Minimal Sterile Neutrino Dark Matter

based on

[2103.16572], [2206.10630]

by

Torsten Bringmann, Paul Frederik Depta, Marco Hufnagel,
Joshua Ruderman, Kai Schmidt-Hoberg, Jörn Kersten

Thursday, December 1, 2022

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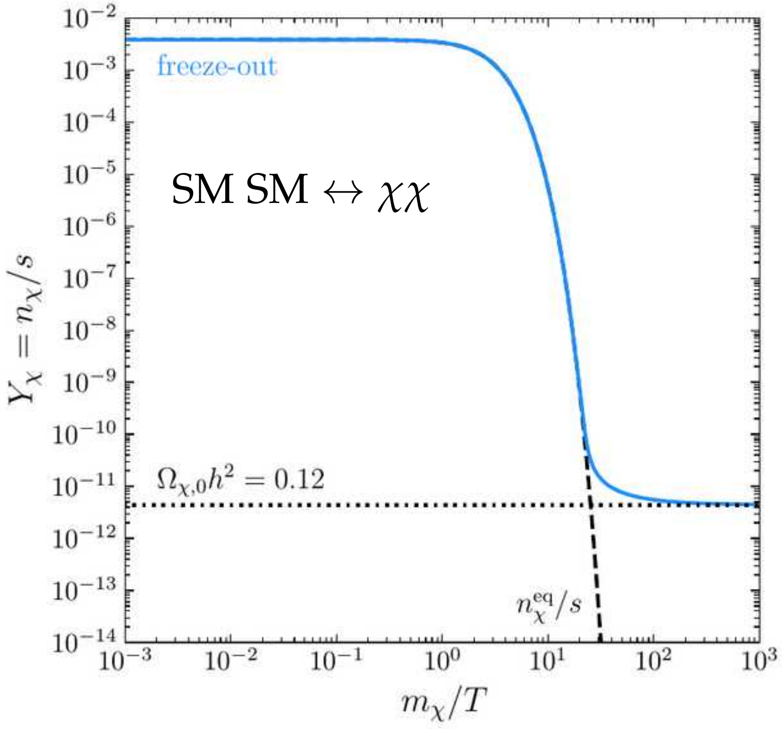
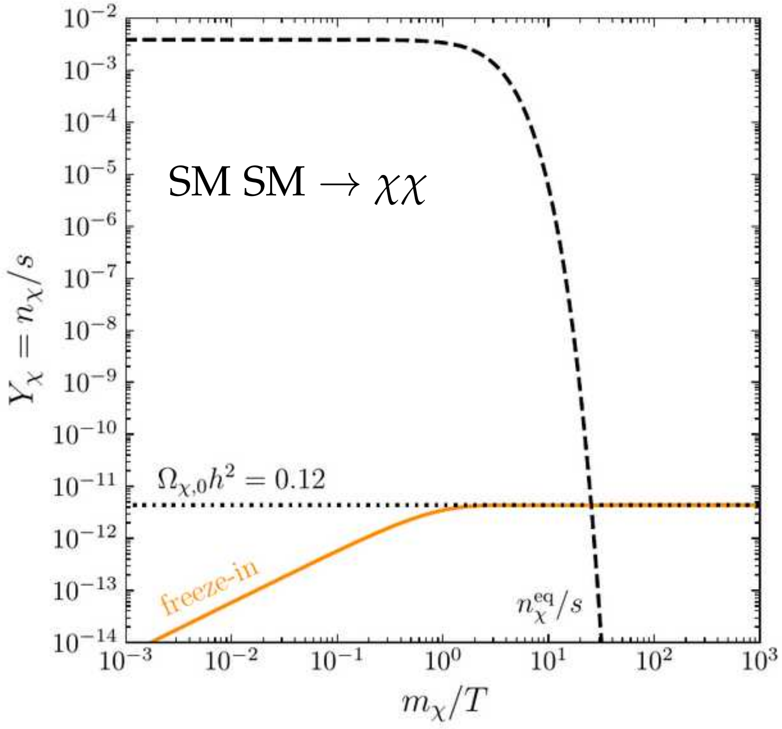
Dark Matter production

Thermal | Non-thermal





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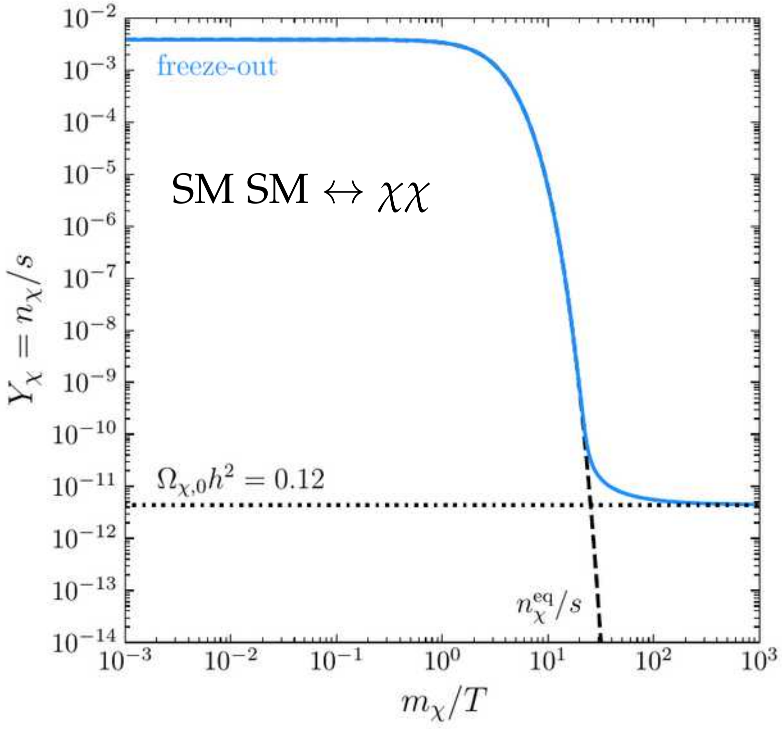
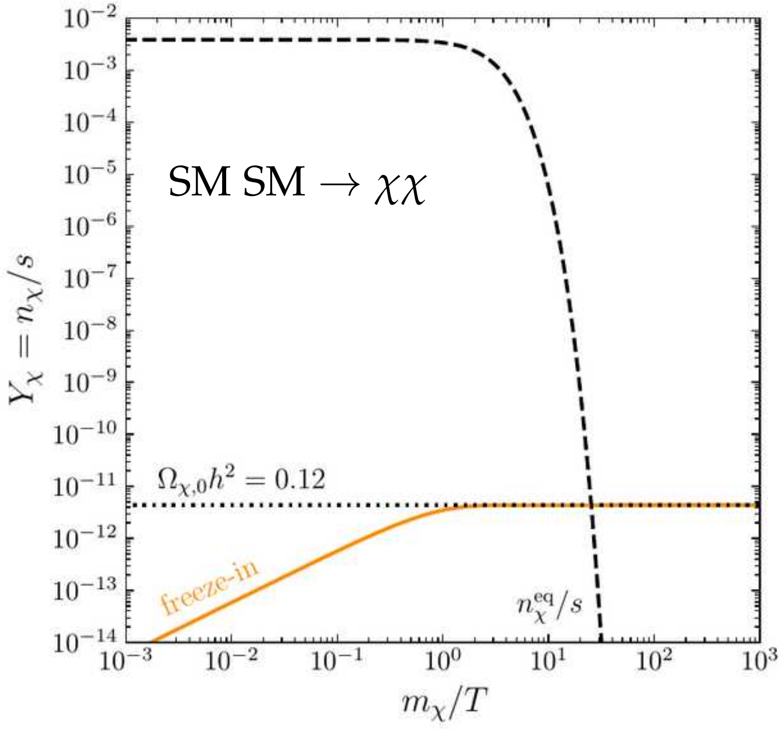


Many freeze-out variants:

- Hidden Sectors
- Cannibal DM [1607.03108]
- Zombie DM [2003.04900]

Non-thermal



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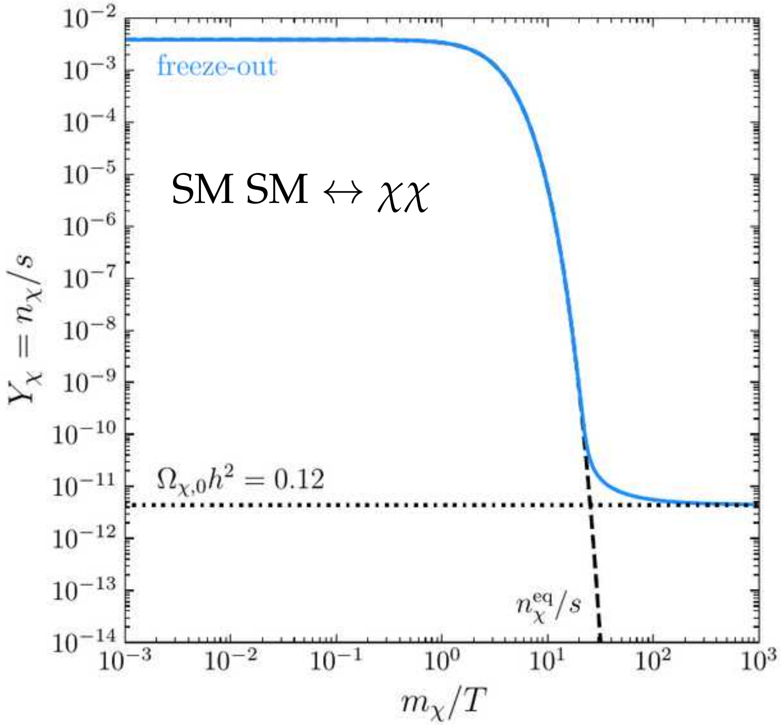
Thermal



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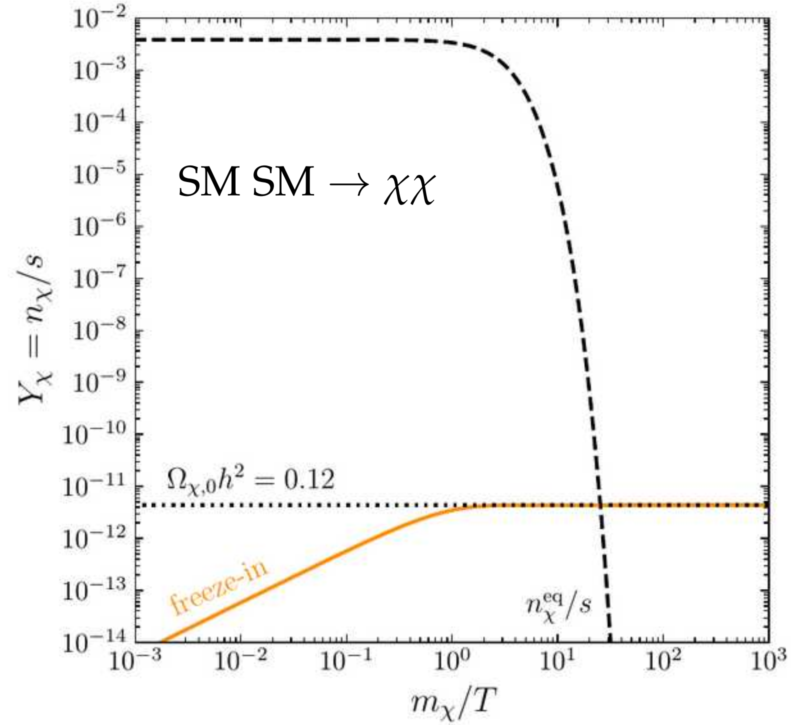
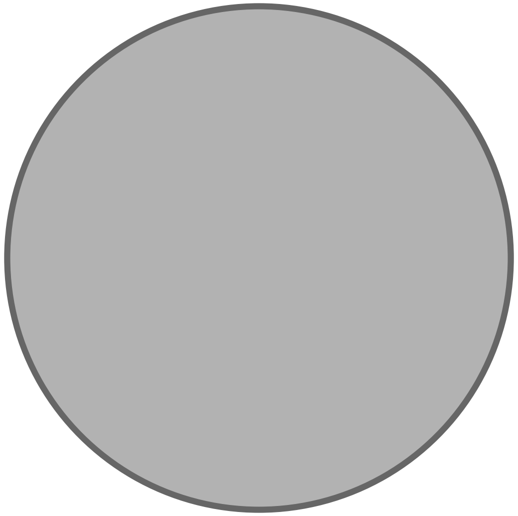


Less freeze-in variants:

Here: freeze-in with exponential instead of linear growth!

[2103.16572], [2104.05684]
Hryczuk, Laletin

Infection of the thermal bath



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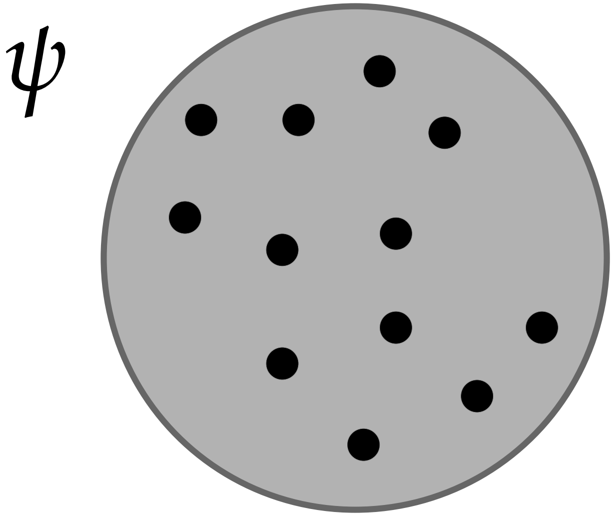

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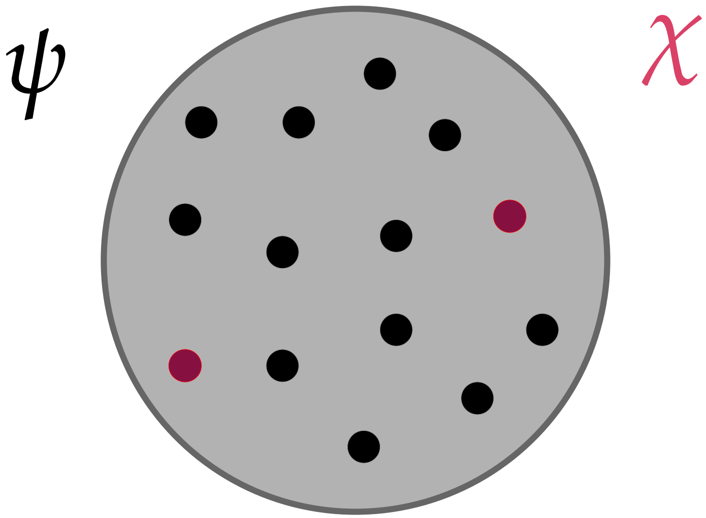

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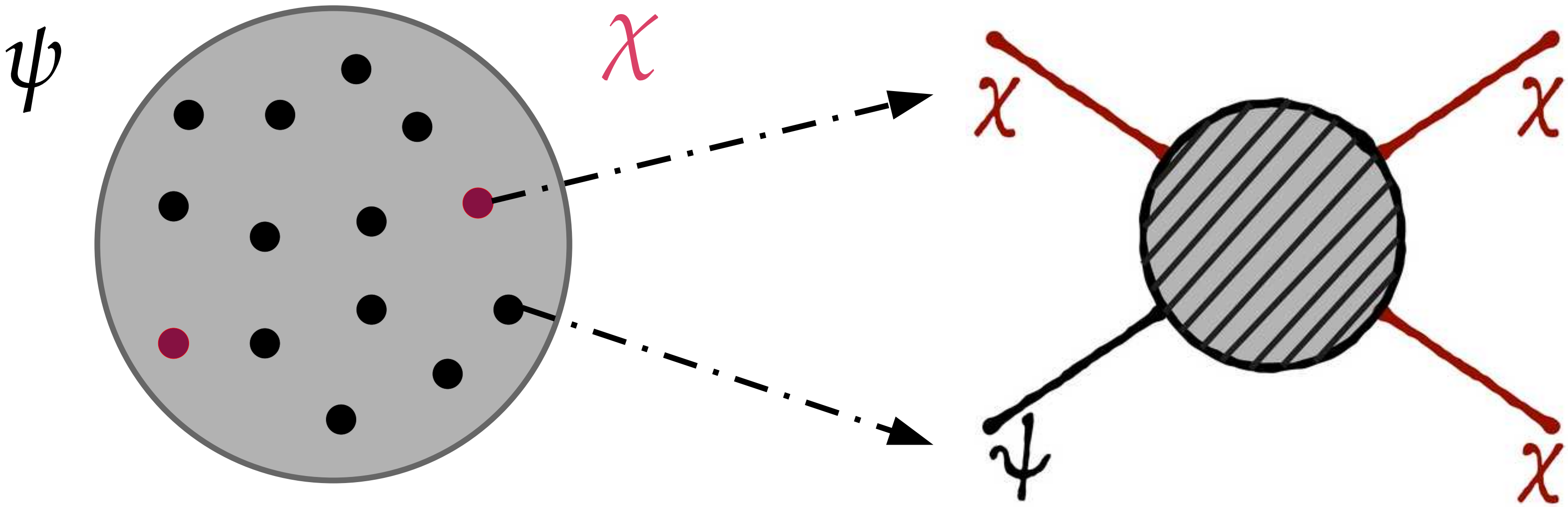

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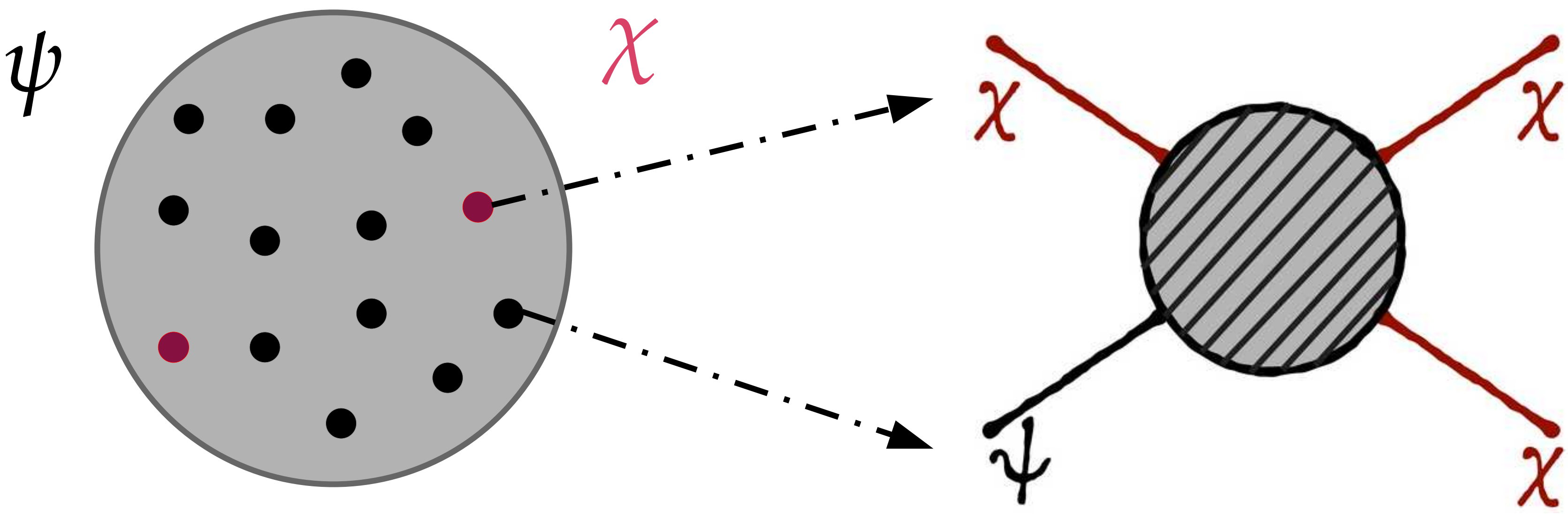
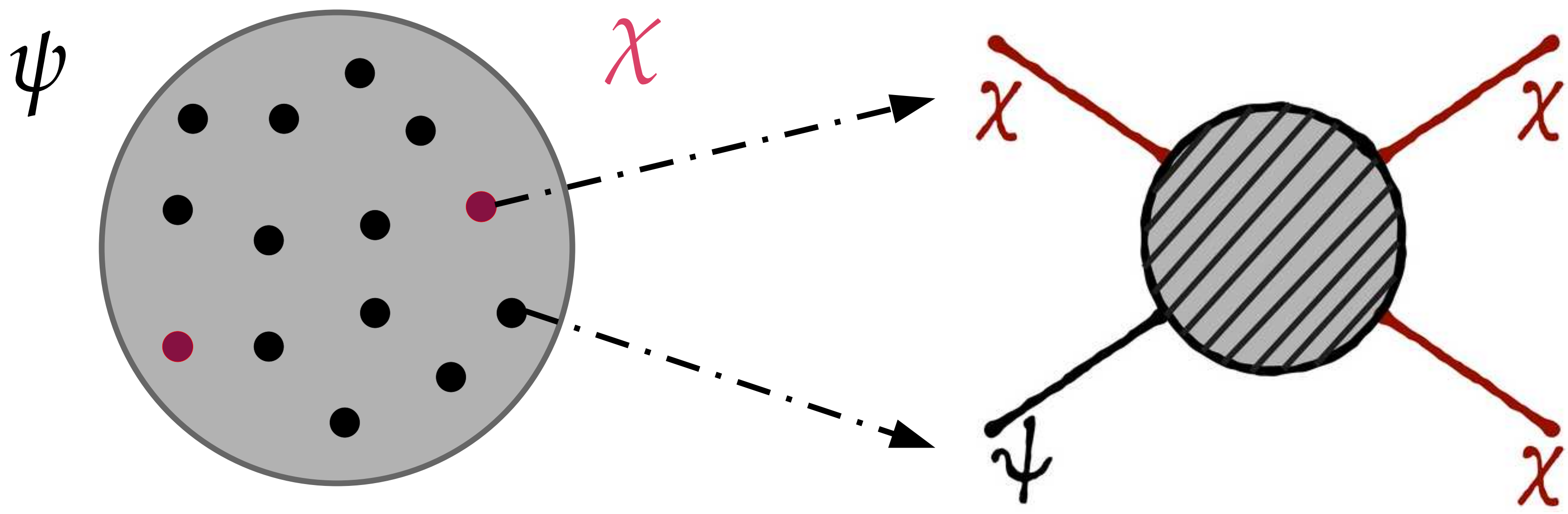


Boltzmann equation:

Infection of the thermal bath



Assumptions:

- $f_\psi = \bar{f}_\psi = \exp(-E/T)$
- $f_\chi = \lambda(T)\exp(-E/T)$

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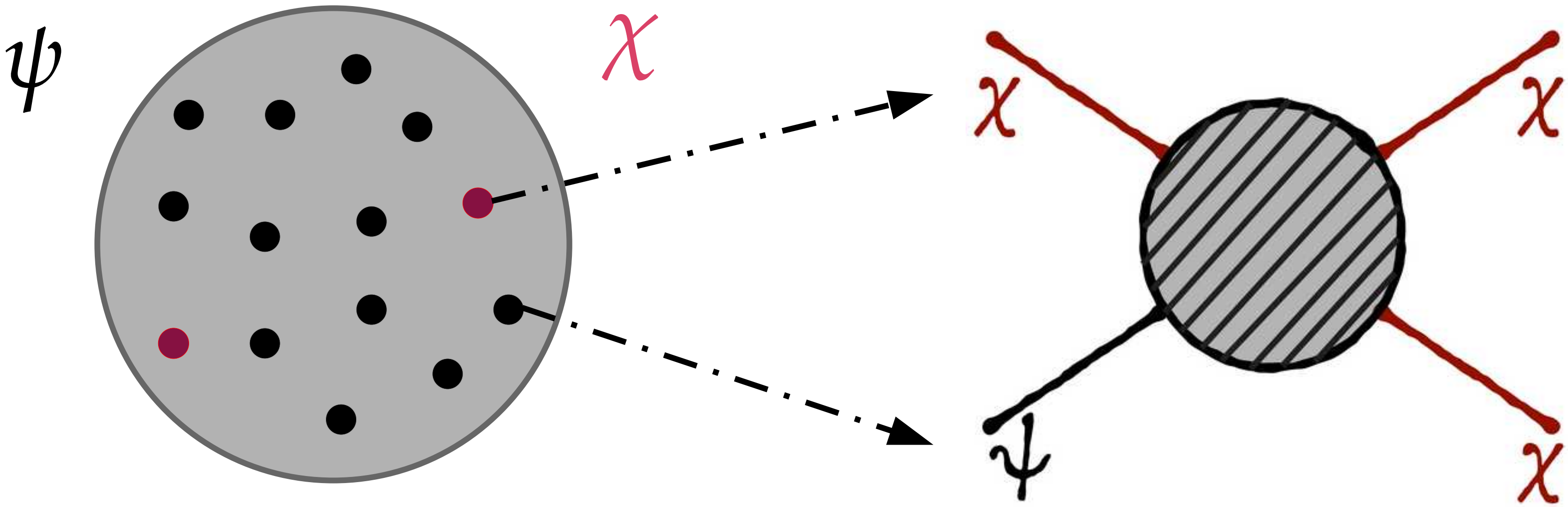

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$$\dot{n}_\chi + 3Hn_\chi = \langle \sigma_{\chi\psi\to\chi\chi} v \rangle \bar{n}_\psi n_\chi$$

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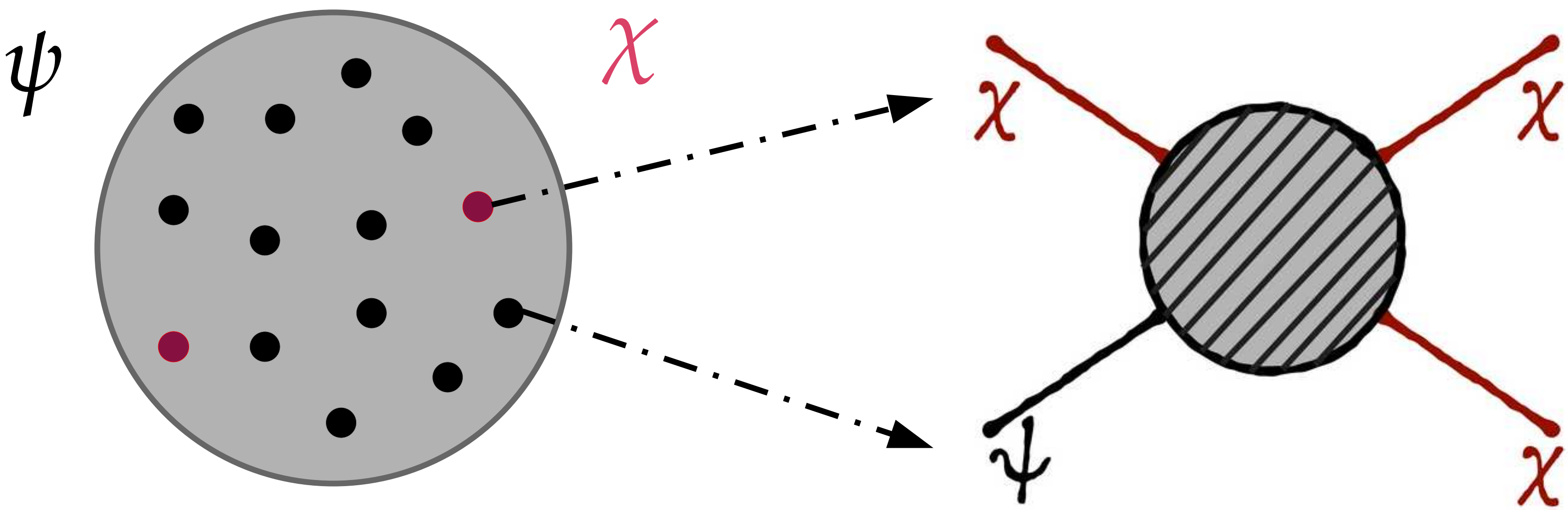

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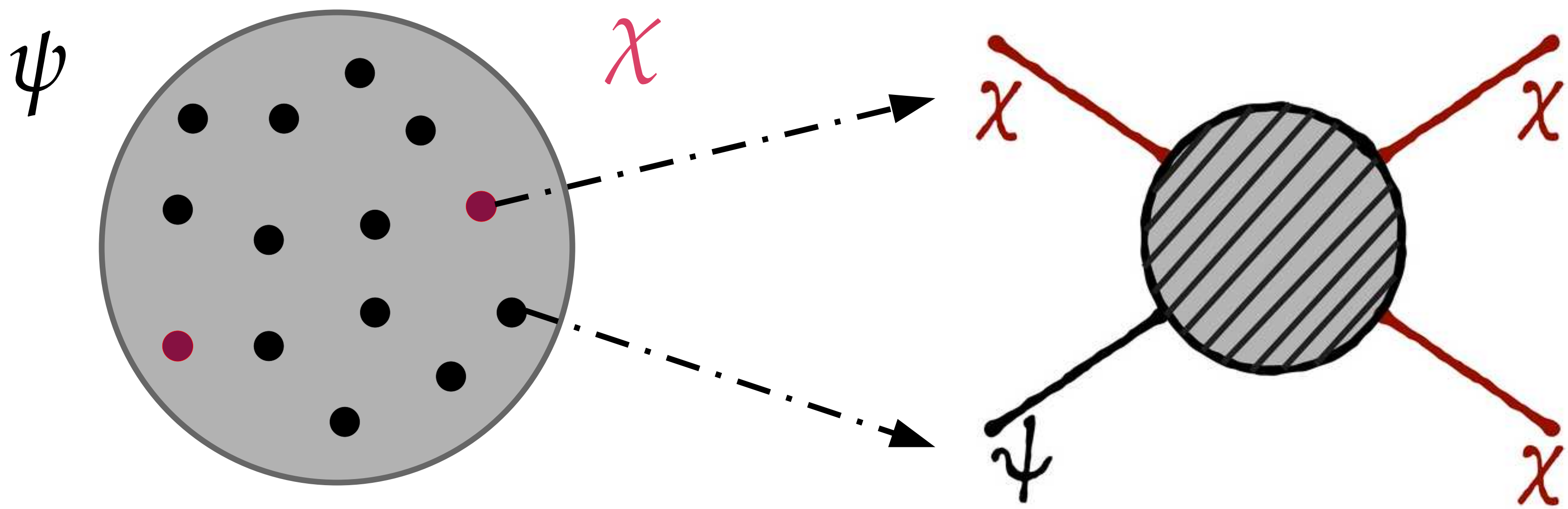

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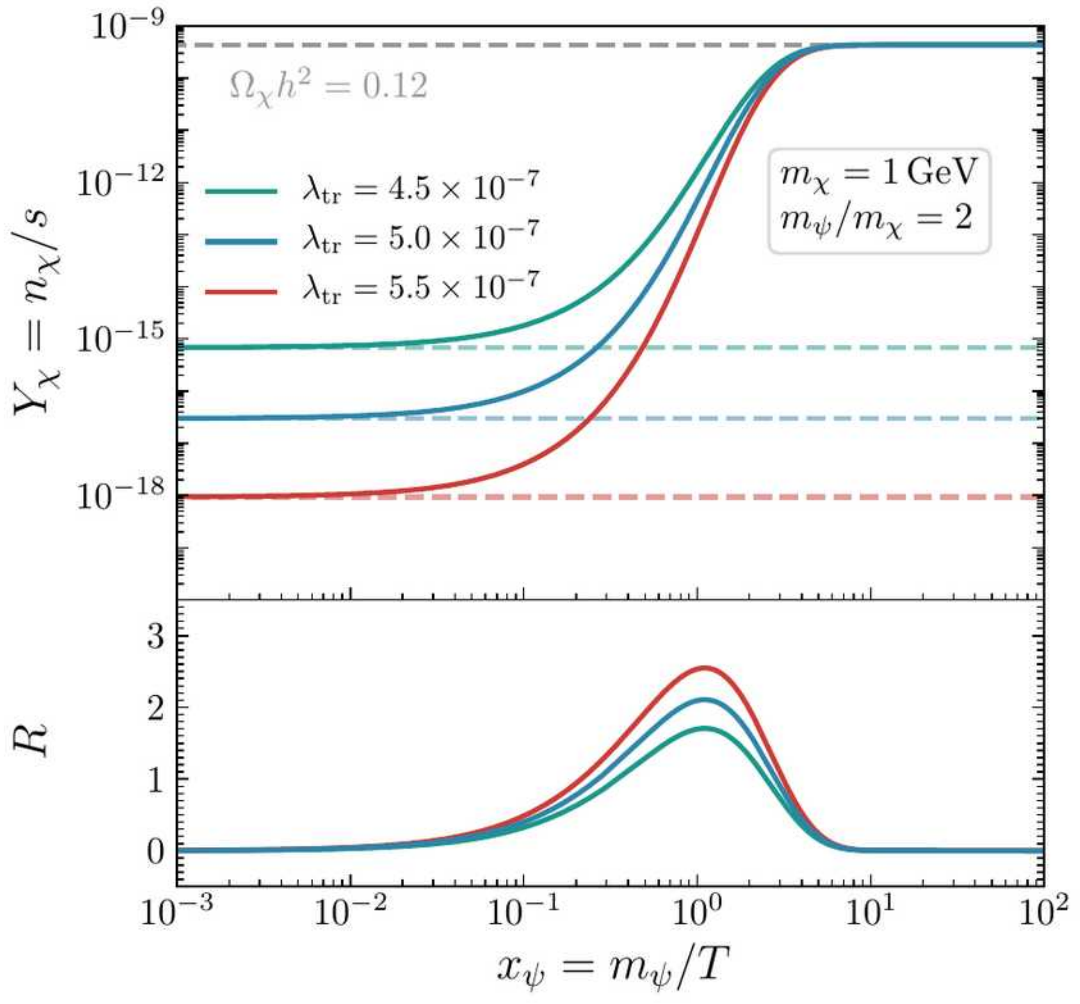
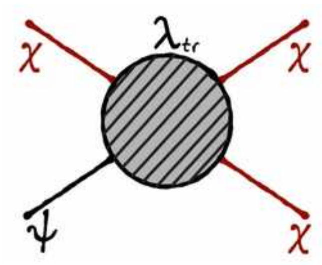
Evolution of the Dark Matter abundance

Exponential growth from an initial seed:

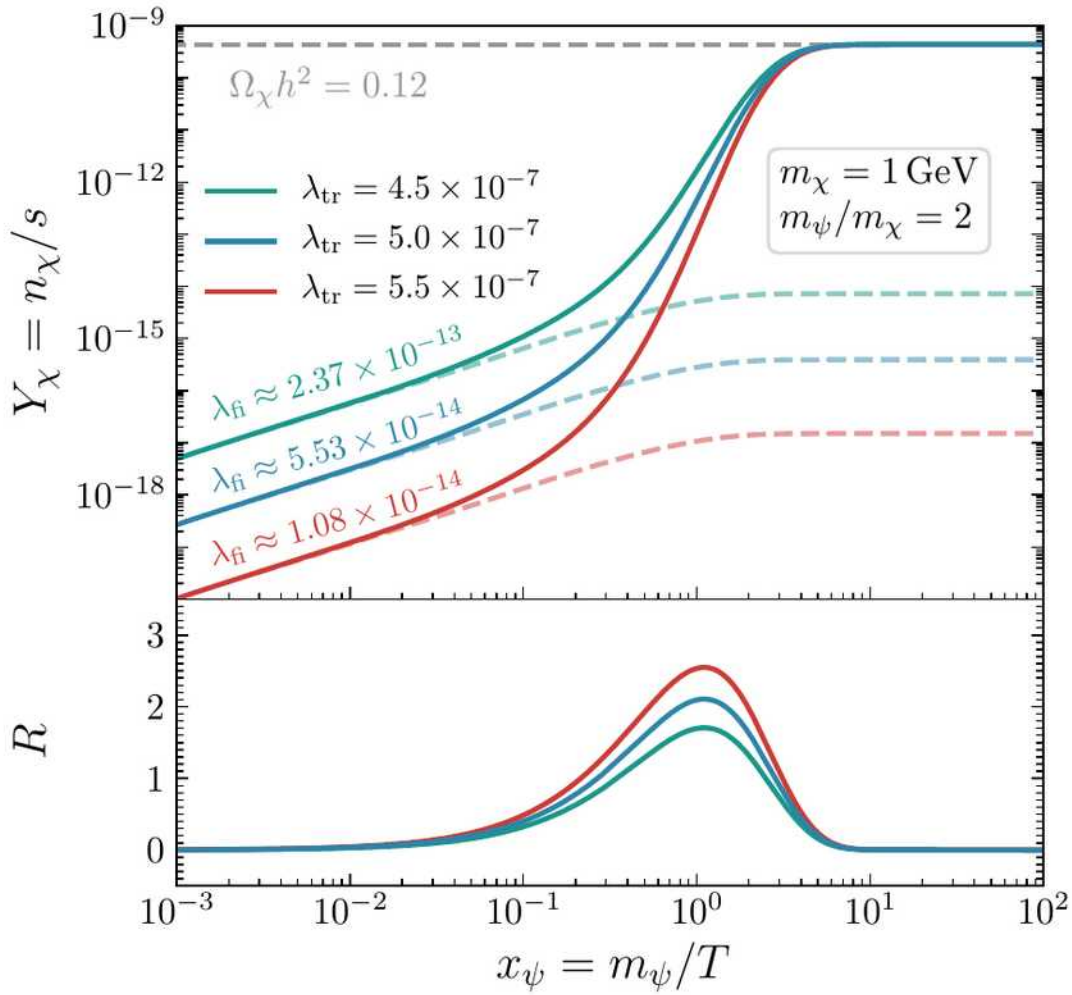


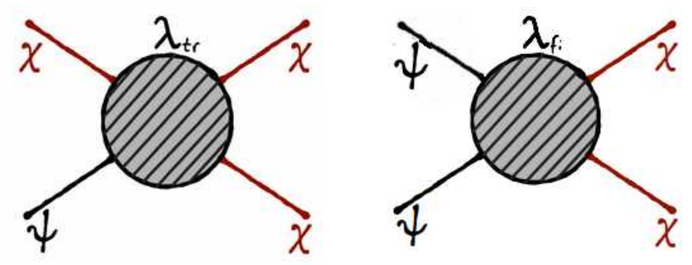


$$Y_\chi(x_\psi \ll 1) = \underbrace{Y_\chi^0}_{\text{Initial condition}} = \text{const.}$$

Evolution of the Dark Matter abundance

Exponential growth after freeze-in phase:





Transmission

$$\dot{n}_\chi + 3Hn_\chi = \langle \sigma_{\chi\psi\to\chi\chi} v \rangle \bar{n}_\psi n_\chi + \langle \sigma_{\psi\psi\to\chi\chi} v \rangle \bar{n}_\psi^2$$

Freeze-in

Evolution of the Dark Matter abundance

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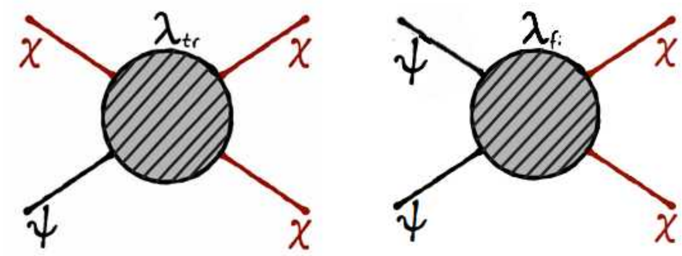

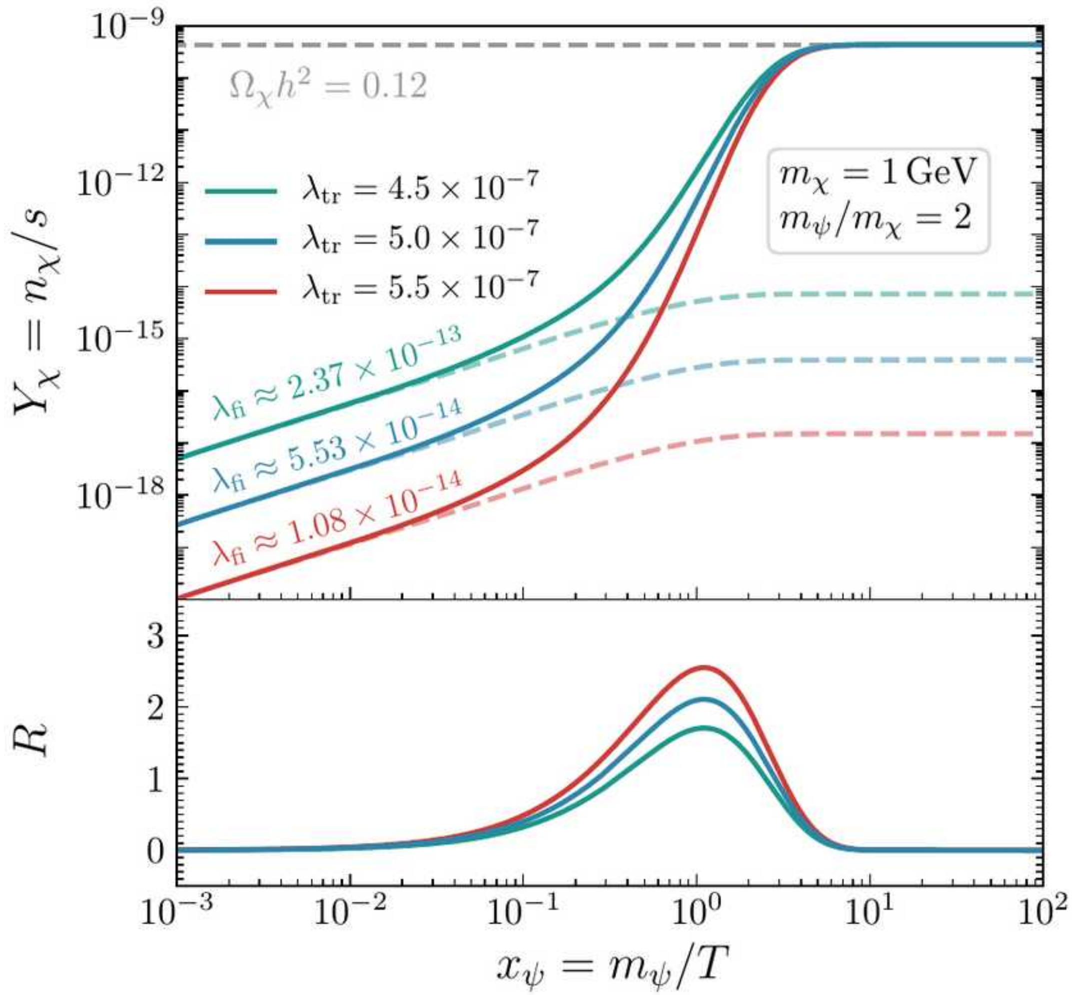

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Freeze-in

Prerequisite:

$$\langle \sigma_{\psi\psi\to\chi\chi} v \rangle \ll \langle \sigma_{\psi\chi\to\chi\chi} v \rangle$$

Model building?

- Natural way to realize $\langle \sigma v \rangle_{\text{fi}} \ll \langle \sigma v \rangle_{\text{tr}}$?

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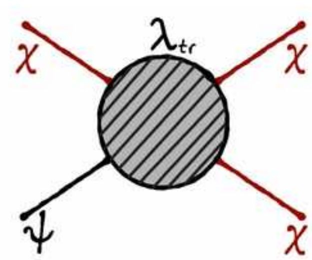
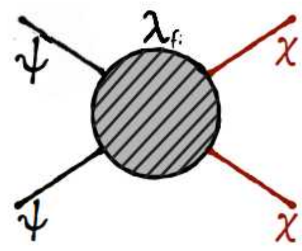


$\propto \theta$



$\propto \theta^2 \ll \theta$

Application to sterile neutrinos

- Sterile neutrinos have been a compelling DM candidate
  $\rightarrow$ Production via Dodelson-Widrow machanism
- But...

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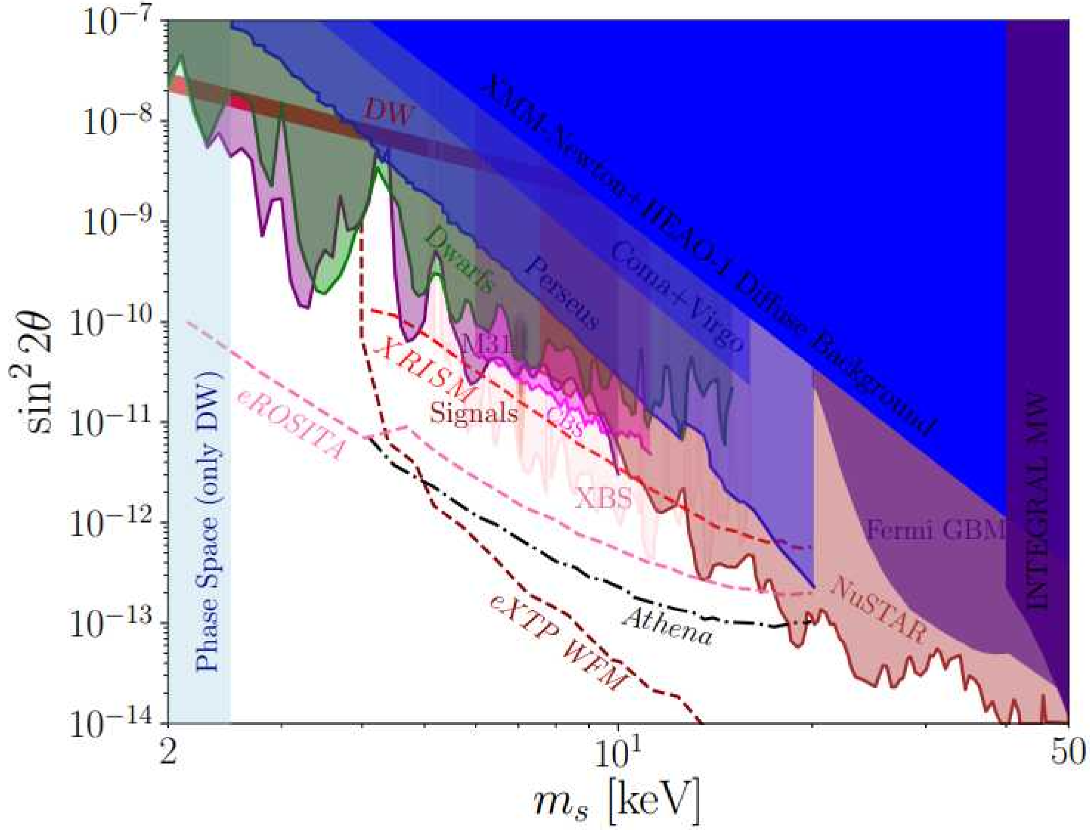

Abazajian al. 2203.07377

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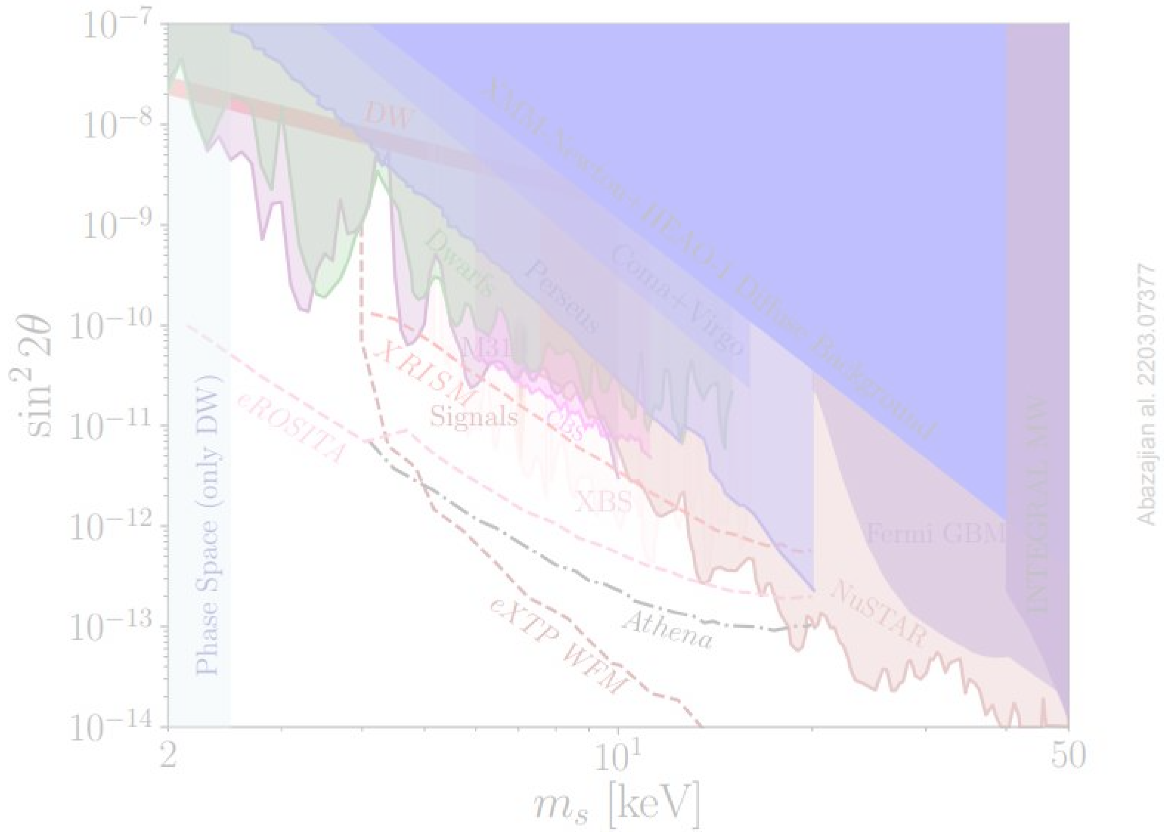

$$\mathcal{L} \supset \frac{y}{2}\phi\bar{\nu}_s\nu_s \longrightarrow \mathcal{L} \supset \frac{y}{2}\phi\left[\theta^2\bar{\nu}_\alpha\nu_\alpha - \theta(\bar{\nu}_\alpha\nu_s + \bar{\nu}_s\nu_\alpha) + \bar{\nu}_s\nu_s\right]$$

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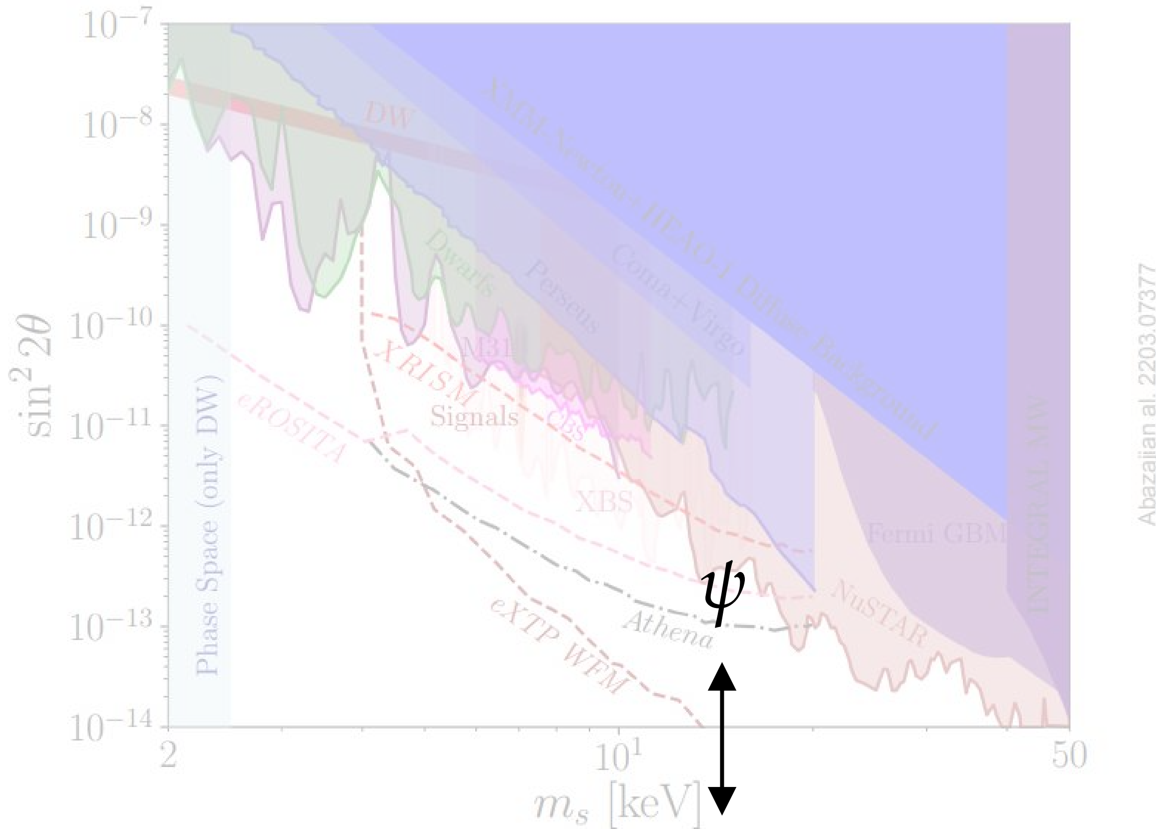

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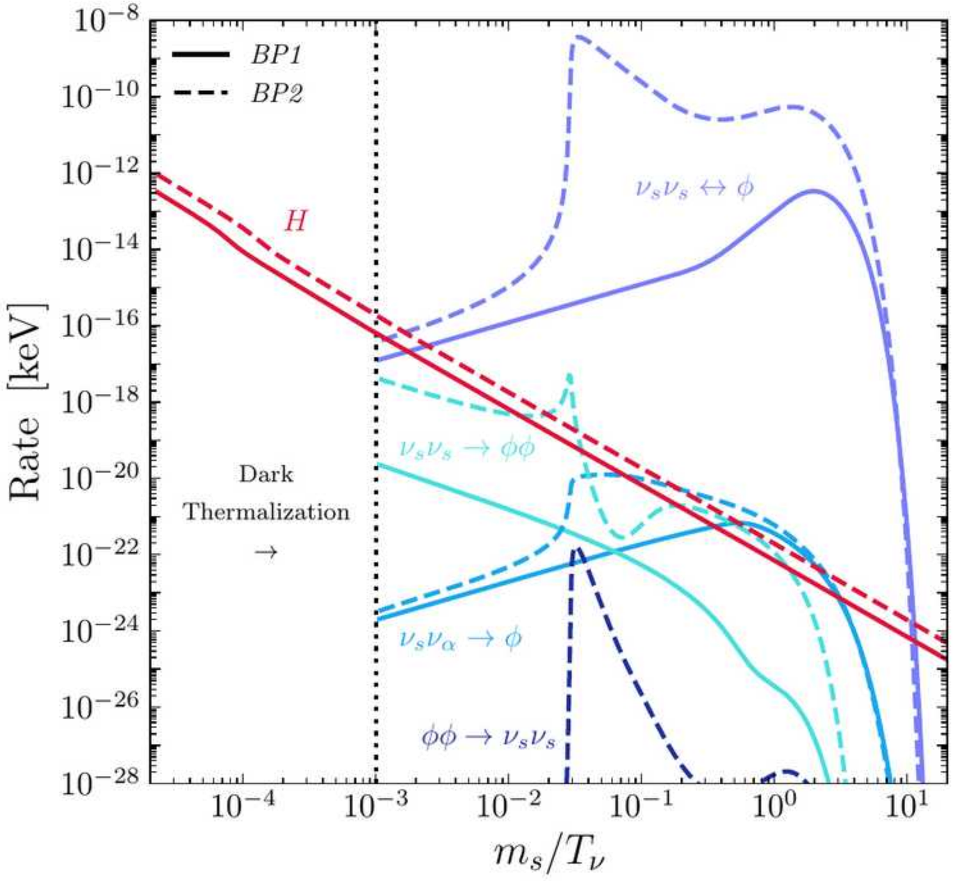
Cosmological evolution

Rapid DS thermalisation via
$\nu_s \nu_s \to \phi, \phi \to \nu_s \nu_s$



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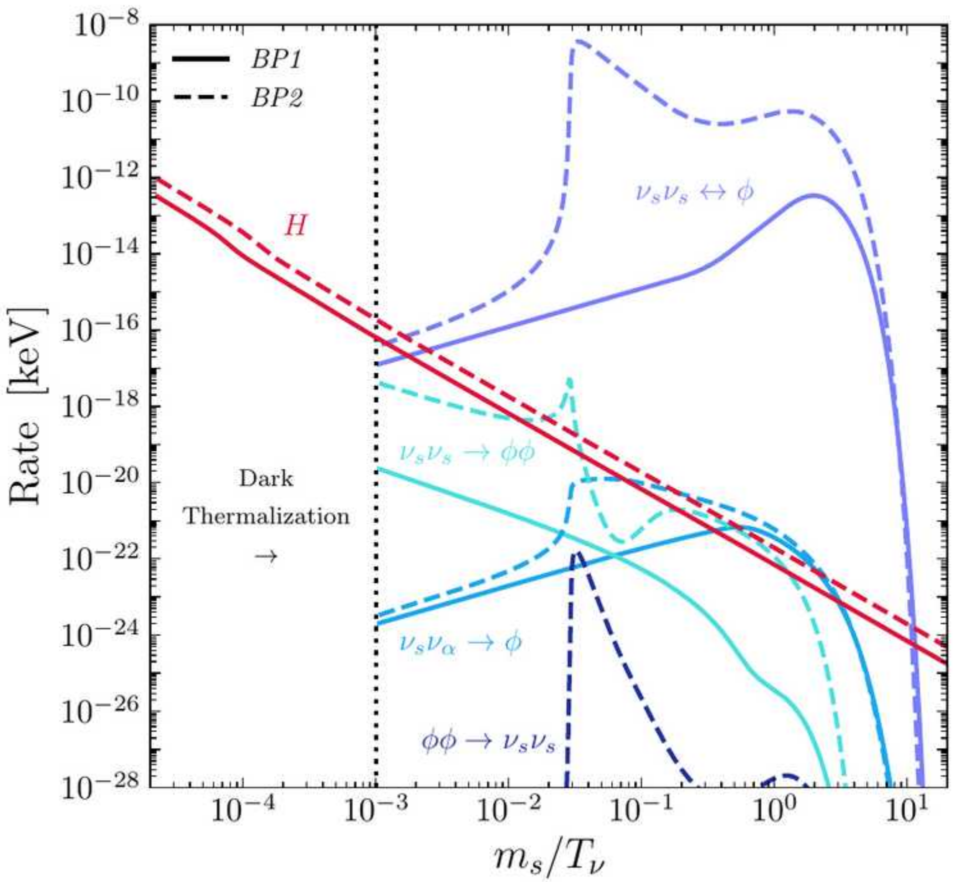
$$f_s = \frac{1}{e^{(E-\mu_s)/T_d} + 1} \quad f_\phi = \frac{1}{e^{(E-\mu_\phi)/T_d} - 1}$$



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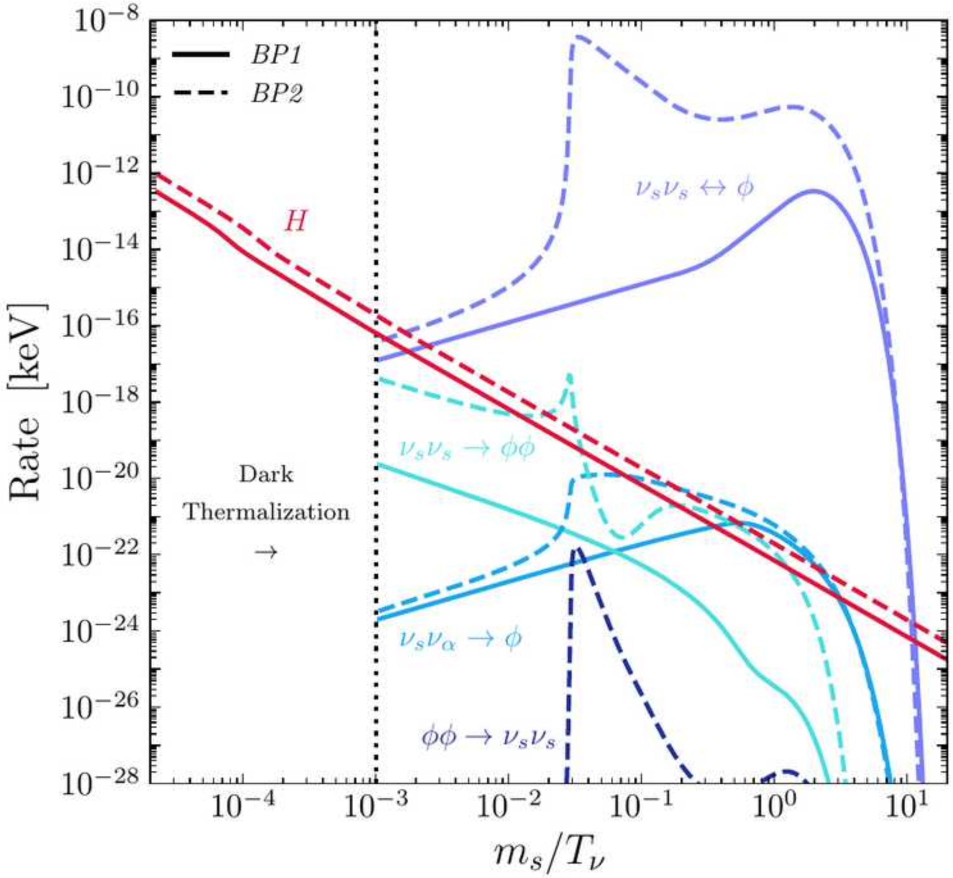

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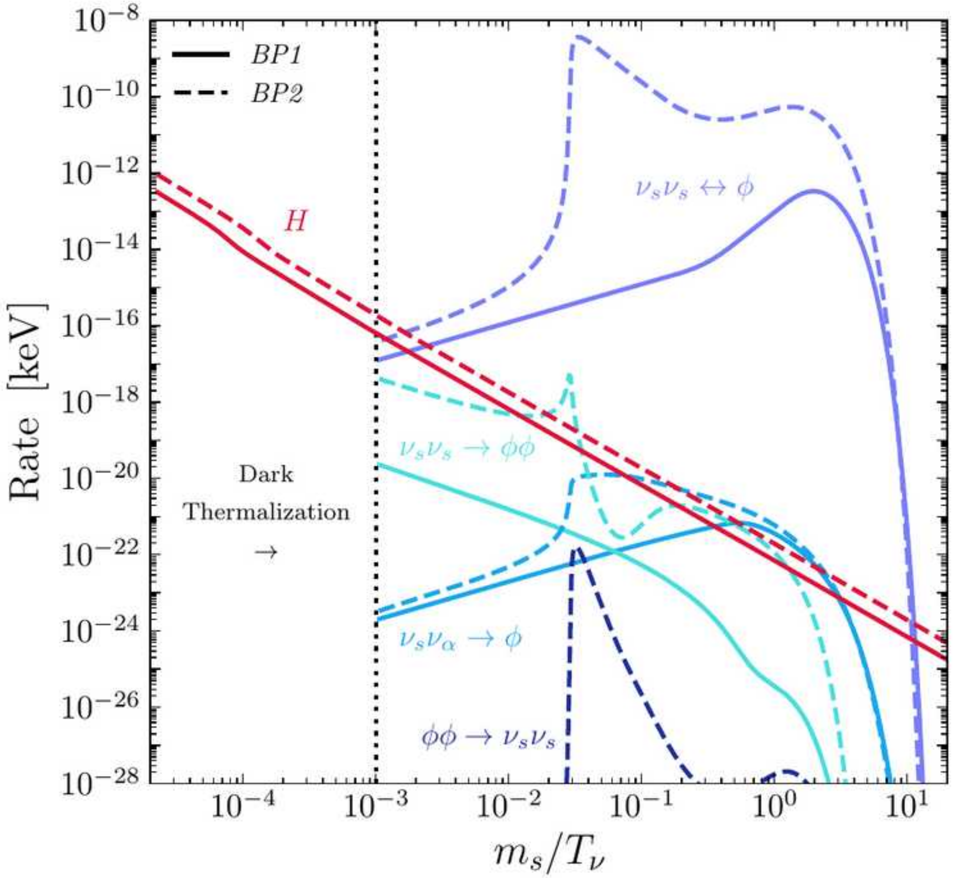
Boltzmann equations:

$$\dot{n}_s + 3Hn_s = C_s$$
$$\dot{n}_\phi + 3Hn_\phi = C_\phi$$
$$\dot{\rho} + 3H(\rho + P) = 0$$



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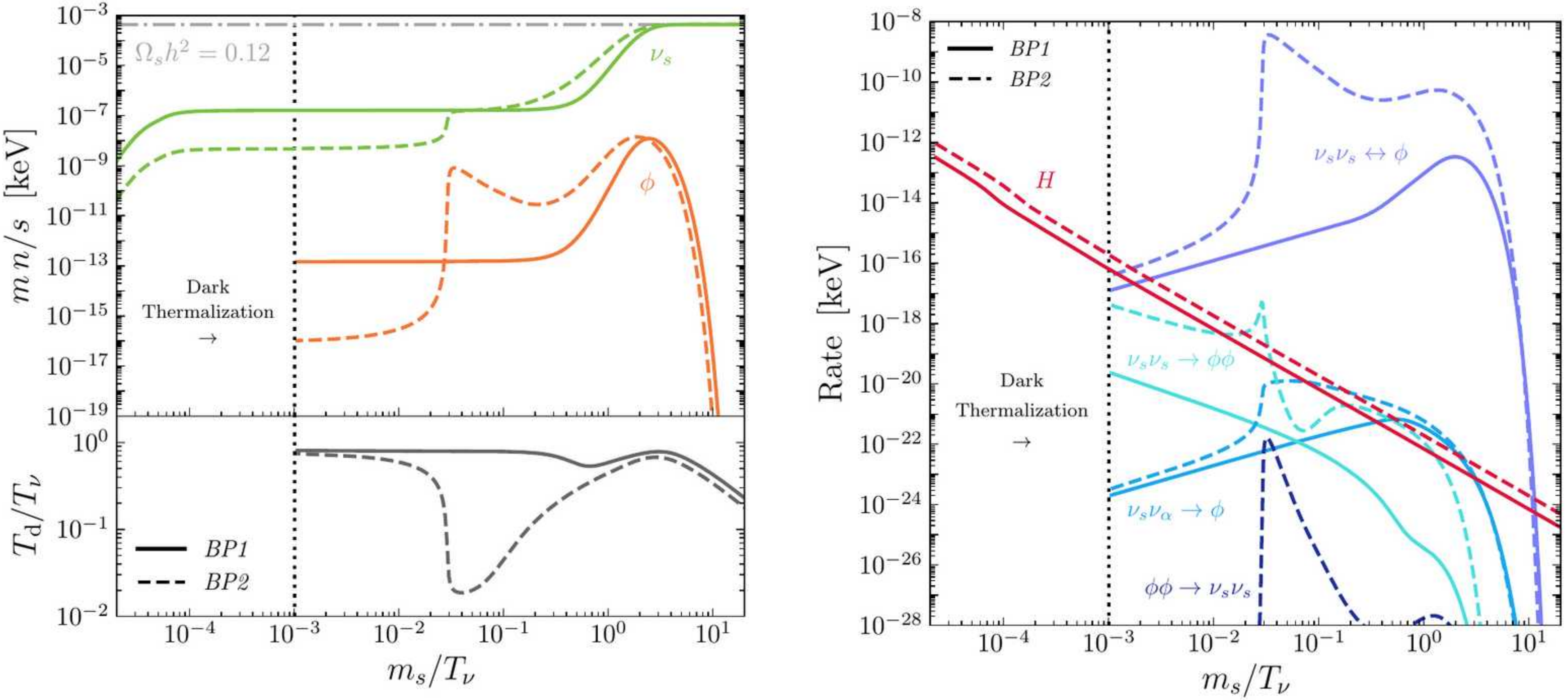

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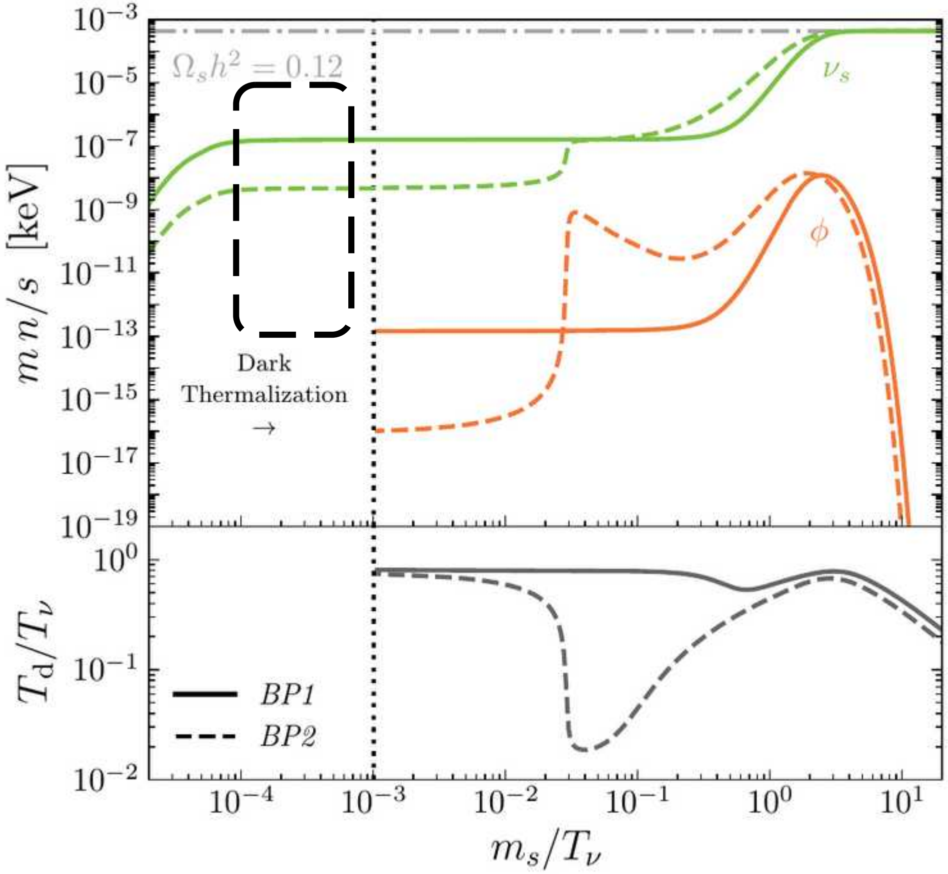
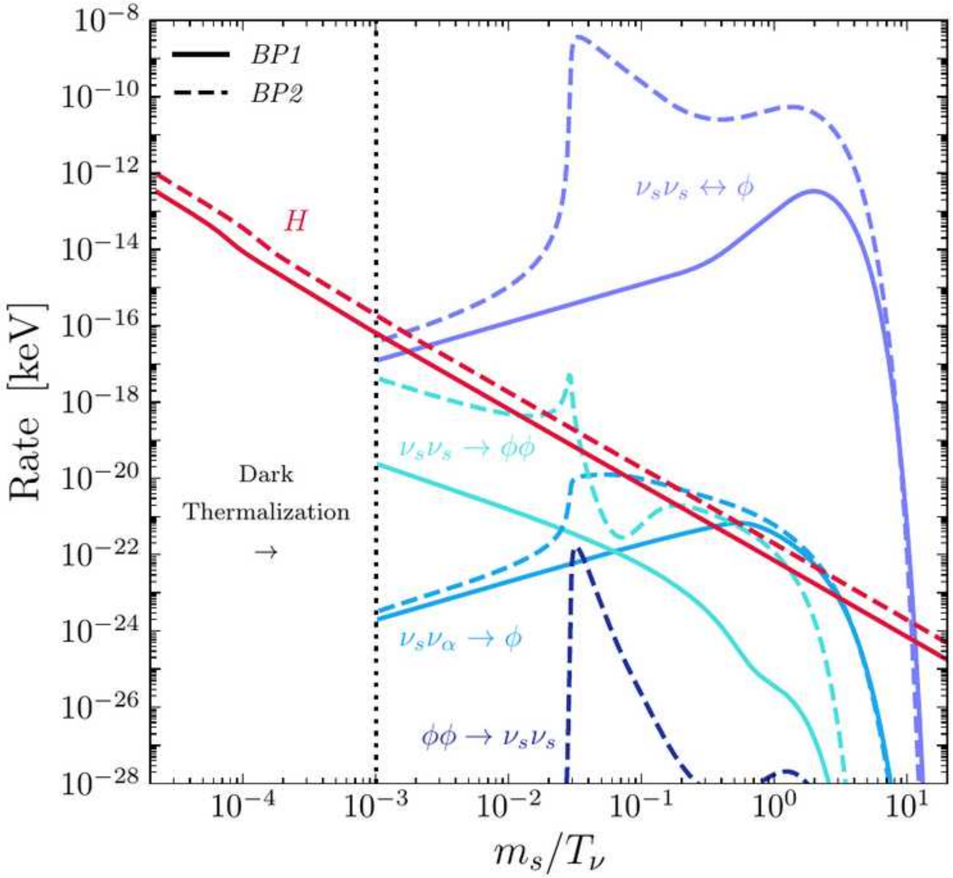
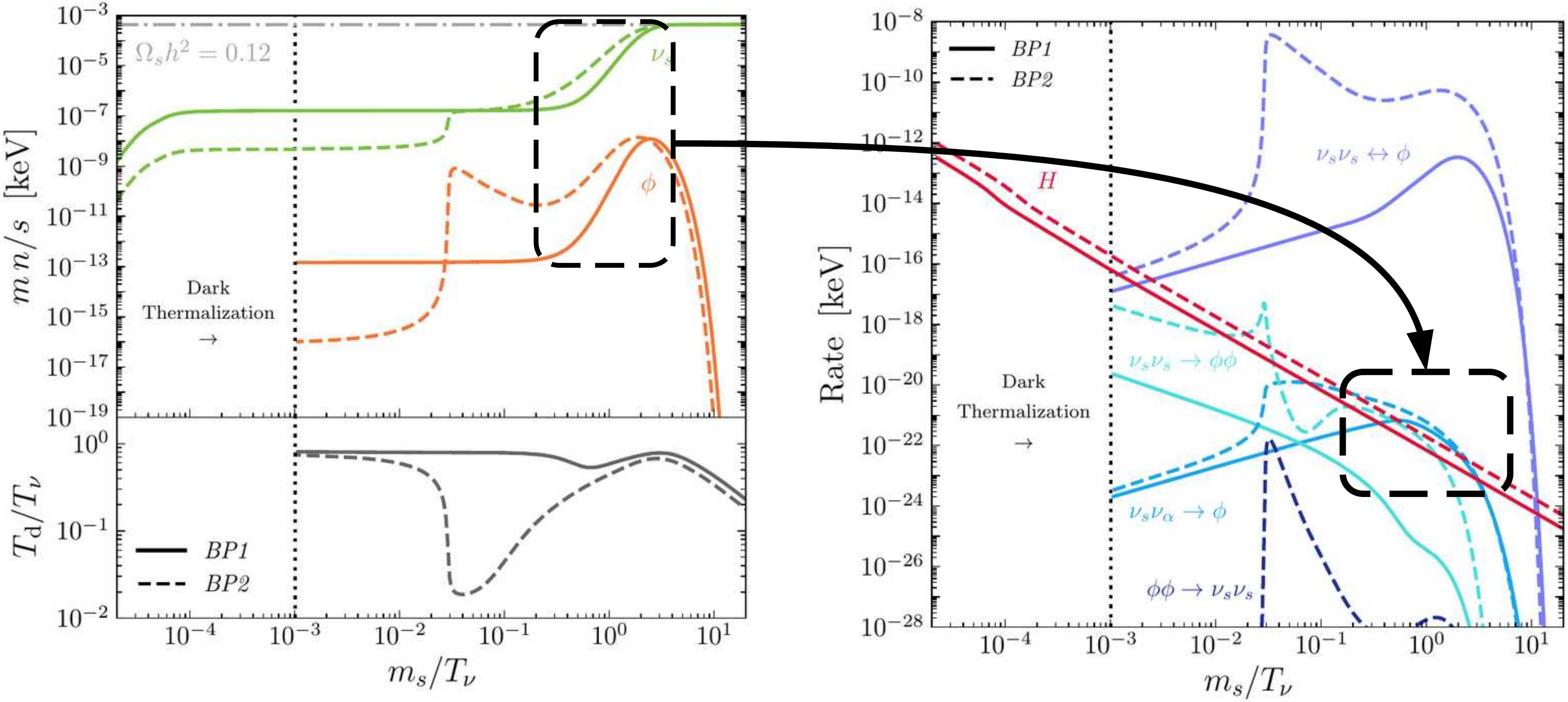




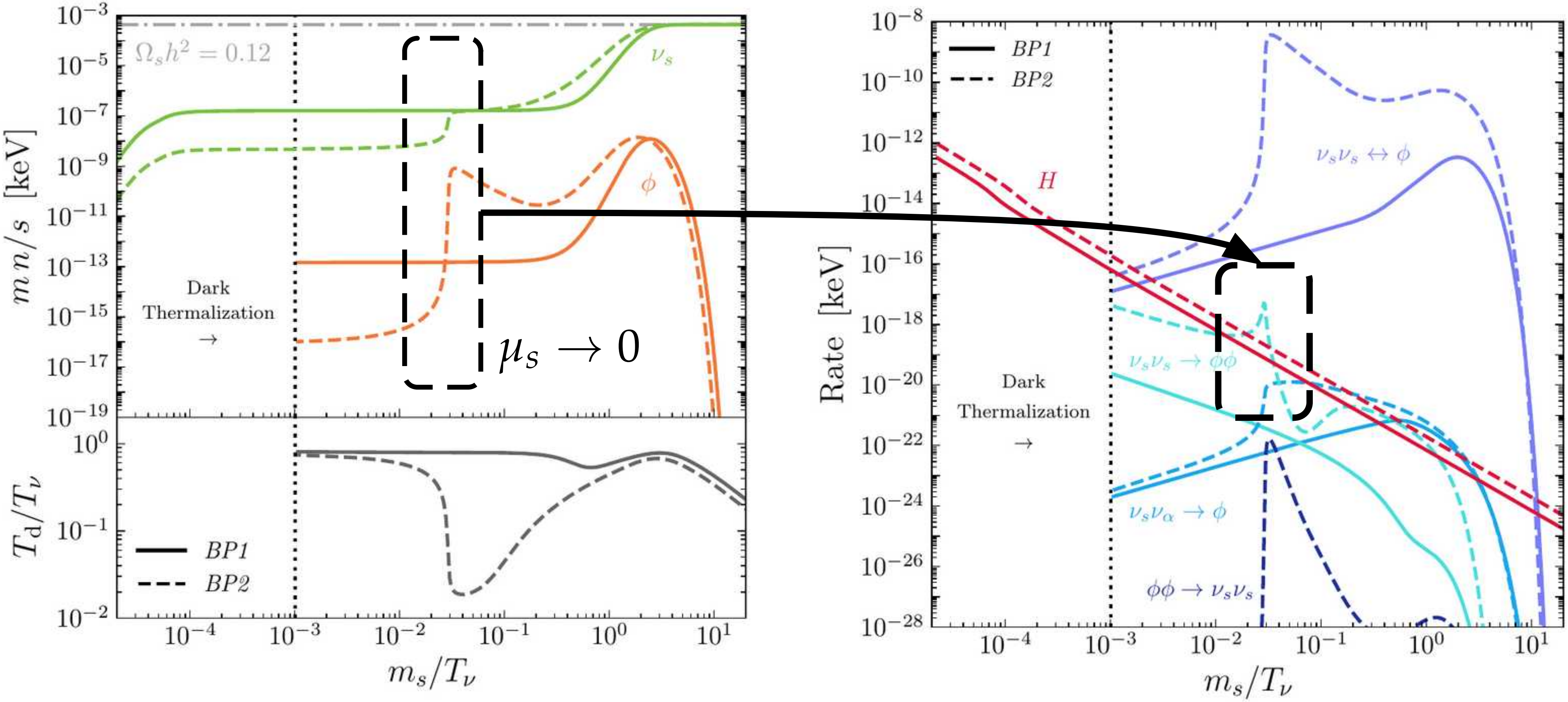
Cosmological evolution

$$\nu_s \nu_\alpha \to \phi, \phi \to \nu_s \nu_s$$



Cosmological evolution

$$\nu_s\nu_s \to \phi\phi, \phi\phi \to 4\nu_s$$



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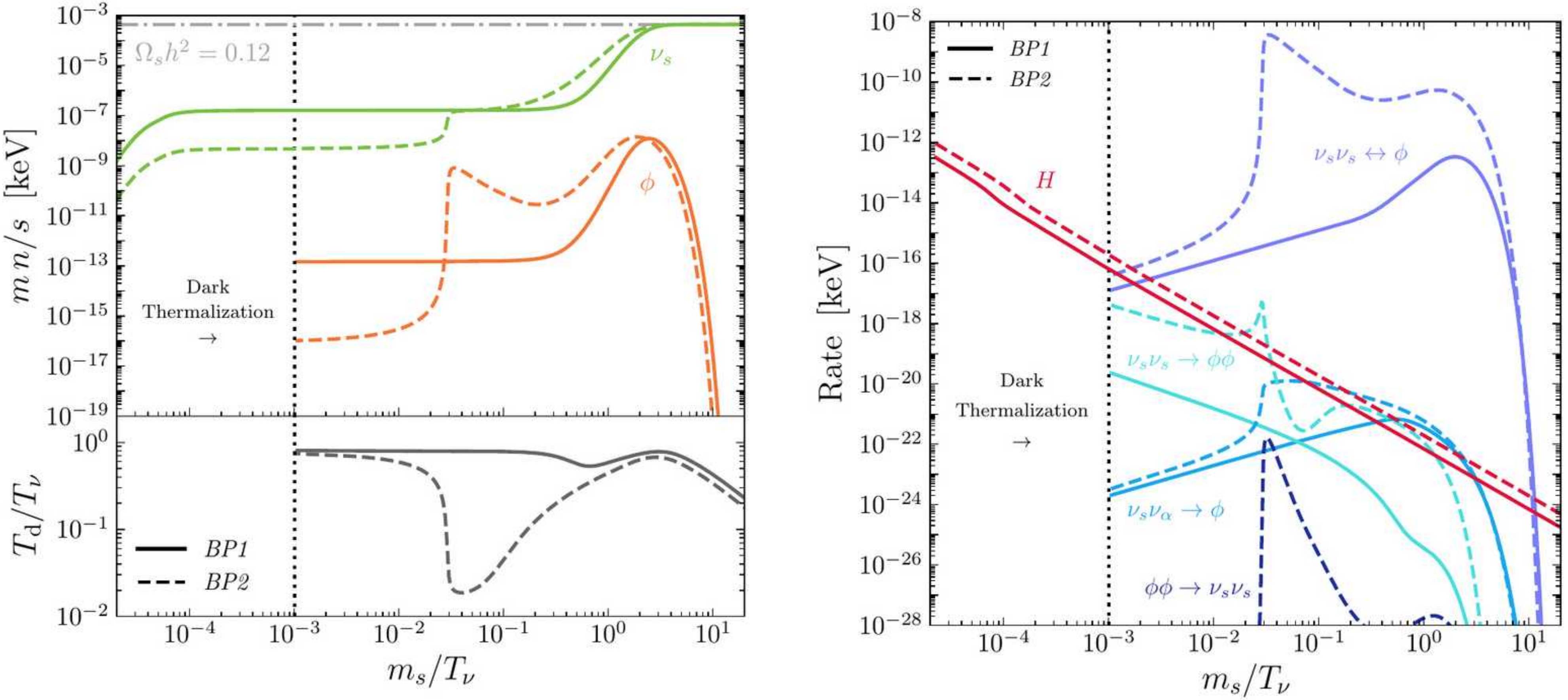
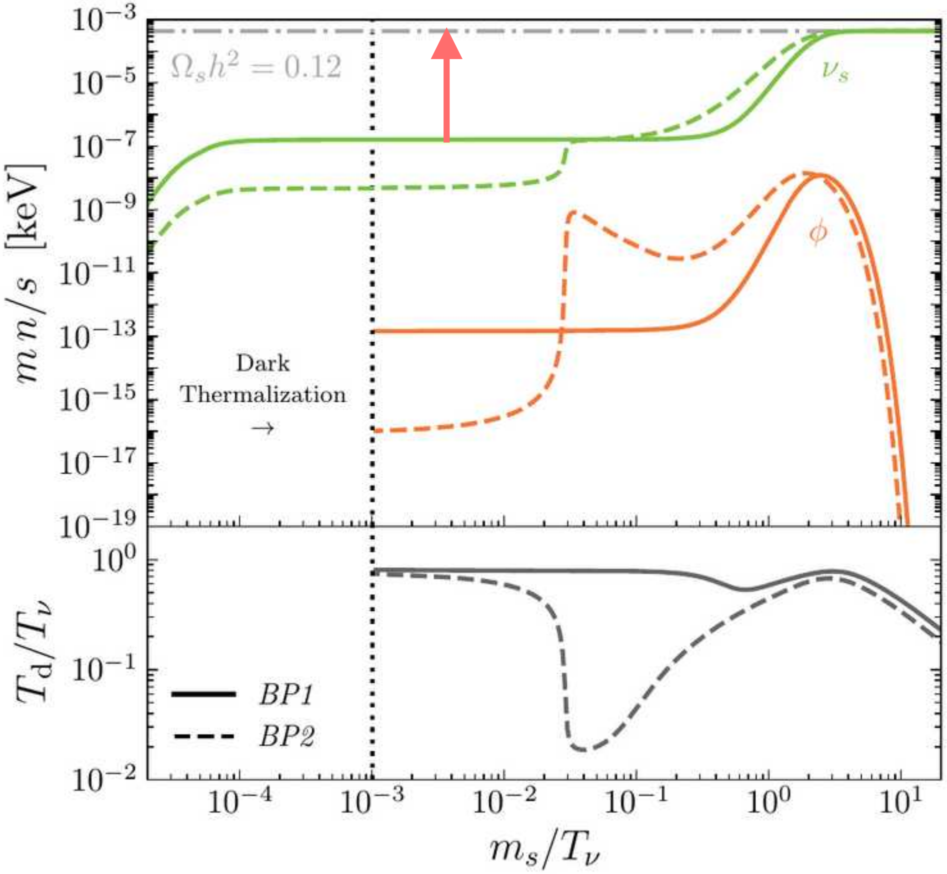
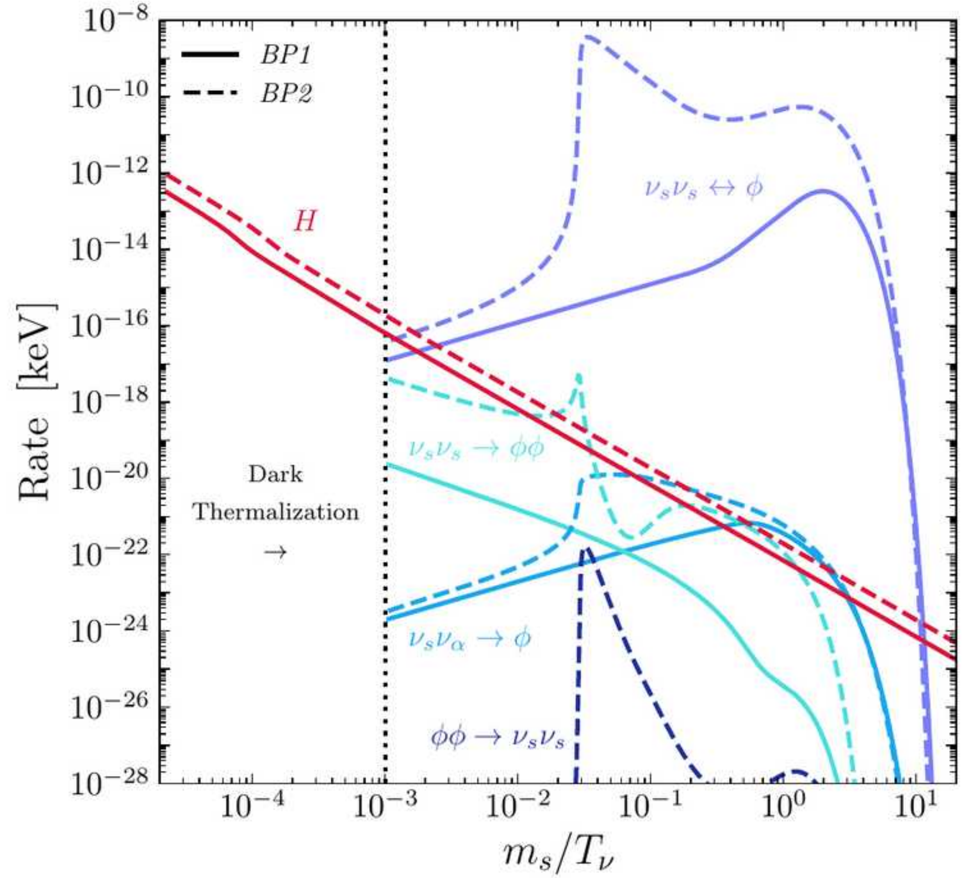


→ Correct relic abundance despite DW underproduction

Cosmological evolution





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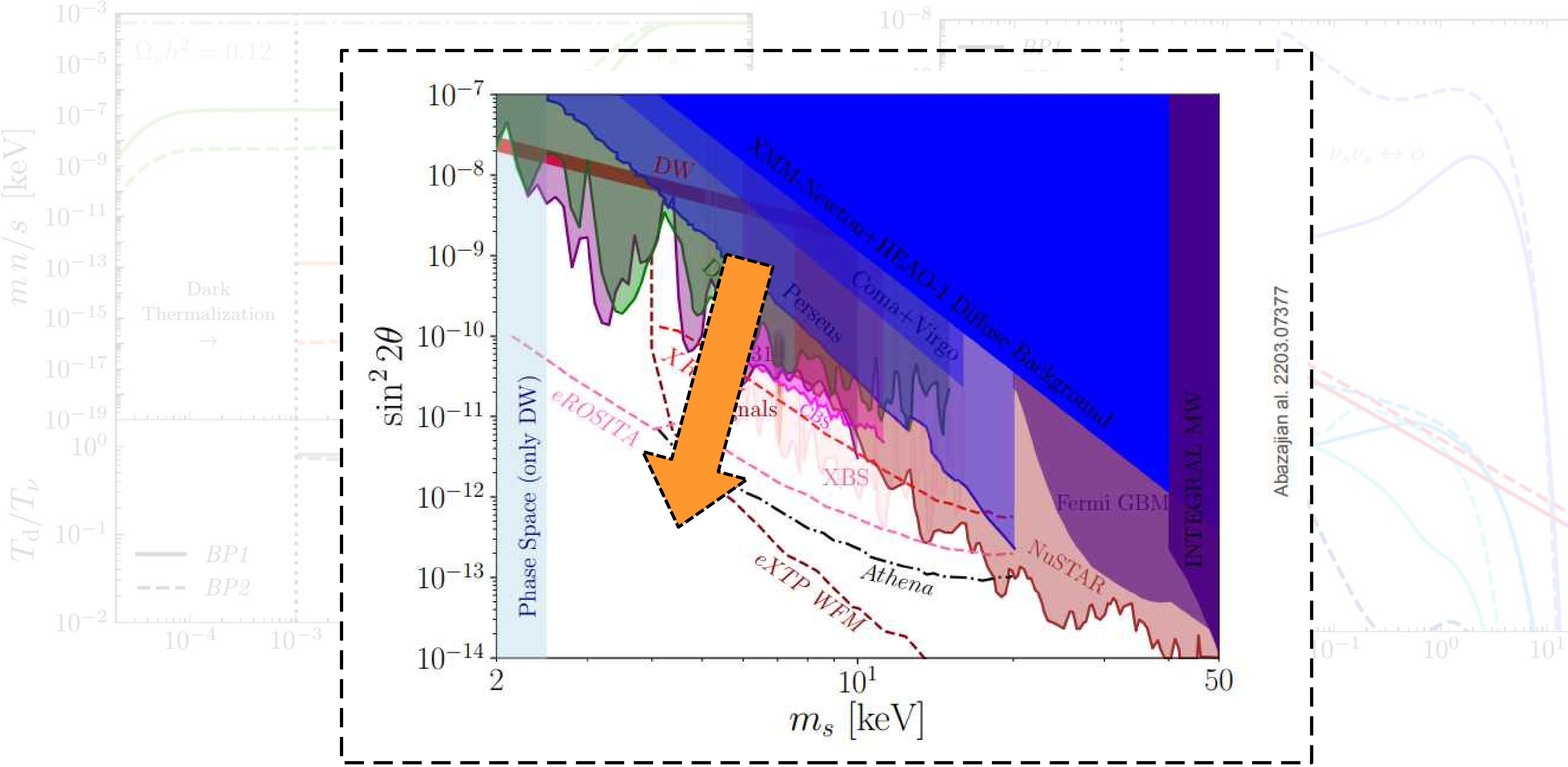

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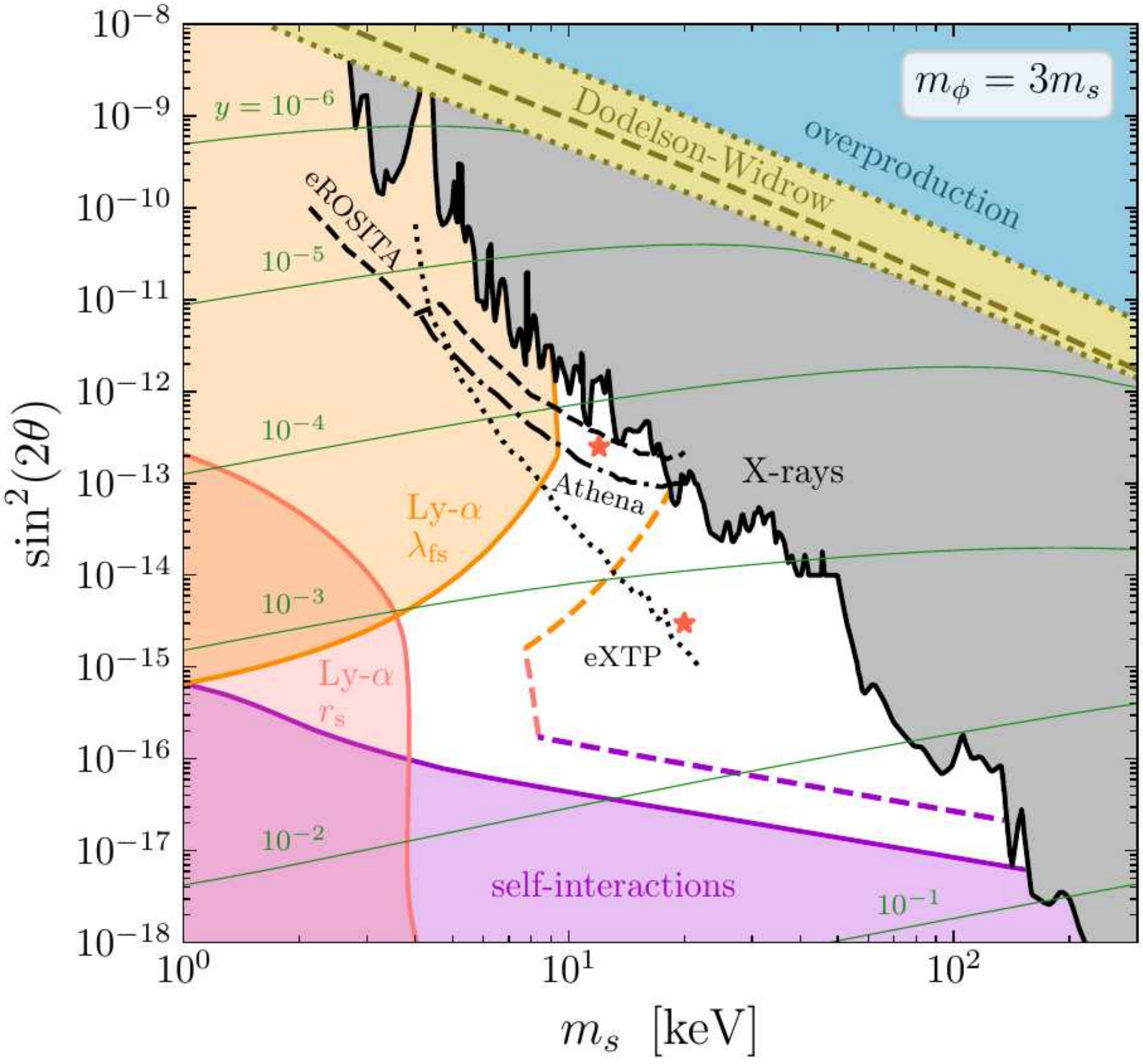
Viable parameter space



Conclusions

- New non-thermal production mechanism for DM involving exponential growth

- Interesting phenomenological consequences

- Pandemic production can realize a minimal model for sterile neutrino dark matter

  $\rightarrow$ Potentially testable in the future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Баярлалаа
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teşekkür ederim
mersi
kia ora
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welalin
tack
tapadh leat
mahalo
спасибо
faafetai lava
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спасибі
blagodaram
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grazzi
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dankie
mauruuru
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nandri
dhanyavad
thank you
gracias
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manana
bedankt
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tanemirt
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kam sah hamnida
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rahmet
ευχαριστώ
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dhanyavadagalu
shukriya
mercé
мерси
তোমাকে ধন্যবাদ
감사합니다
xièxie
merci