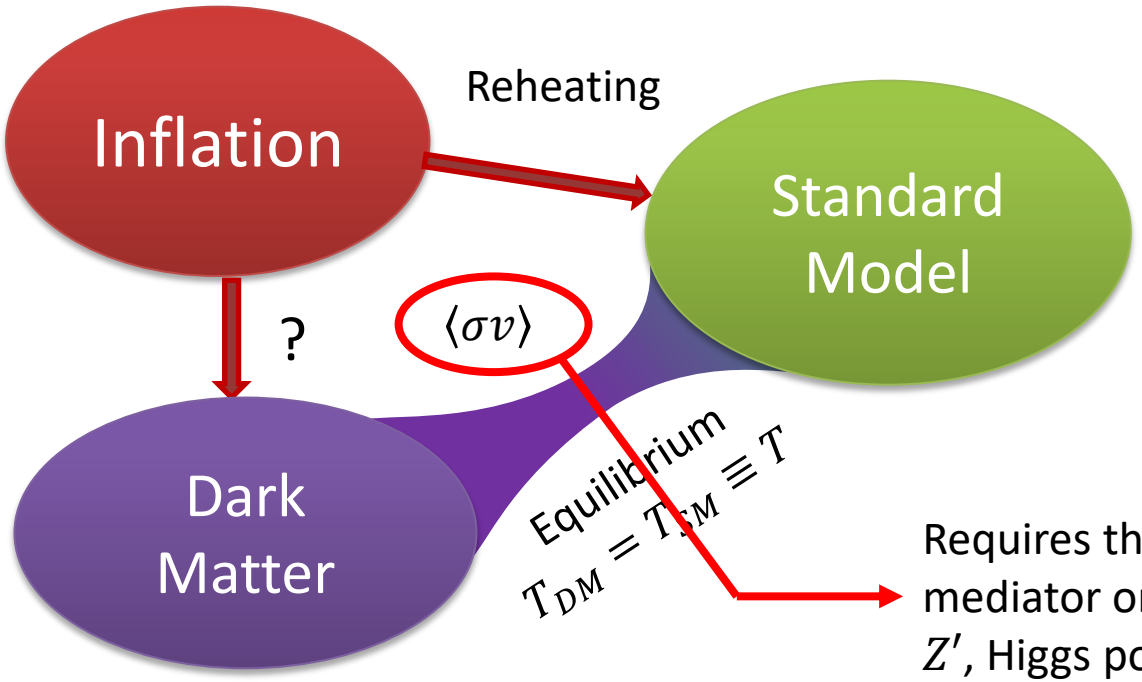

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More and more disfavored by direct detection experiments…

WIMP miracle:

$\langle\sigma v\rangle \sim \langle\sigma v\rangle_{EW}$ and $m_{DM} \sim \mathcal{O}(100)$ GeV

$\Downarrow$

$\Omega h^2 \sim 0.12$

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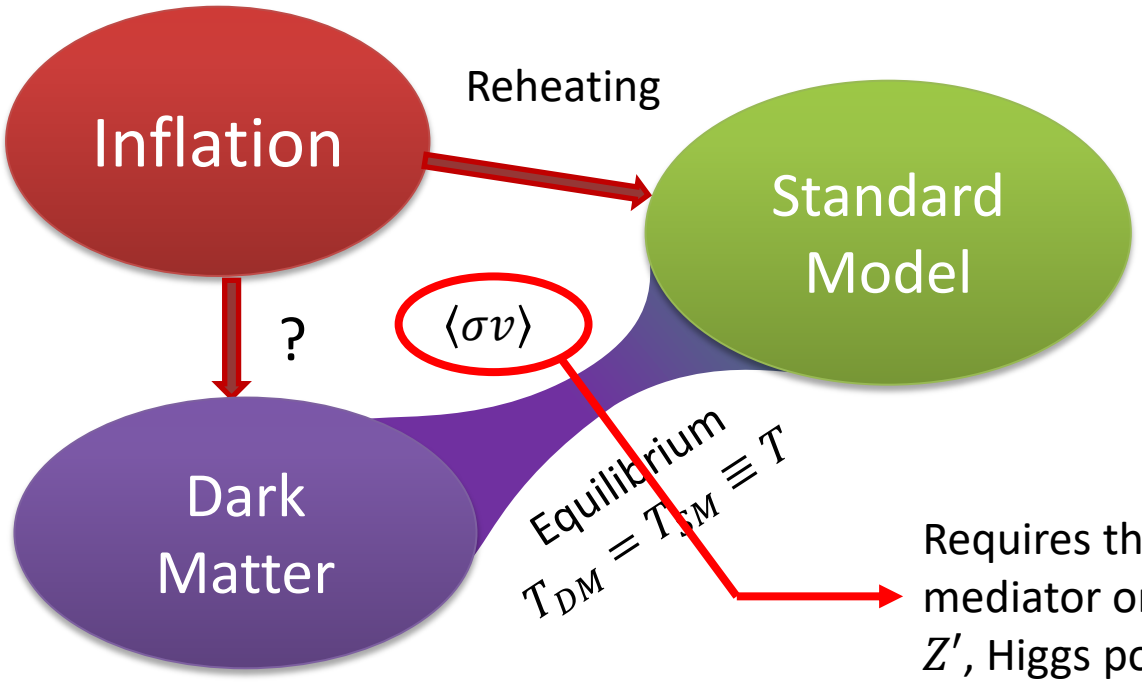

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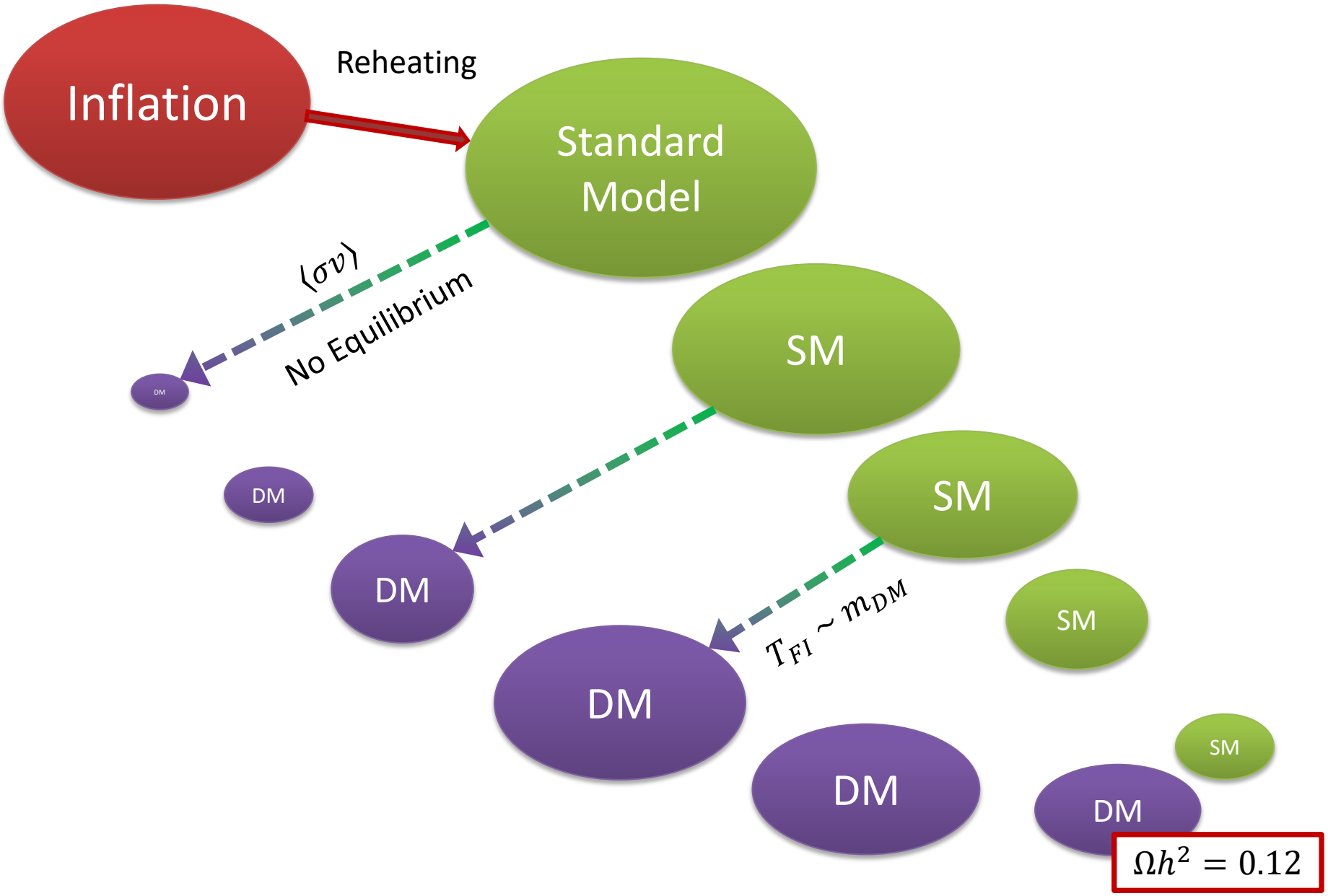

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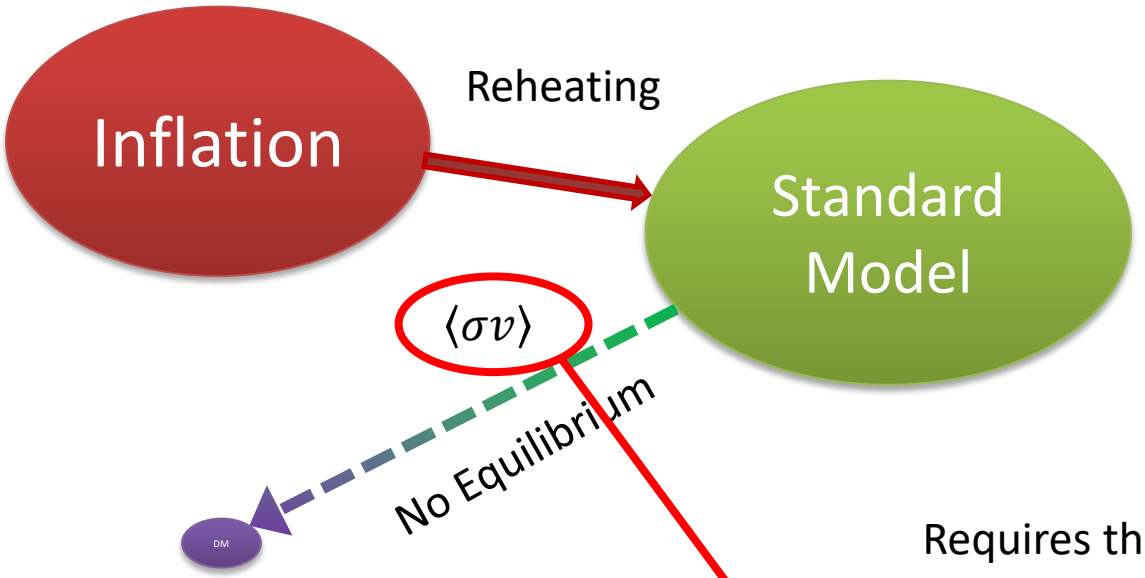

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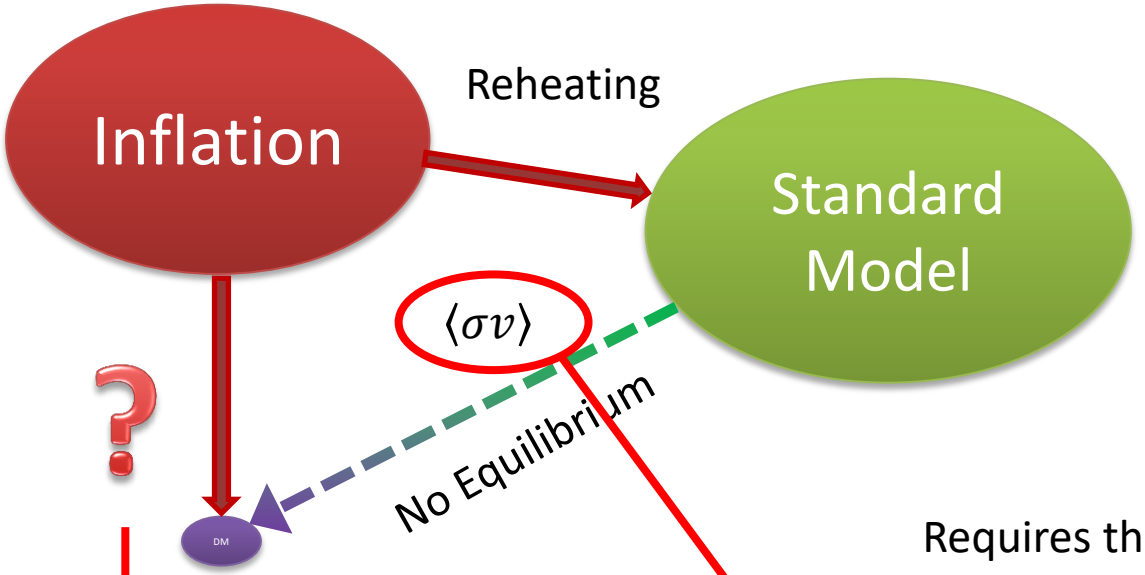

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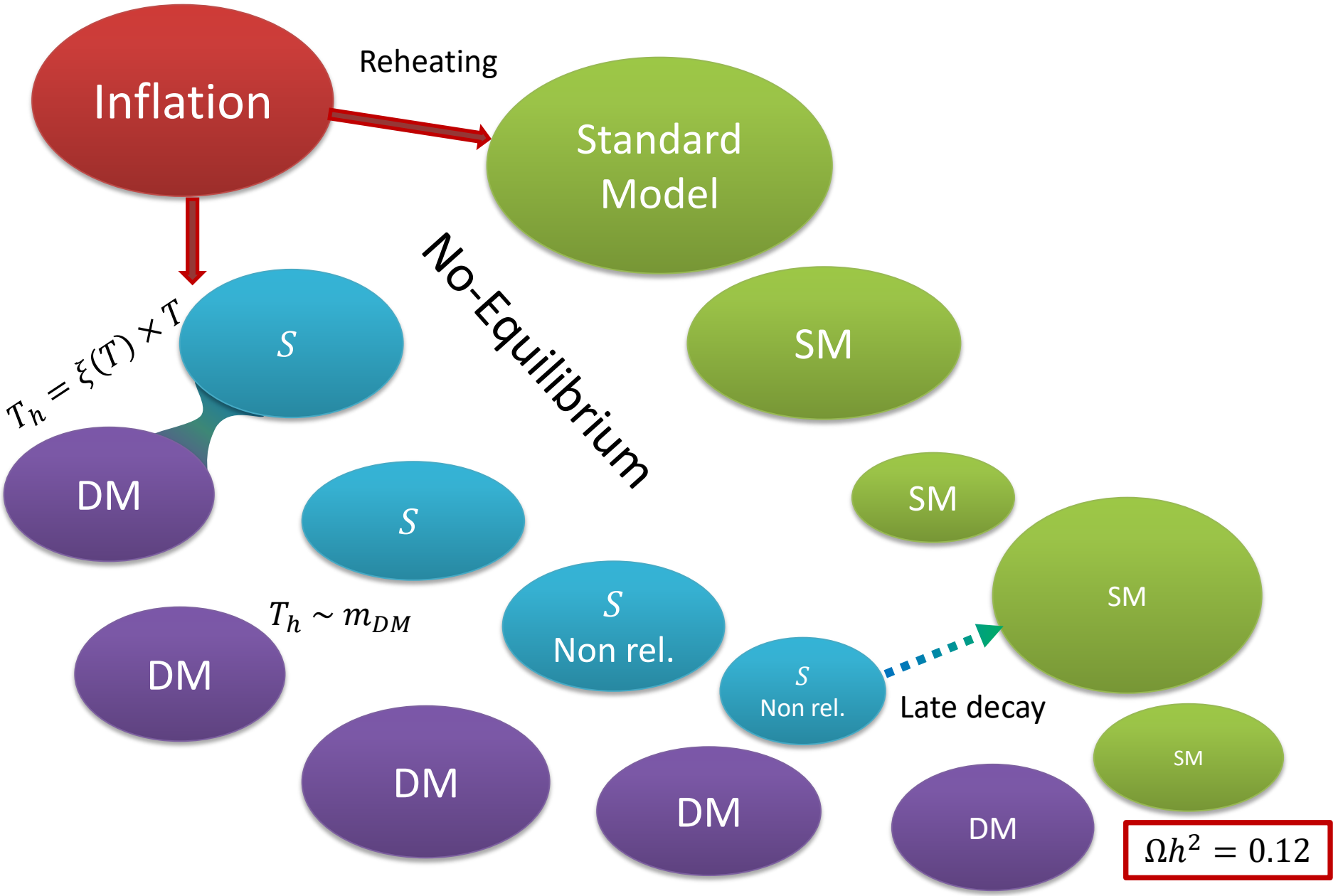
No reason a priori to suppress the production of DM through inflaton decay…

Decoupled Hidden sector [Hooper et al., '16]



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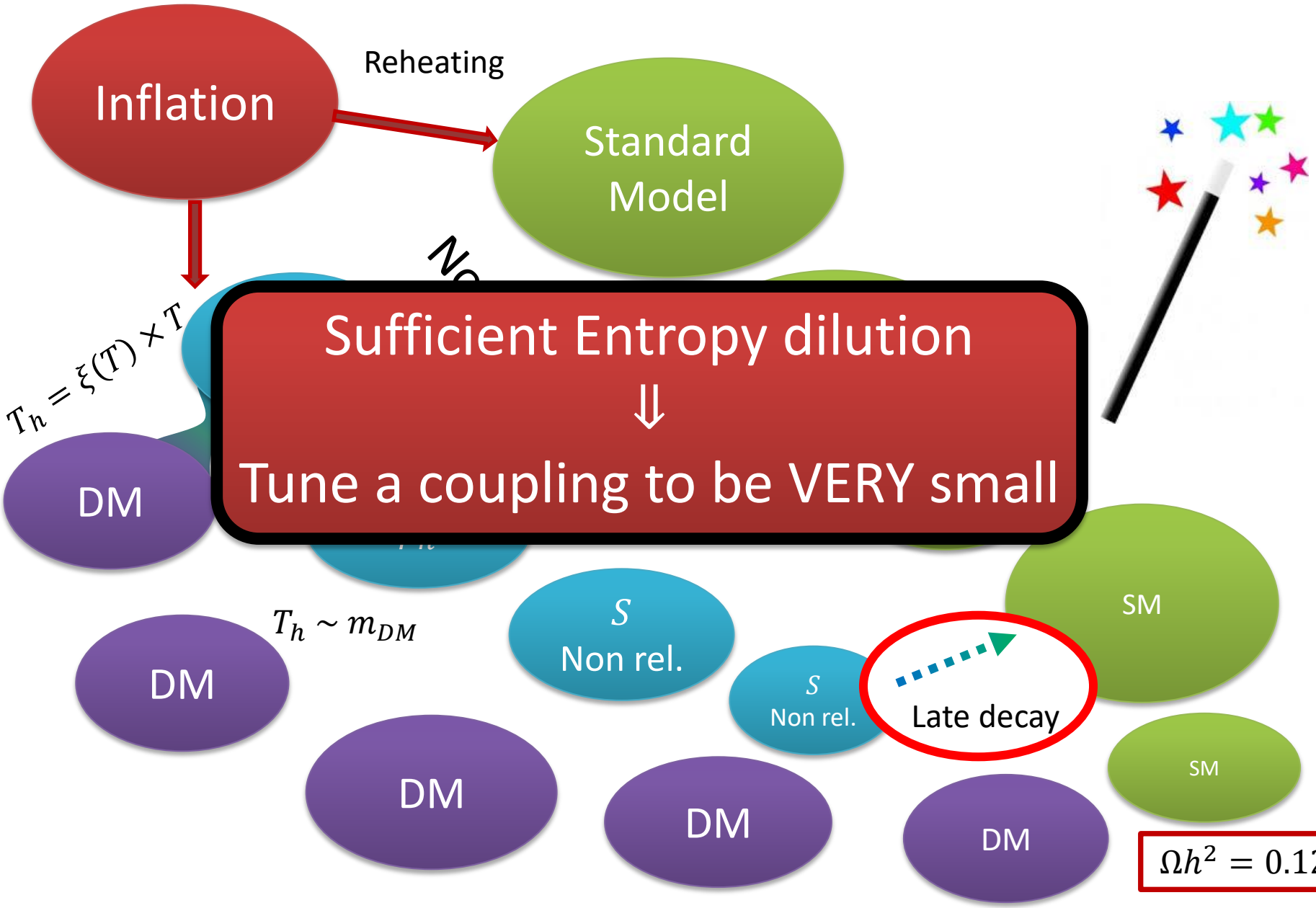
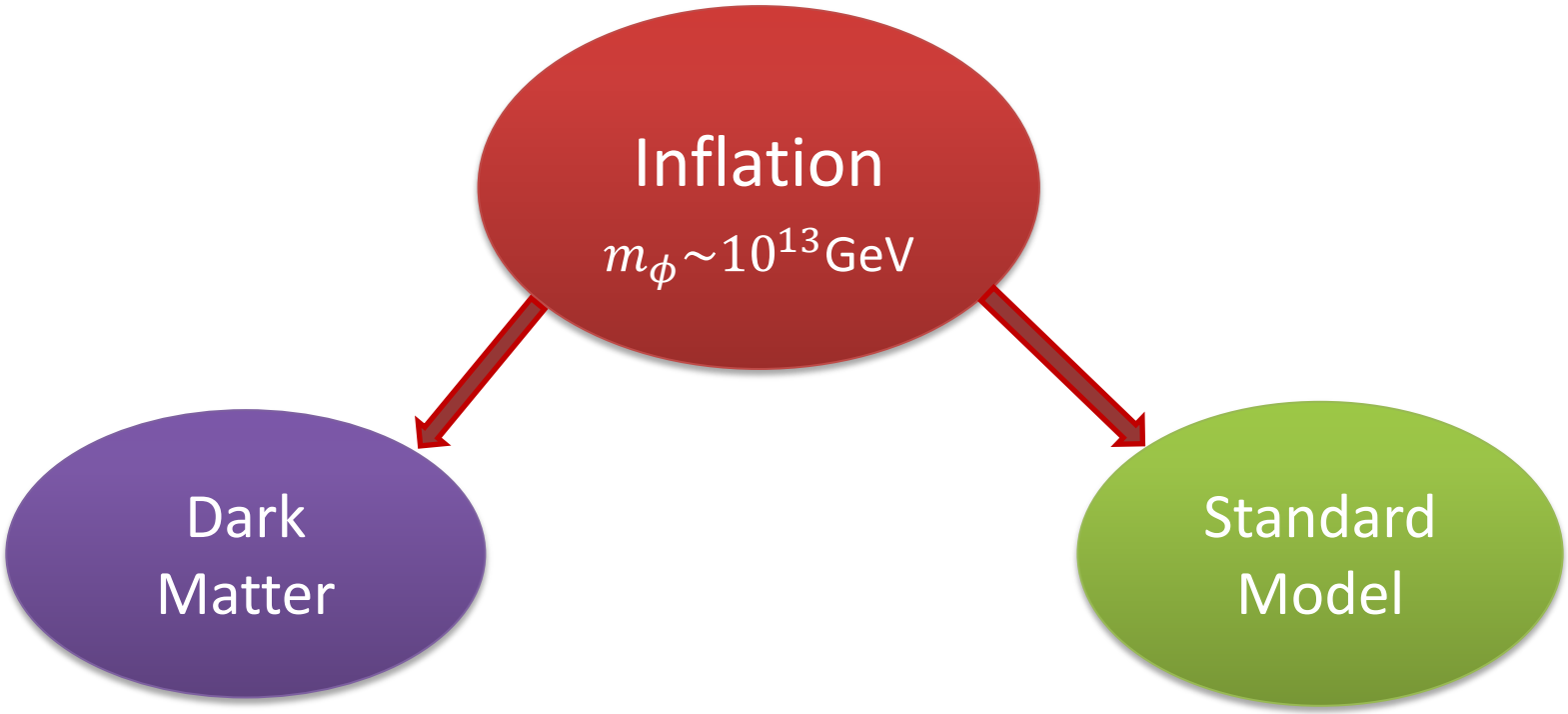


The inflaton portal to DM



[Dev, Mazumdar, Qutub 13'], [Heurtier 17']

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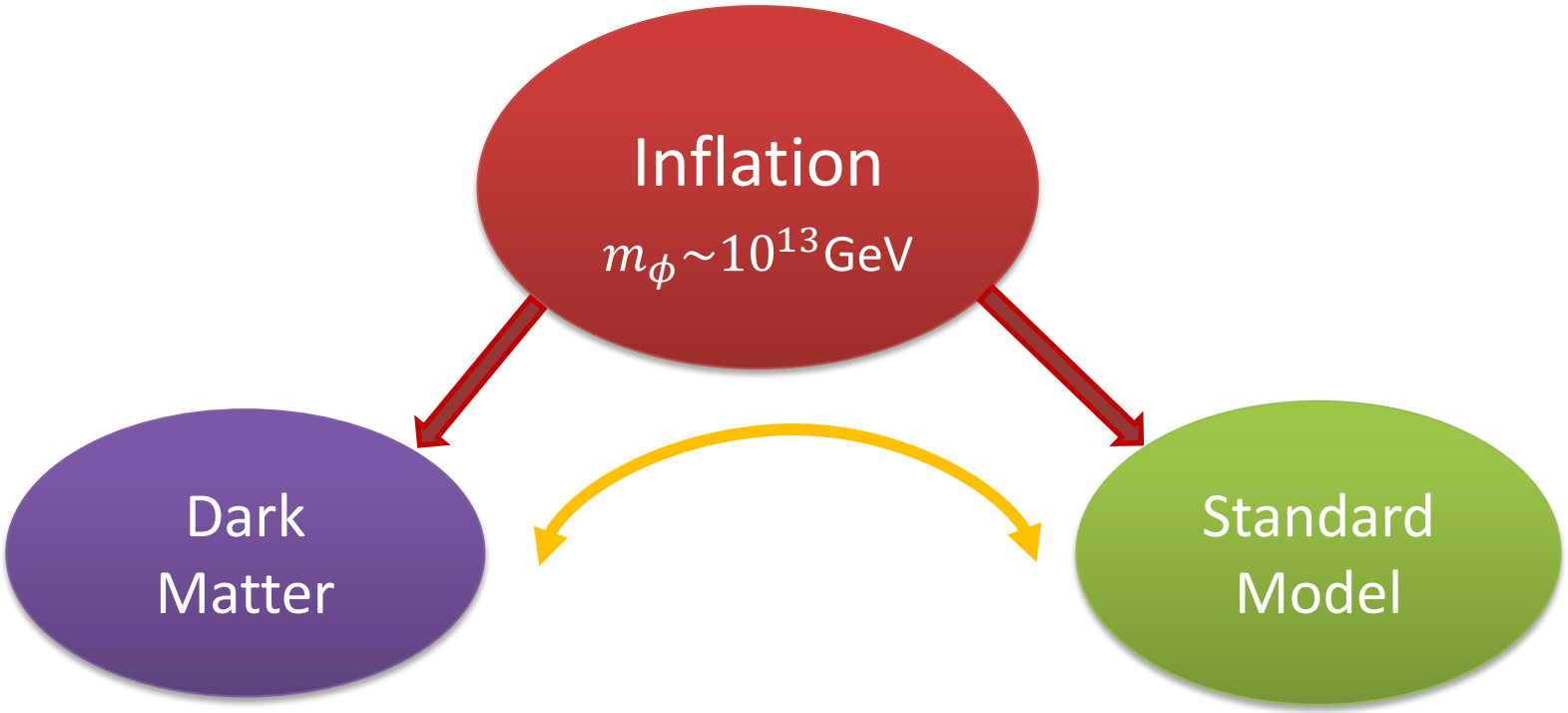


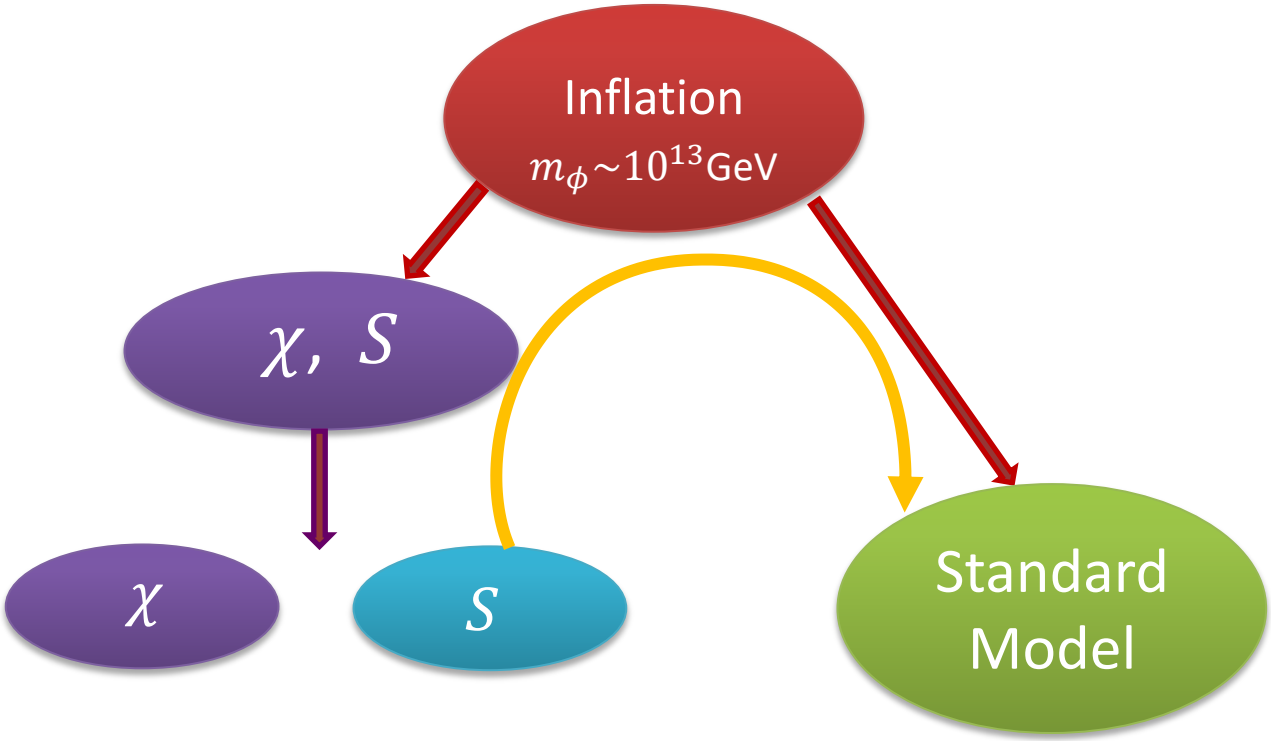
$m_\phi \sim 10^{13}$GeV $\rightarrow$ Annihilation cross section feeble

$\rightarrow$ No possible thermal scenario

[Dev, Mazumdar, Qutub 13'], [Heurtier 17']

The inflaton portal to DM

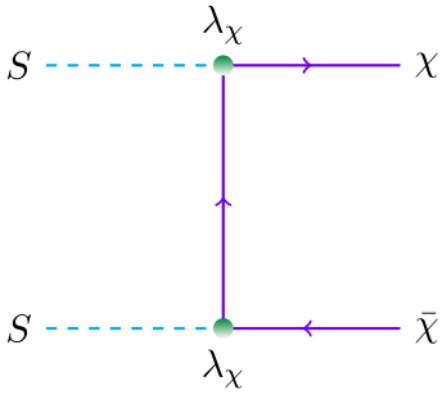
Highly decoupled sectors?

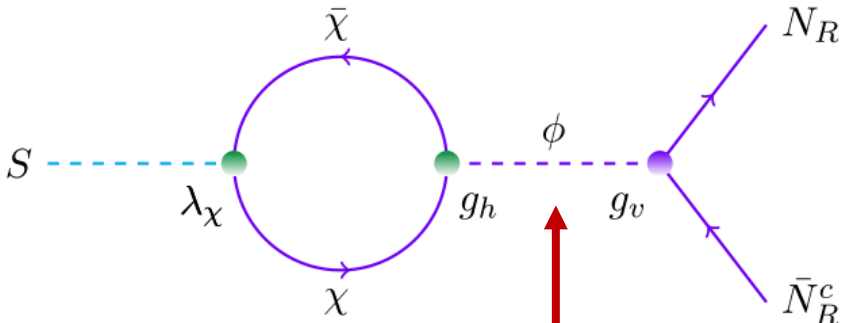


$m_\phi \sim 10^{13}$GeV ⟶ Late decay of the hidden sector

The Model

[F.Huang, L.H., coming soon]





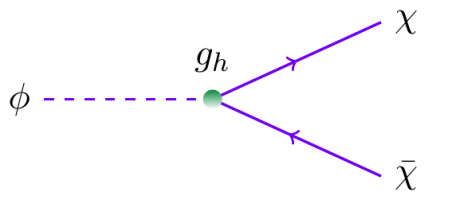
$m_\phi = 10^{13} GeV$

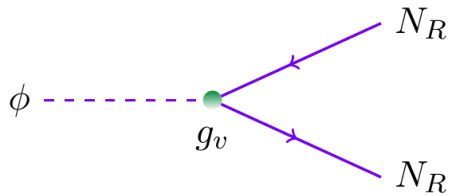
Thermal decoupling of dark matter in the dark sector

Natural suppression of the hidden scalar decay width…

g_h/g_v ⟶ T_h/T_v after inflation

$$\xi_{\rm inf} \equiv \left(\frac{T_h}{T}\right)_{\rm inf} = \left(\frac{g^\star_{\rm inf}}{g^\star_{h,\,\rm inf}}\right)^{1/4} \times \left(\frac{\rho_h}{\rho_v}\right)^{1/4}$$





Relic Density

[F.Huang, L.H., coming soon]

$$\Omega_\chi h^2 \longrightarrow \Omega_\chi h^2 \times \frac{S_i}{S_f}$$

Thermal decoupling in the dark sector

Entropy Suppression

$$\Omega_\chi h^2 \approx 8.5\times10^{-11}\frac{m_\chi\sqrt{g_\star+g_\star^h\xi^4}}{T_f^h g_\star}\left(\frac{a+3\xi b m_\chi/T_f^h}{\mathrm{GeV}^{-2}}\right)^{-1}$$

$$\frac{S_f}{S_i} \approx 1.83\langle g_\star{}^{1/3}\rangle^{3/4}\frac{m_S Y_S \tau_S^{1/2}}{m_p^{1/2}}$$

$$a \sim b \sim \alpha_\chi^2/m_\chi^2$$

Inflaton suppressed decay rate

$$\Gamma_S \sim (g_h g_v)^2 \frac{m_S^5}{m_\phi^4}$$

Relic Density

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Generic range of masses

$$\frac{\Omega_\chi h^2}{S_f/S_i} \approx 0.38 \left(\frac{10^{13}\mathrm{GeV}}{m_\phi}\right)^2 \left(\frac{g_h g_v}{(0.1)^2}\right) \left(\frac{m_\chi}{10\mathrm{PeV}}\right)^{7/2} \left(\frac{m_\chi/m_S}{10}\right)^{-3/2} \left(\frac{0.1}{\alpha_\chi}\right)^2$$

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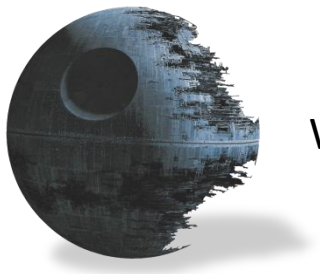

WIMP miracle

The Inflaton miracle !!!

Relic Density

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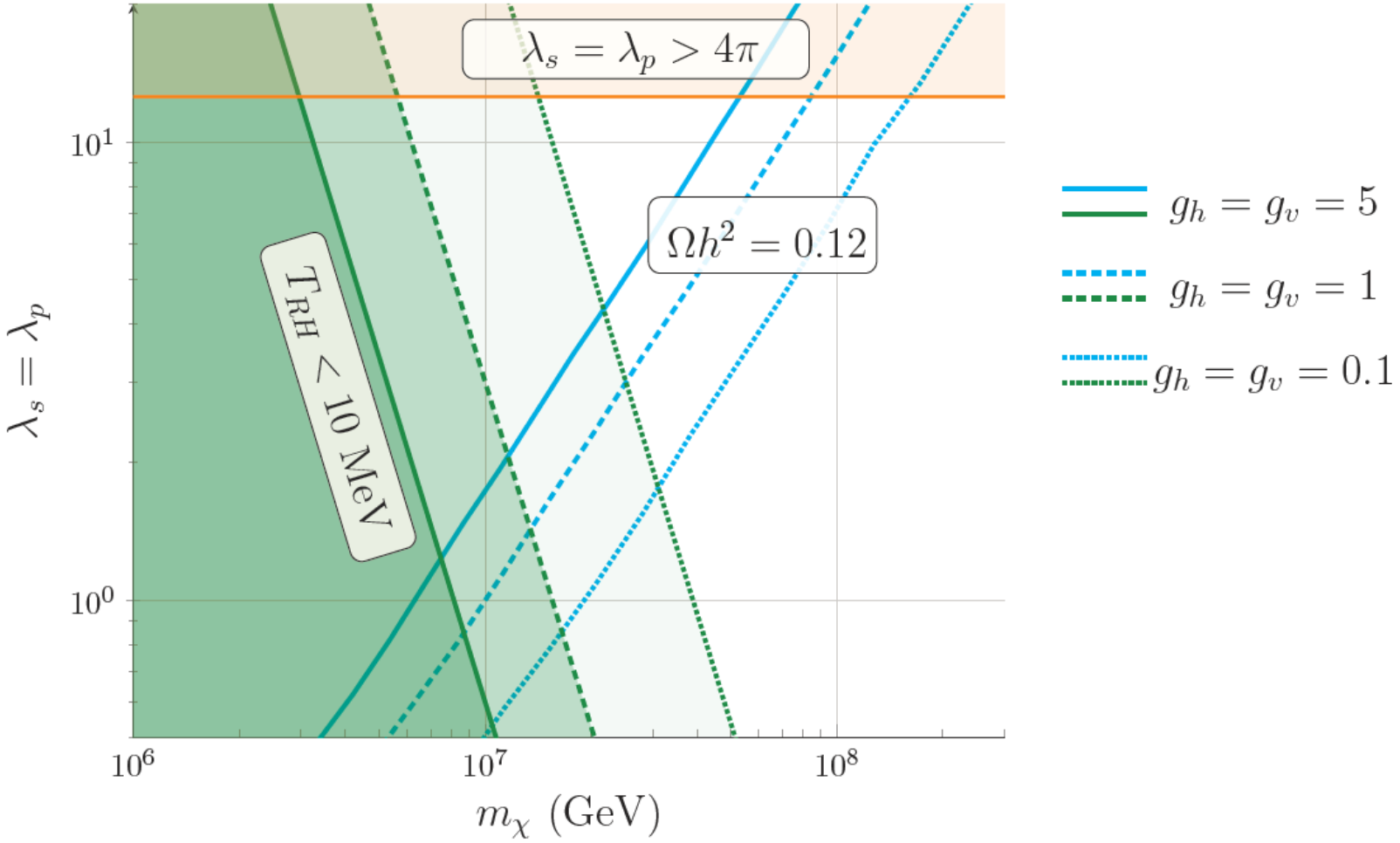


Experimental signatures ?

Dark matter features :

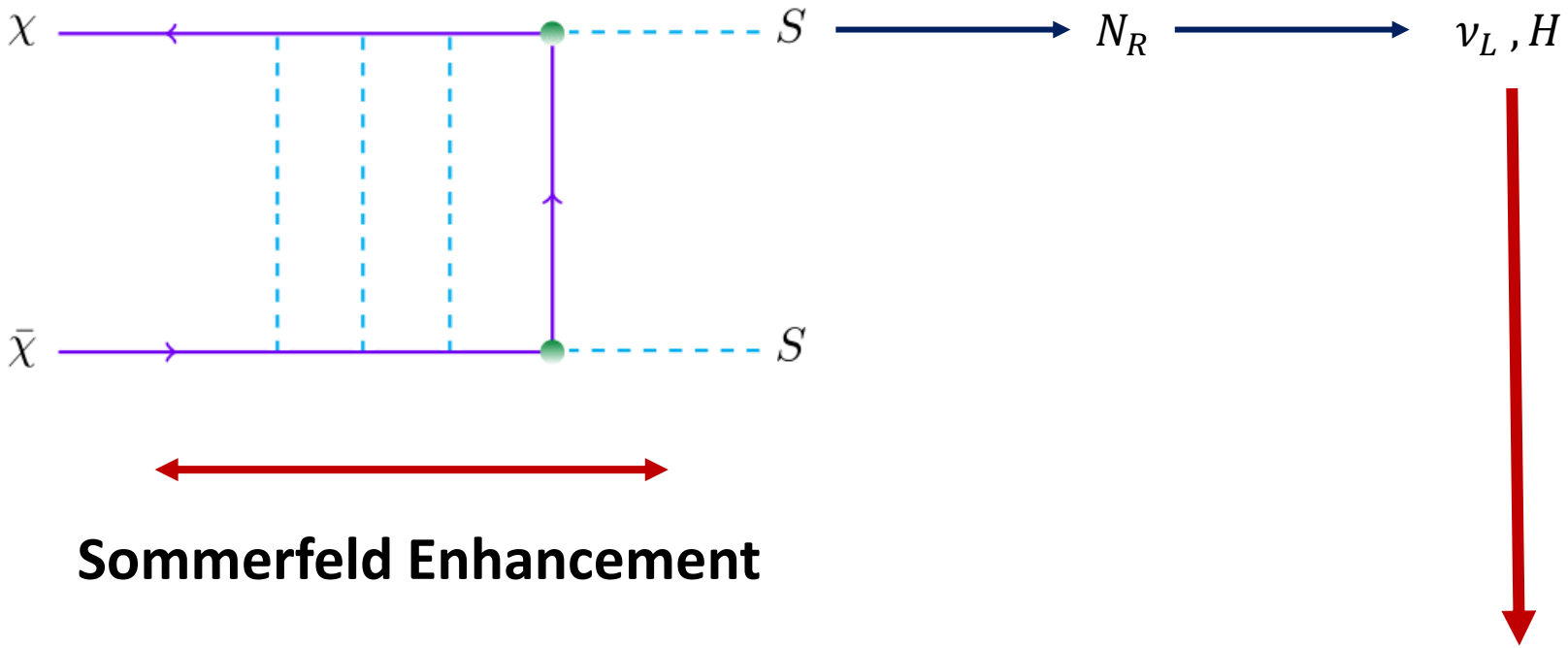
- 10 PeV – EeV dark matter
- Very feeble interaction with the standard model

→ **No Direct Detection constraints**

- Significant annihilation into dark scalars
- Dark scalar lifetime < 0.01s

→ **Indirect Detection ?**

Experimental signatures ?



Sommerfeld Enhancement

At the 10 PeV – EeV scale !

High Energetic Cosmic Rays

Experimental signatures ?

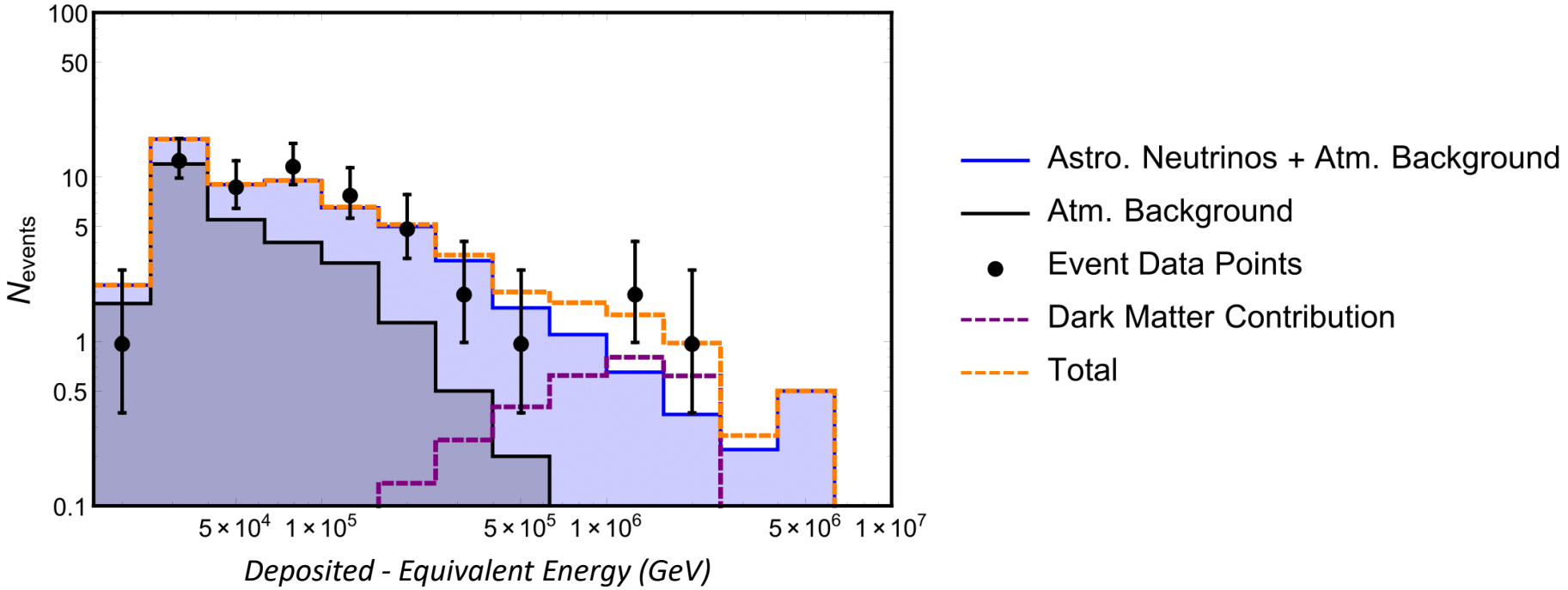


Illustration for $m_{DM} = 3\ PeV$, $v_{rel} = 10^{-3}$, $\lambda = 2.8$

Unfortunately $m_{DM} > 10\ PeV$ …

To be continued…

Conclusion

- Dark matter production usually requires fine tuning or the introduction of arbitrary mass scales

- We propose an ***inflaton portal*** to a highly decoupled dark sector

→ **Reheating process explicitely present in the scenario**

→ **Natural choices of couplings lead to the correct relic abundance**

- The model escapes direct detection

- Indirect detection may be relevant in the neutrino sector (IceCube? ANITA?...)