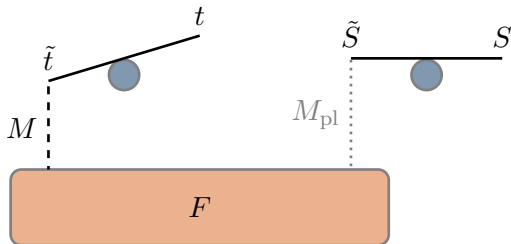


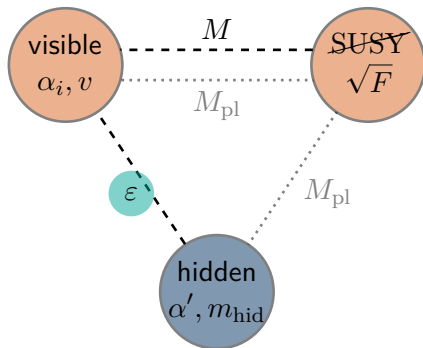
# REALLY supersymmetric dark sectors

1806.XXXX (see also 1607.03110)

Avital Dery, **Jeff Dror**, Laurel Haskins, Yonit Hochberg, Eric Kuflik



- Supersymmetry at some scale?
- Visible sector **not** supersymmetric
- **What about dark sector?**



- similar to stealth SUSY & SUSY sector DM

[Fan, Reece, Ruderman - 1105.5135]

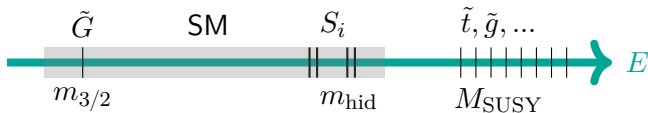
[Morrissey, Poland, Zurek - 0904.2567]

- Supersymmetric dark sector  $\Rightarrow \Delta m \simeq 0$
- Generally,

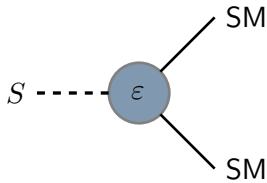
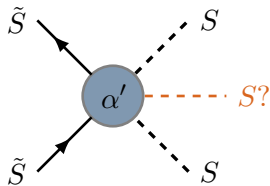
$$\frac{\Delta m}{m_{\text{hid}}} \sim \left\{ \begin{array}{l} \text{through SM} \quad \varepsilon \frac{m_{\text{hid}}}{m_{\text{SM}}} \\ \text{through SUSY} \quad \frac{F/M_{\text{pl}}}{m_{\text{hid}}} \end{array} \right\}$$

- Need

$$\varepsilon \ll m_{\text{hid}}/M_{\text{SUSY}} < 1$$



- What determines the relic density?
- (possibly) relevant types of processes:



$$\begin{aligned} \langle \sigma v \rangle_{2 \rightarrow 2} &\simeq \sigma \times \langle v \rangle \\ &= \frac{4\pi\alpha'^2}{m_{\text{hid}}} \times \frac{1}{\sqrt{x'}} \longleftarrow m_{\text{hid}}/T' \end{aligned}$$

$$\Gamma \simeq \varepsilon^2 m_{\text{hid}}$$

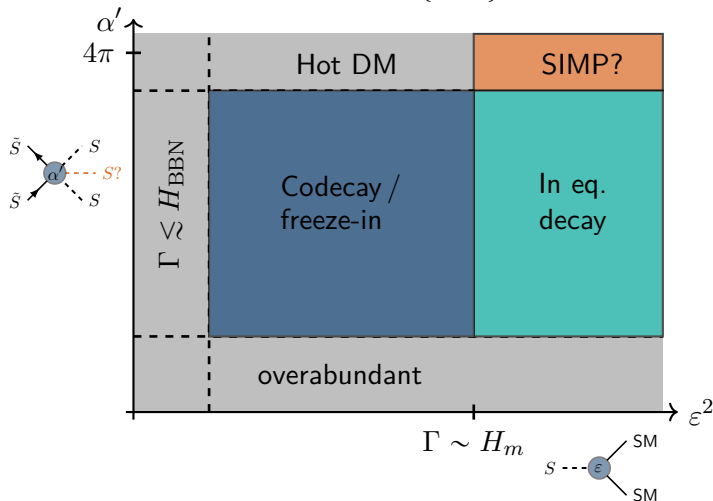
[Griest, Seckel - PRD 43 3191 (1991)]

[Kopp, Liu, Slatyer, Wang, Xue - 1609.02147]

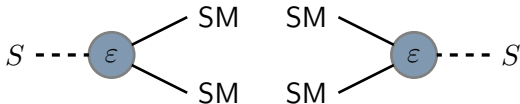
# The supersymmetric phase diagram



- $\Delta m/m_{\text{hid}} \ll 1 \Rightarrow$  dynamics fixed by  $\{\varepsilon, \alpha'\}$  (and  $m_{\text{hid}}$ )



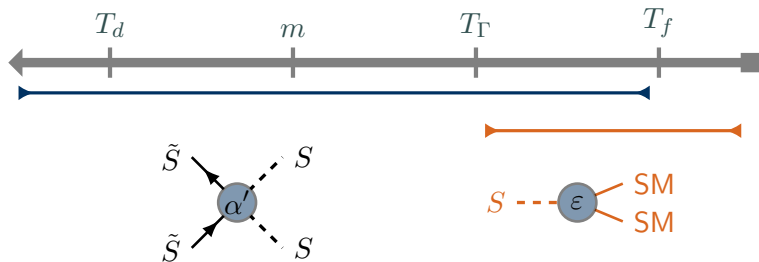
- Inverse decays can be fast
- Dark sector in equilibrium past  $T = m$



- $\tilde{S}$  in equilibrium,  $n' \propto x^{-3/2} e^{-x}$
- similar to coannihilation
- Freezeout when  $n'_f = H_f / \langle \sigma v \rangle_f$

$$\Omega = \frac{\rho_0}{\rho_c} = \frac{m n'_f s_0}{\rho_c s_f} \simeq \underbrace{\frac{x_f}{\langle \sigma v \rangle_f}}_{\propto x_f \sqrt{x'_f}} \overbrace{\left( \frac{s_0}{\rho_c} \frac{m H_m}{s_m} \right)}^{10^{-11} \text{ GeV}^{-2}}$$

- Codecay thermal history: [JD, Kuflik, Ng - 1607.03110]  
[Farina, Pappadopulo, Ruderman, Trevisan - 1607.03108]

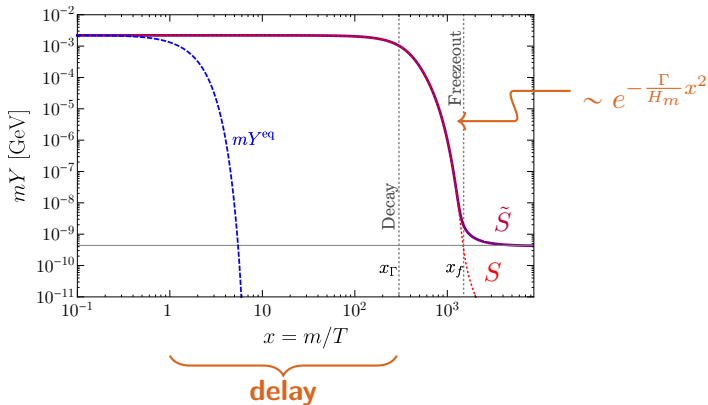


- Same form for  $\Omega$ :

$$\frac{\Omega}{\Omega_{ineq}} \sim \frac{x_f \sqrt{x'_f}}{100}$$

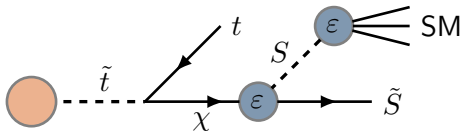
$\Gamma \sim H(x_f)$       canb?  $\rightarrow x'_f \sim \begin{cases} x_f^2 \\ 1 \end{cases}$

- Solving the Boltzmann equations for no cannibalization:
- $Y_i \equiv n_i/s$

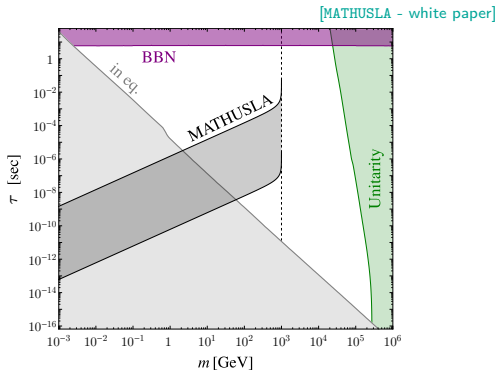




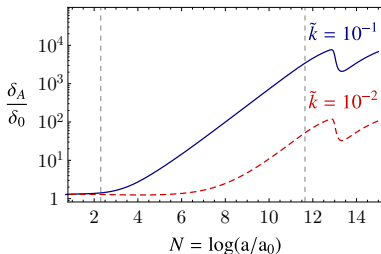
- Prediction: long lived particles



- Constraints:



- **Early matter domination?** [JD, Kuflik, Melcher, Watson - 1711.04773]
- Increase in DM substructure
- Kin. equilibrium w/ SM  
⇒ perturbations are erased.
- Not present in codecay
- Number of e-folds:

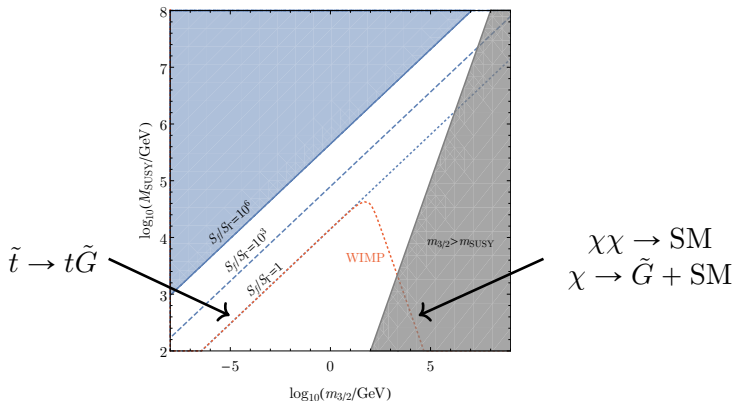


$$\log \frac{a_\Gamma}{a_{\text{MD}}} \sim \frac{1}{3} \log \frac{n_m}{n_\Gamma}$$

$$(n_m \sim m^3 \text{ and } \Gamma^2 \sim H_\Gamma^2 \sim mn_\Gamma/M_{\text{pl}})$$

$$\log \frac{a_\Gamma}{a_{\text{MD}}} \sim \frac{1}{3} \log \frac{m^4}{M_{\text{pl}}^2 \Gamma^2}$$

- $\tilde{G}$ : overproduced from freeze in, freeze out+decay, reheating [Hall, Ruderman, Volansky - 1302.2620]
- In codecay phase, production is suppressed!



- Can have gauge-mediated **split** supersymmetry



- 1 new chiral superfield:

$$W \supset \frac{m_{\text{hid}}}{2} S^2 + \frac{g'}{3} S^3 + \varepsilon S H_u H_d + \mu H_u H_d$$

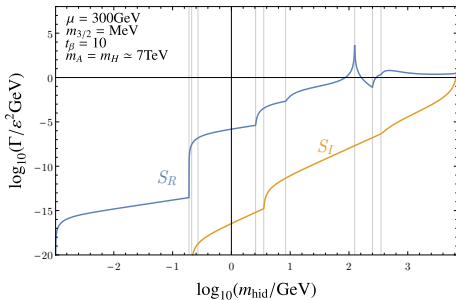
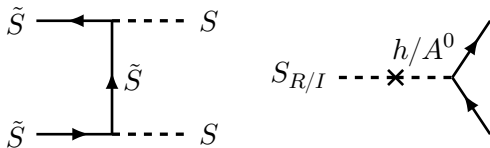
- 3 states:  $\tilde{S}$  ( $R_p$ -odd),  $S_R, S_I$  ( $R_p$ -even)

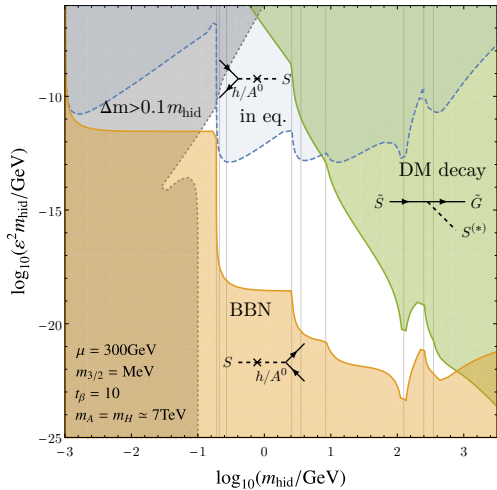
- split by  $\varepsilon$ :

$$m_{\tilde{S}}^2 - m_{S_{R/I}}^2 = \pm \frac{g' \varepsilon v^2 \mu}{m_{\text{hid}}}$$

- $S_R$  and  $S_I$  decay through mixing with  $h$  and  $A^0$
- $\tilde{S}$  is almost stable
  - can decay to gravitino through  $S_R/S_I$

- Thermal history set by





- Dark sector can be really supersymmetric
- **SUSY usually**  $\Rightarrow$  **codecay**
- New detection directions:
- indirect detection
- matter domination
- long-lived states
- alleviate gravitino problem
- simple singlet model

what is this?

