

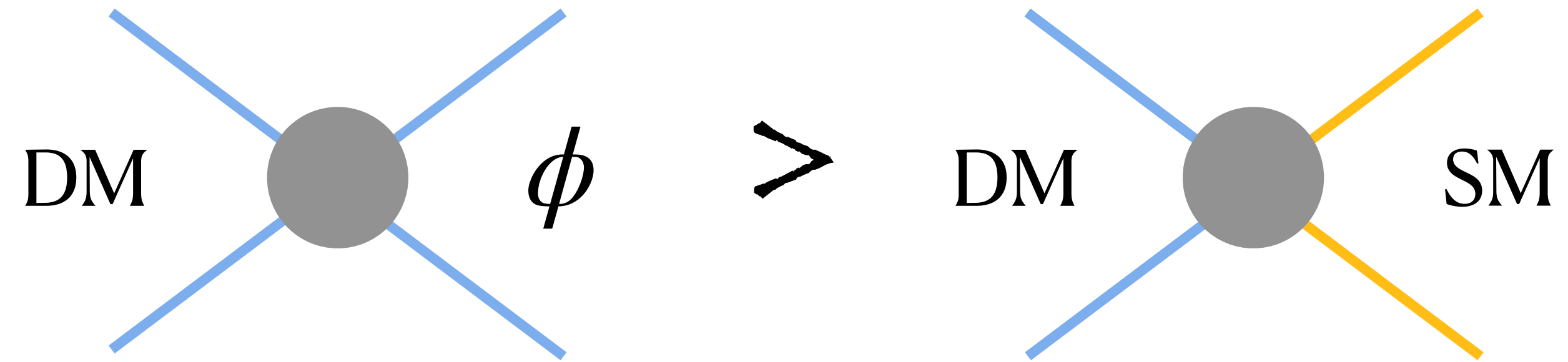
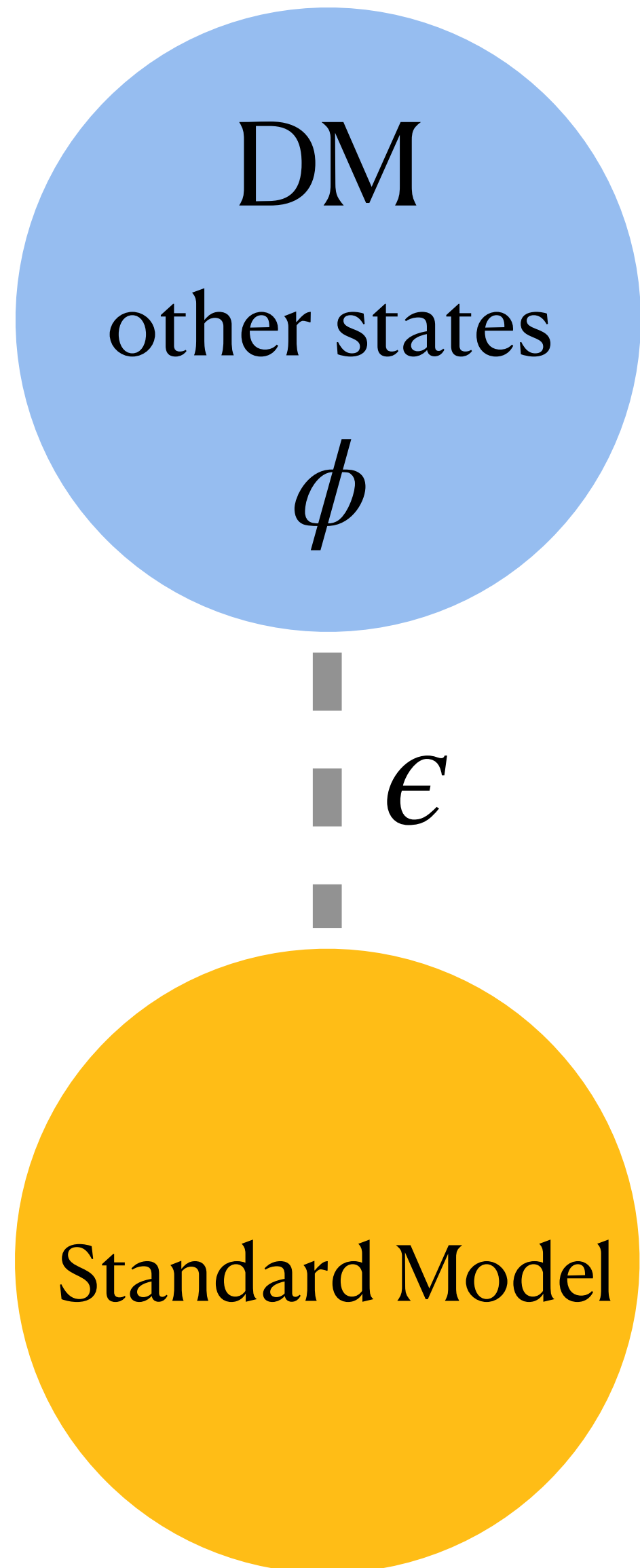
Why Secluded Dark Matter at Neutrino Telescopes?

Filippo Sala

Dark Ghosts, Granada, 31 Mar 2022



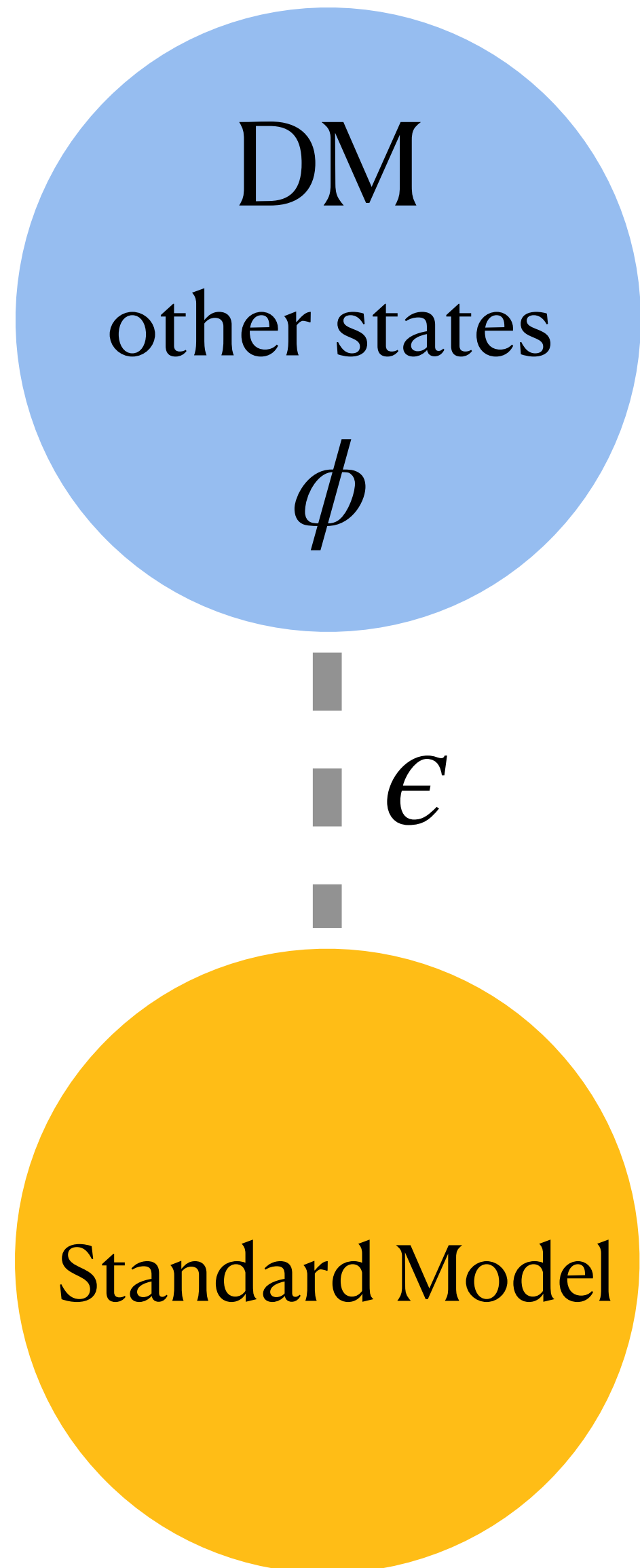
Secluded Dark Matter



Example:

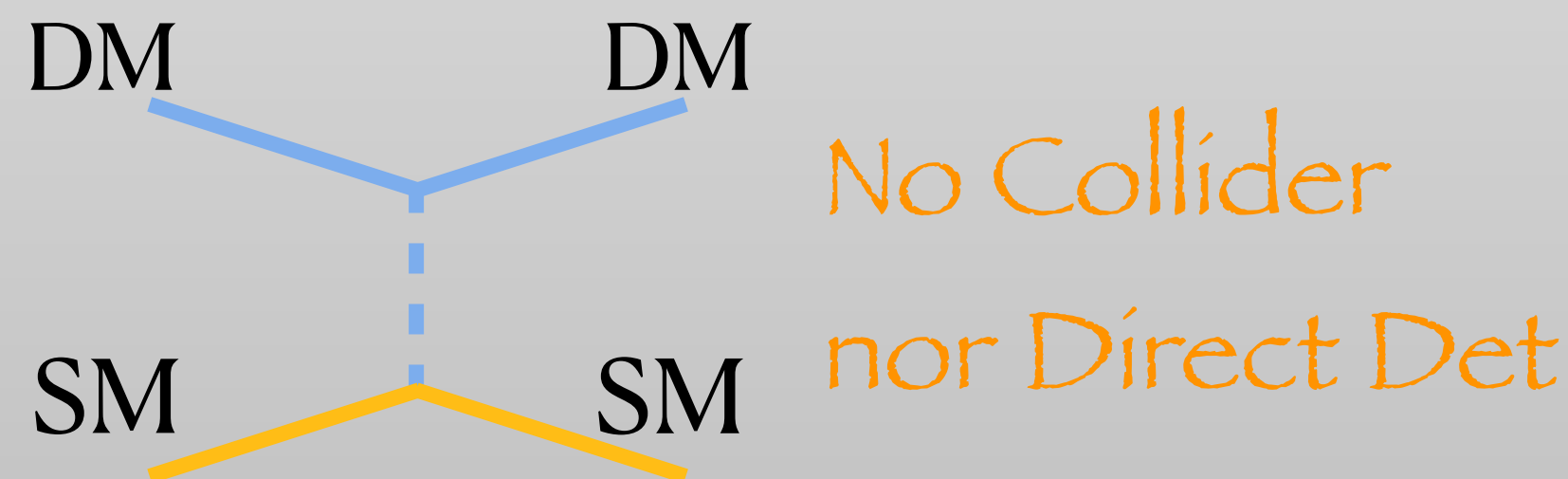
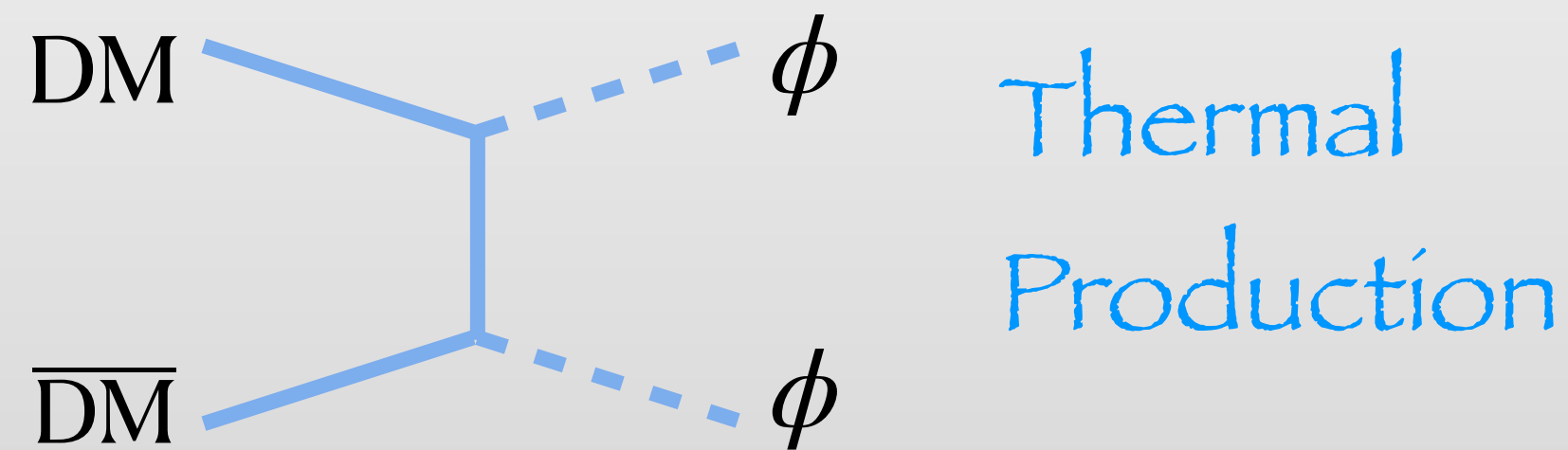
$$\mathcal{L}_{eff} \sim g_D \phi (\overline{\text{DM}} \text{DM} + \epsilon \overline{\text{SM}} \text{SM})$$

Secluded Dark Matter: Examples



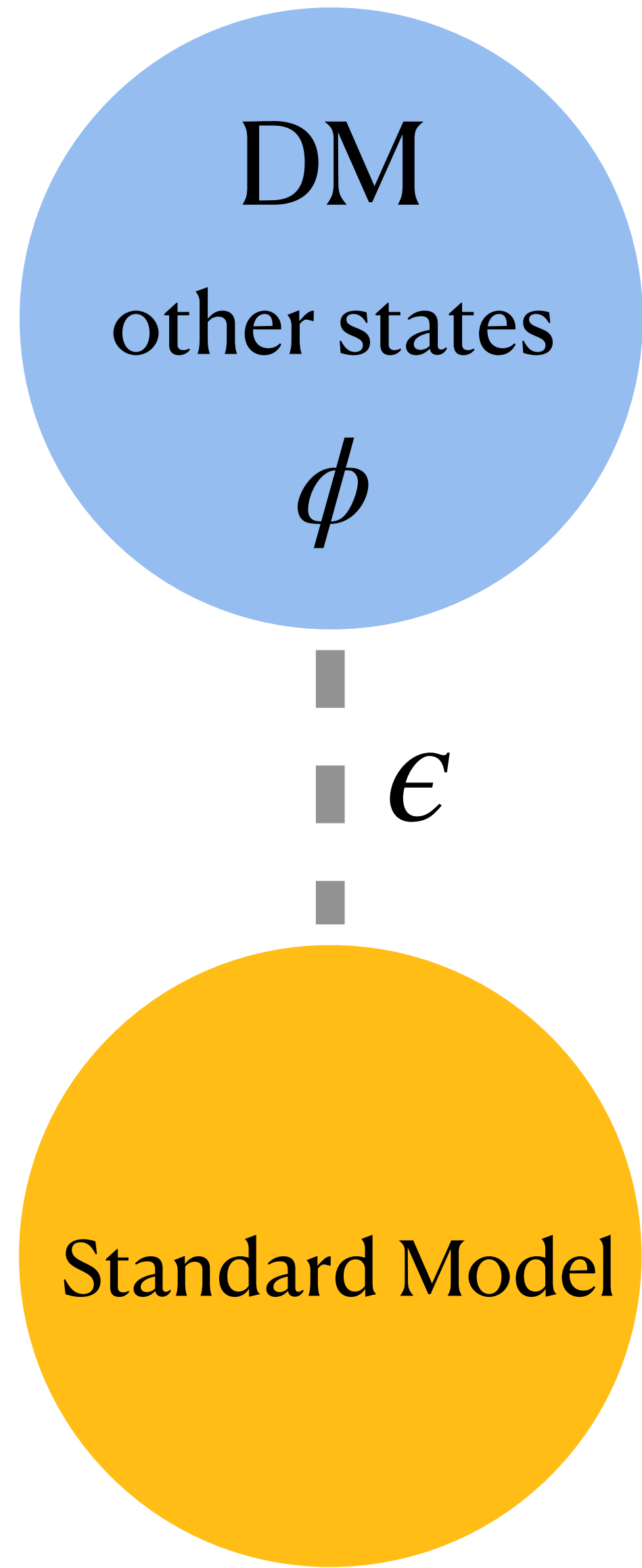
Original proposal $\epsilon \ll 1$

$$\mathcal{L} = g_D \phi (\overline{\text{DM}} \text{DM} + \epsilon \overline{\text{SM}} \text{SM})$$



Pospelov+ 0711.4866, ...

Secluded Dark Matter: Examples



Original proposal $\epsilon \ll 1$

$\mathcal{L} = g_D \phi (\overline{\text{DM}} \text{DM} + \epsilon \overline{\text{SM}} \text{SM})$

DM ϕ

$\overline{\text{DM}}$ ϕ

Thermal Production

DM DM

SM SM

No Collider
nor Direct Det

Pospelov+ 0711.4866, ...

Composite Dark Matter

M_{DM}

M_{π}

DM π

$\overline{\text{DM}}$ π

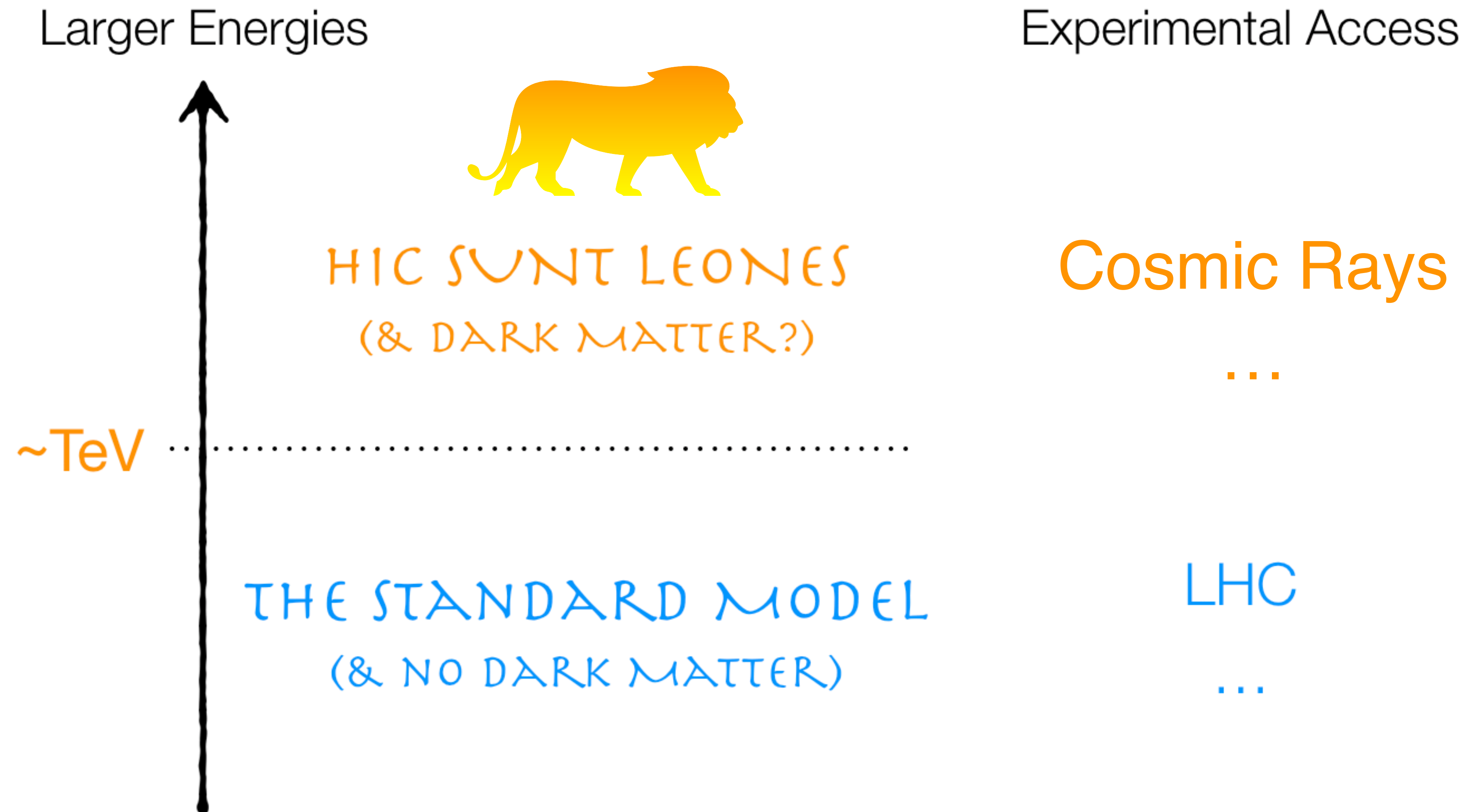
SM

DM DM

Antipin+ 1503.08749, ...

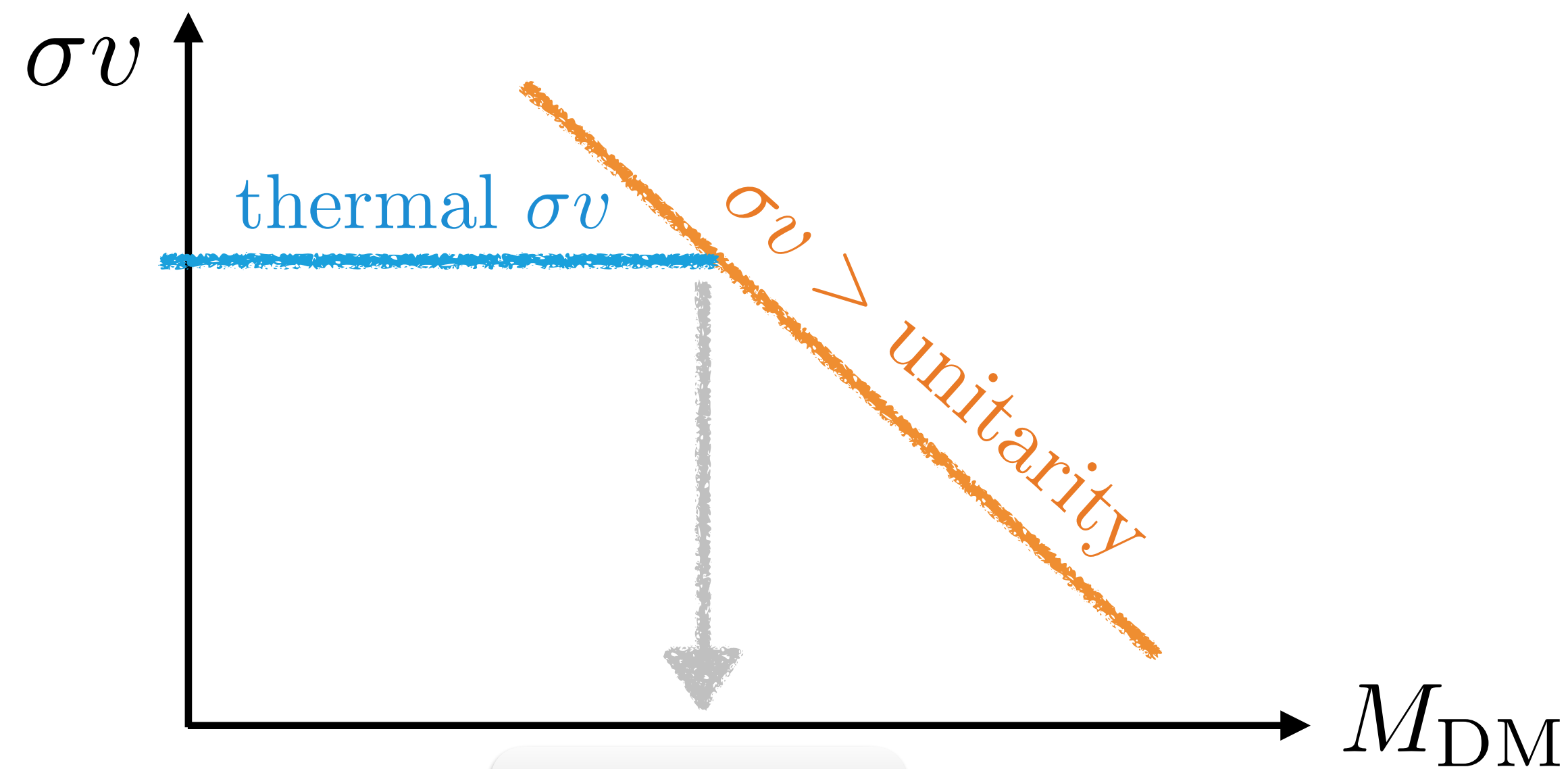
Why else ?

Because of Heavy Dark Matter



The Unitarity Bound (on DM DM \rightarrow anything)

$$S S^\dagger = 1 \quad \Rightarrow \quad \sigma^j v_{\text{rel}} \leq \frac{4\pi(2j+1)}{v_{\text{rel}}} \frac{1}{M_{\text{DM}}^2}$$



$\simeq 100 \text{ TeV}$

The Unitarity Bound: Going Beyond

Hypothesis of Uni. Bound

Drop it

1. DM-SM at (chemical) **equilibrium**

Abundance by **Freeze-in**, ...

e.g. Gravitino DM, inflaton decays
see Hall+ 0911.1120, Garcia+ 2004.08404

2. Universe dominated by **radiation**

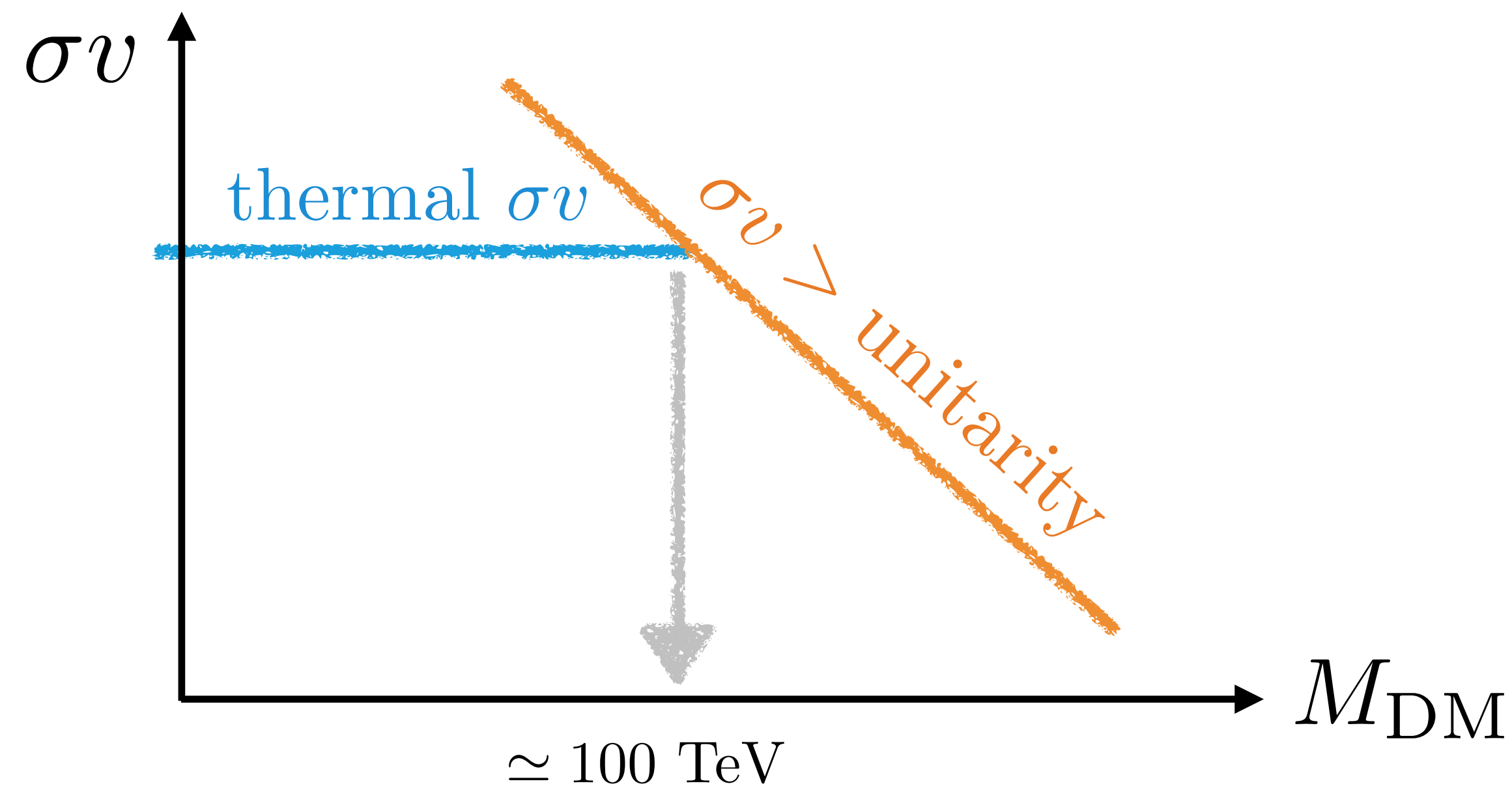
This Talk

...

Universe dominated by Matter or Vacuum Energy

Both dilute abundance of pre-existing relics!

$$\Omega_{\text{DM}} \propto \frac{1}{\sigma v} \frac{1}{\text{Dilution}}$$

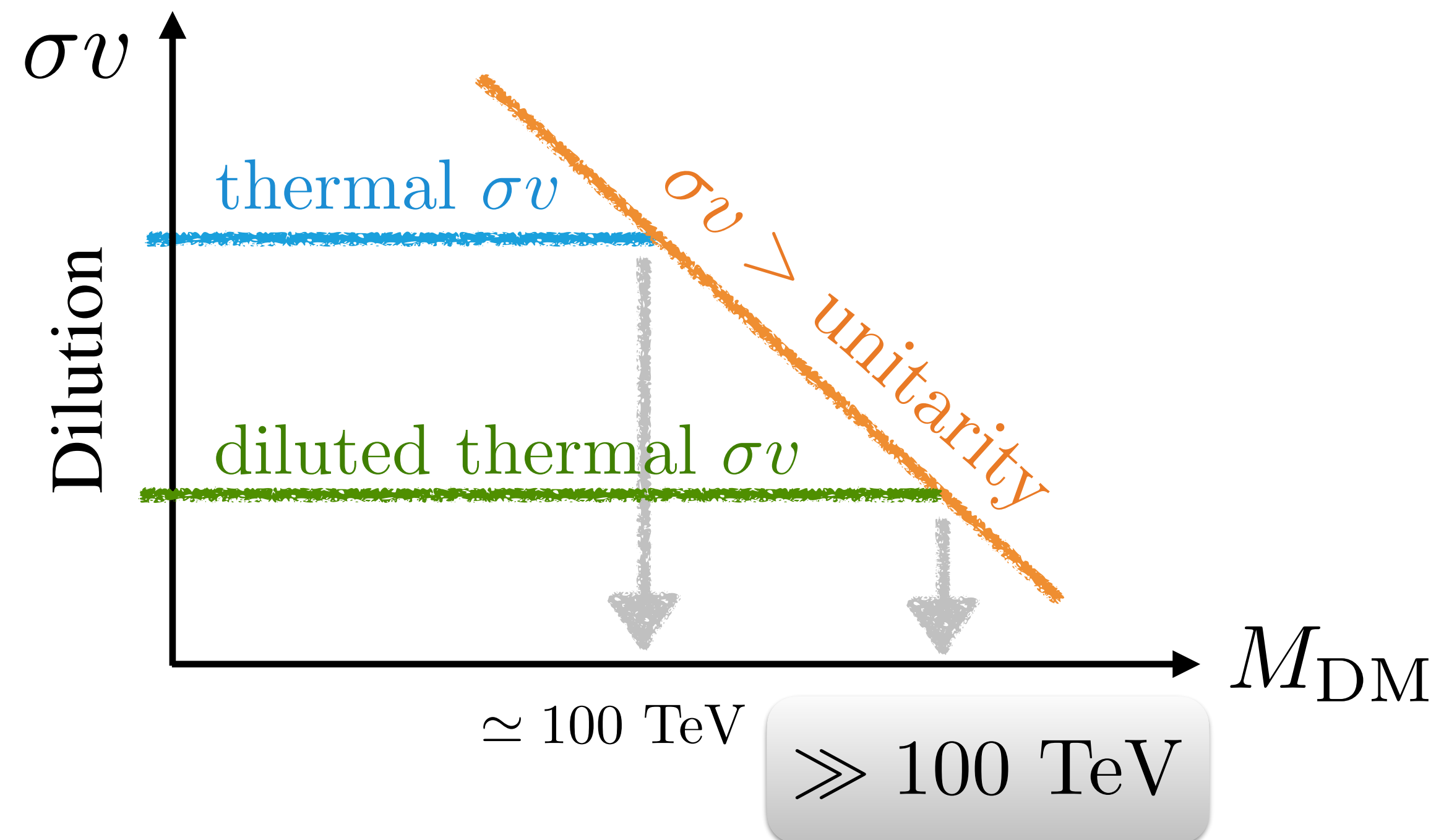


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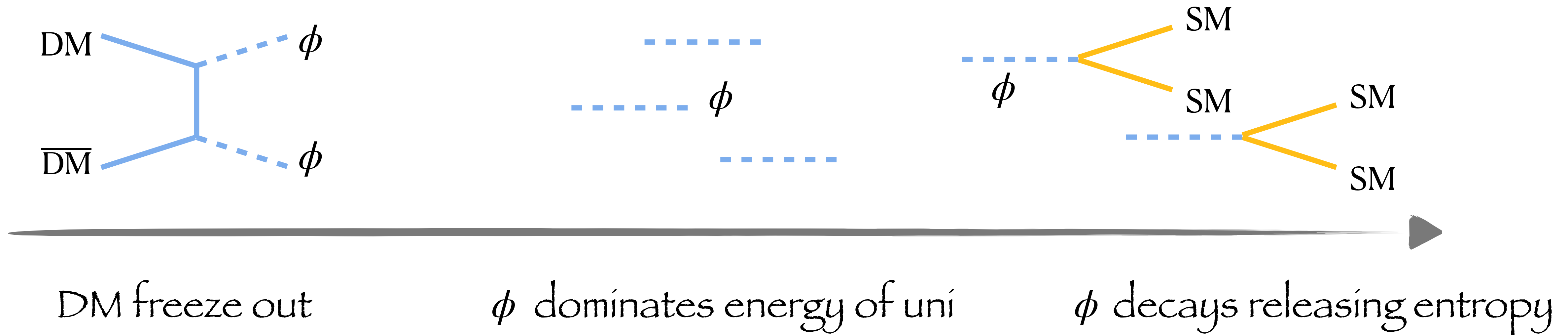
smaller $\langle \sigma v \rangle_{\text{FO}}$



Matter Domination & Secluded DM

Berlin+1602.08490
Cirelli+1612.07295

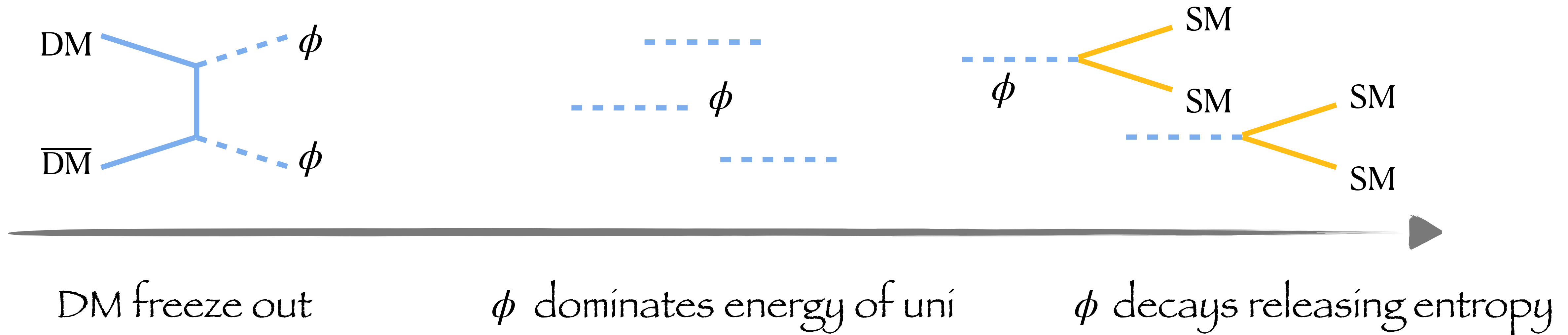
$$\mathcal{L} = g_D \phi (\overline{\text{DM}} \text{DM} + \epsilon \overline{\text{SM}} \text{SM}) \quad \epsilon \ll 1$$



Matter Domination & Secluded DM

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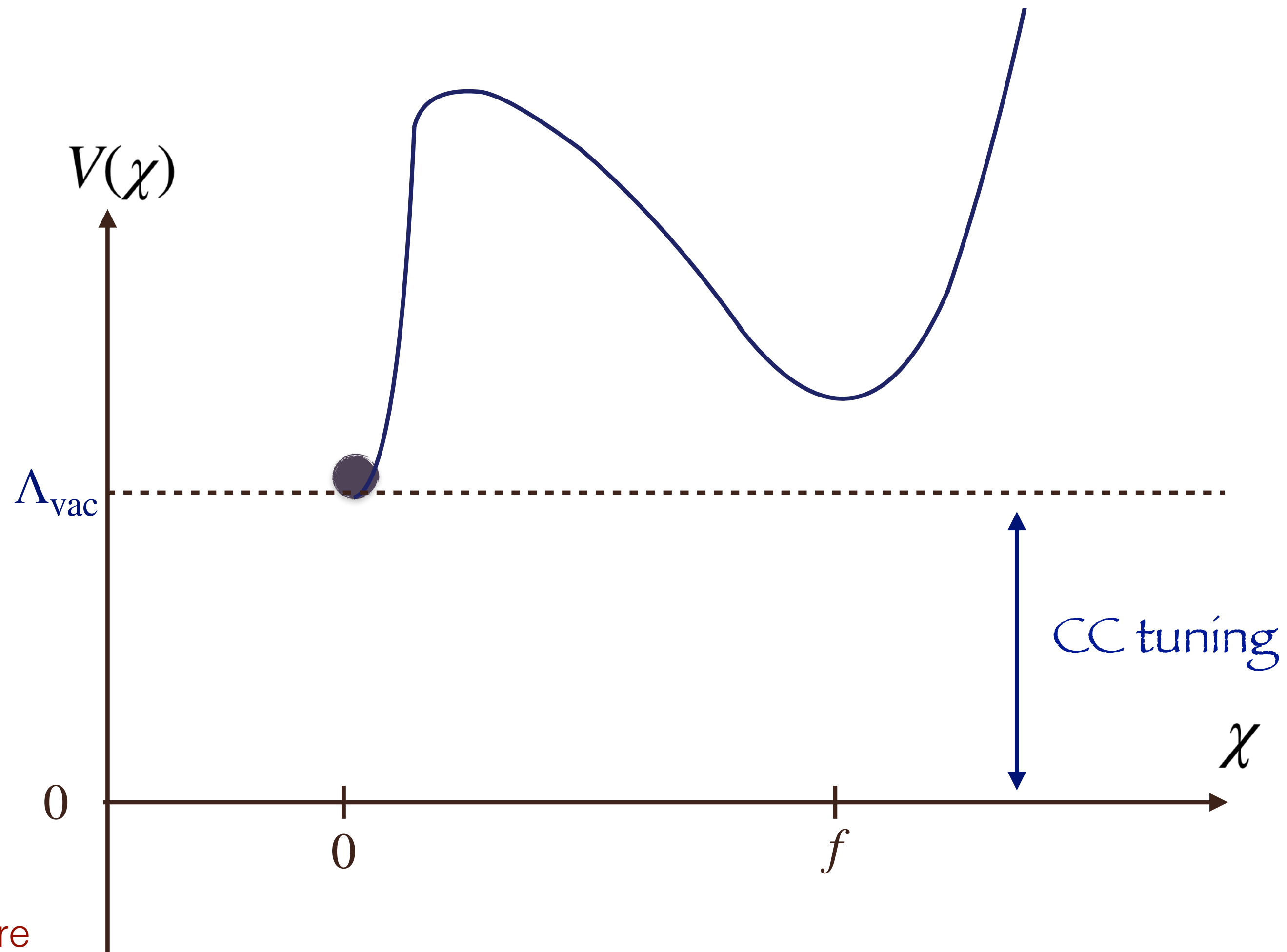
$$\mathcal{L} = g_D \phi (\overline{\text{DM}} \text{DM} + \epsilon \overline{\text{SM}} \text{SM}) \quad \epsilon \ll 1$$



$$M_{\text{DM}}^{\text{max}} \simeq 2.4 \times 10^3 \text{ PeV} \left(\frac{m_\phi}{100 \text{ PeV}} \right)^{\frac{1}{2}} \left(\frac{\tau_\phi}{0.03 \text{ sec}} \right)^{\frac{1}{4}}$$

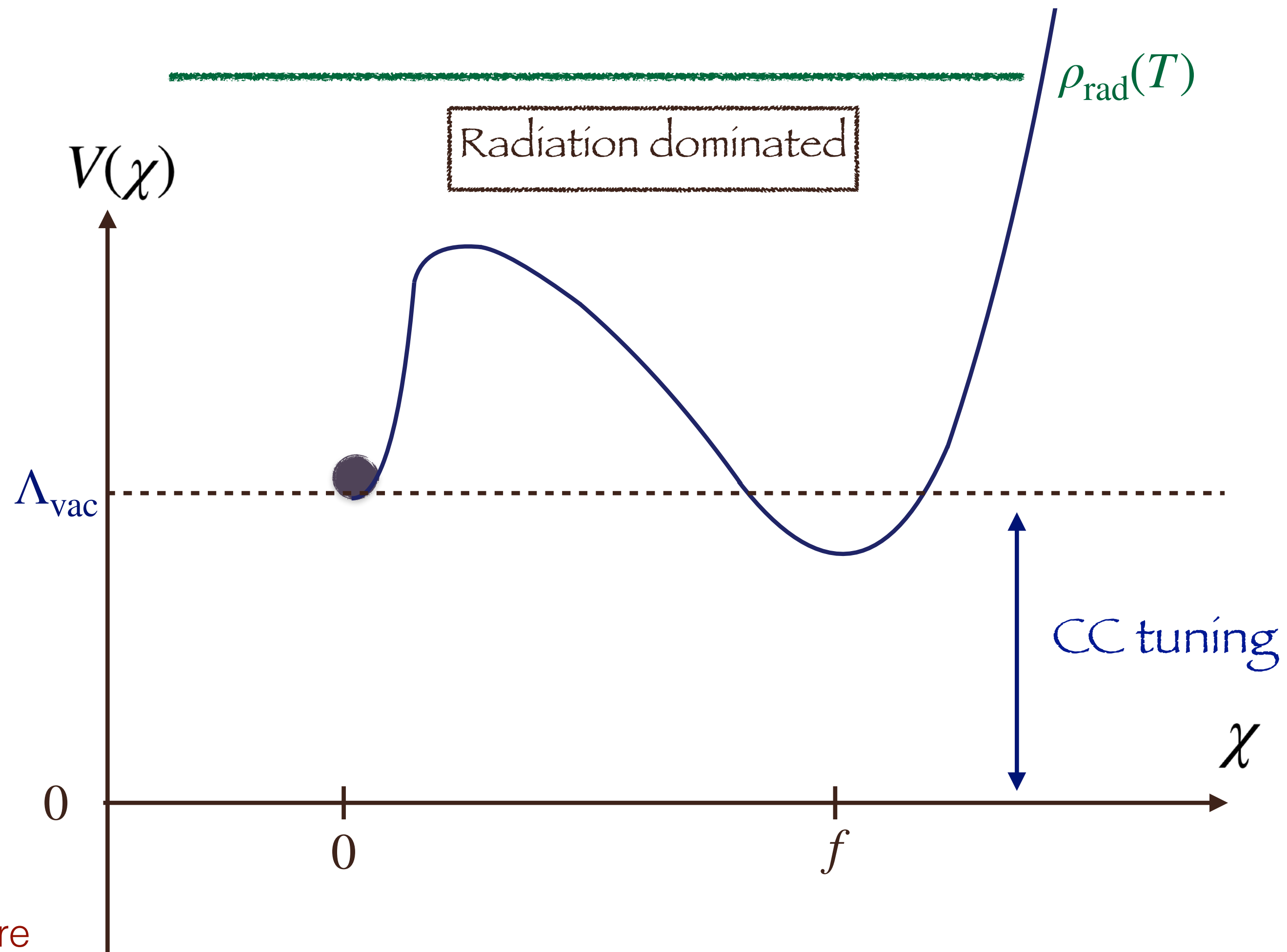
Cirelli Gouttenoire Petraki FS
1811.03608

Vacuum Energy Domination from phase transition



animation by Yann Gouttenoire

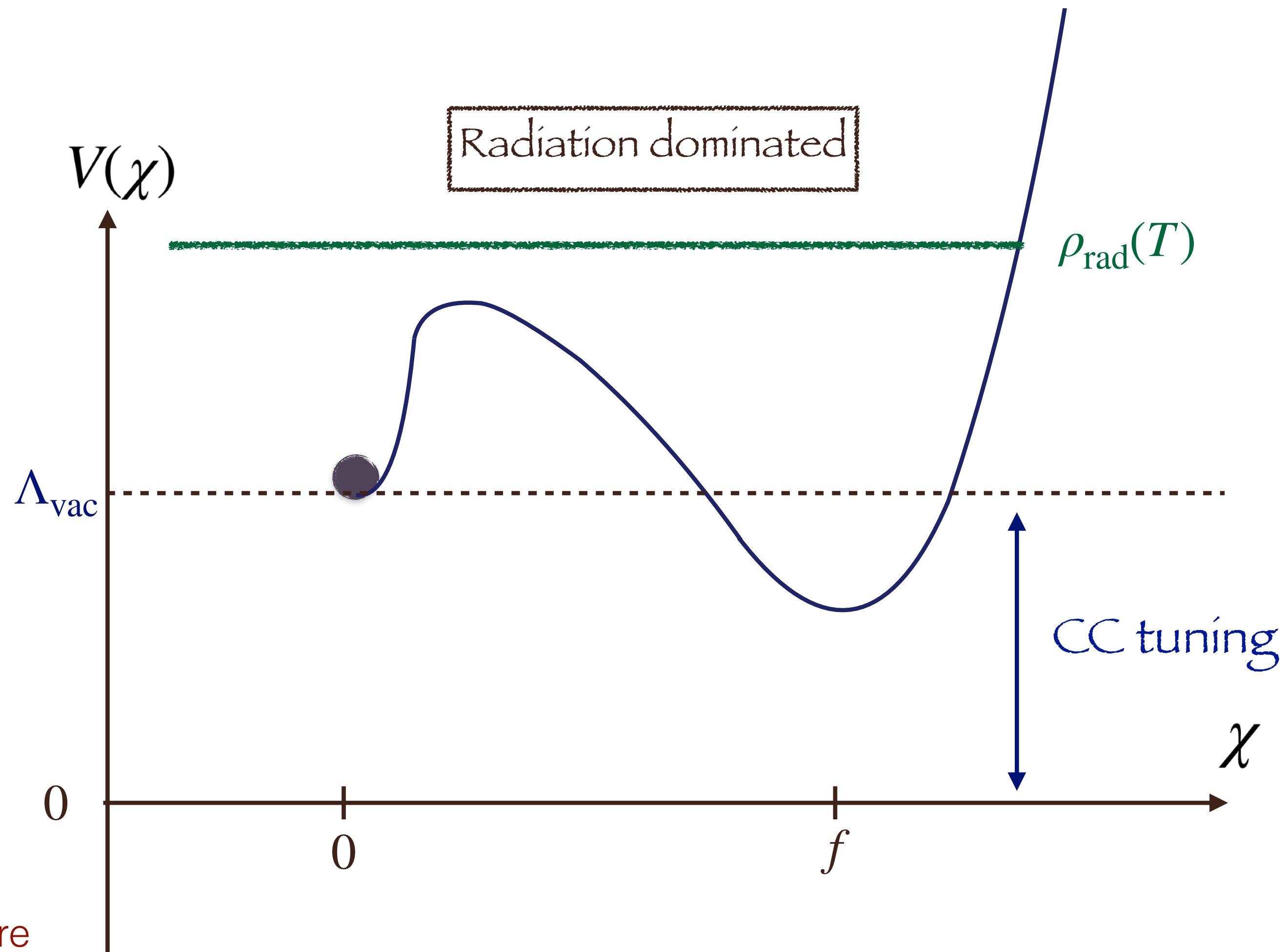
Vacuum Energy Domination from phase transition



animation by Yann Gouttenoire

$$H \equiv \frac{\dot{a}}{a} = \frac{1}{M_{\text{Pl}}} \sqrt{\rho_{\text{rad}} + \Lambda_{\text{vac}}} \quad \rho_{\text{rad}} \approx T^4$$

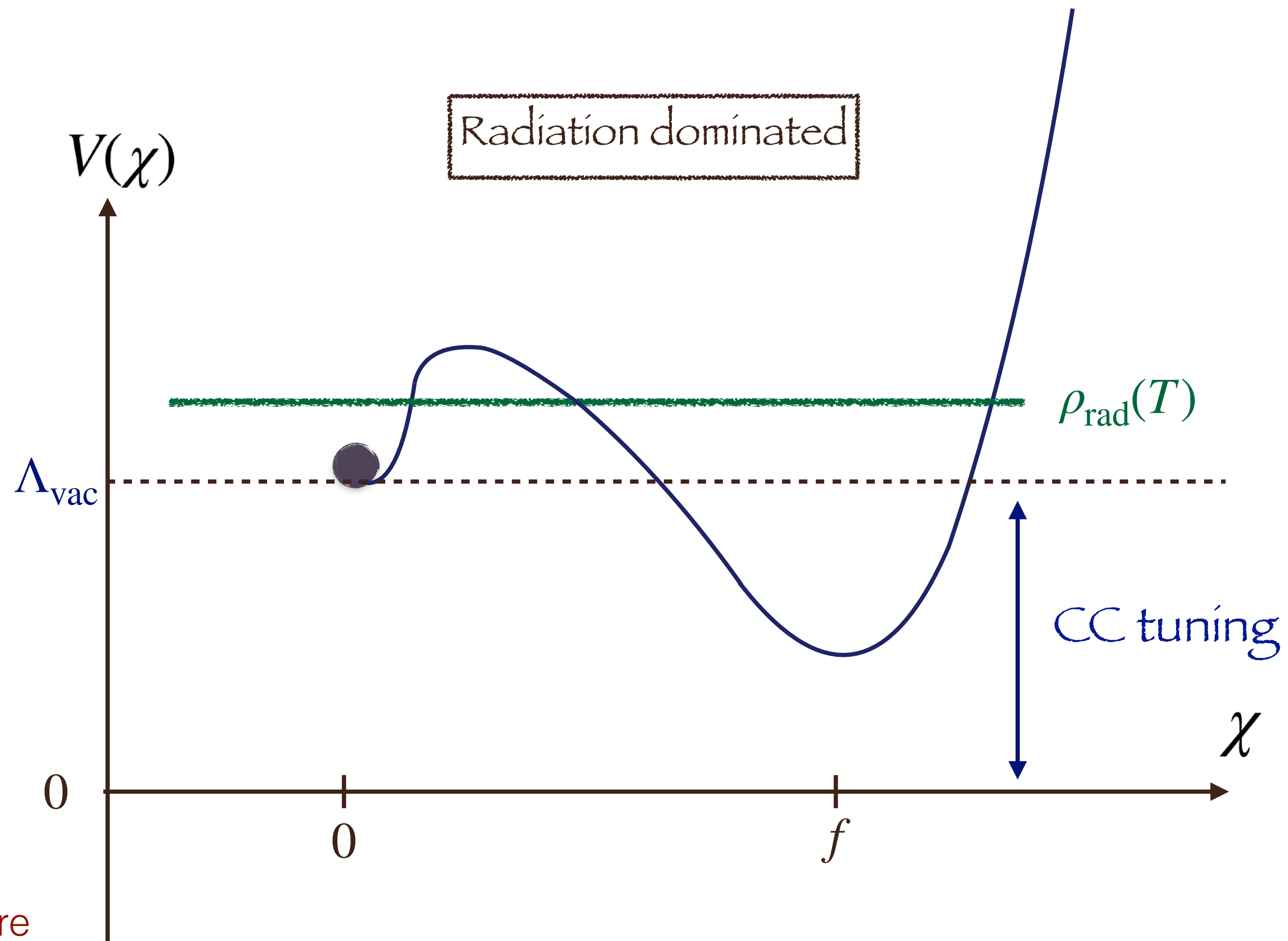
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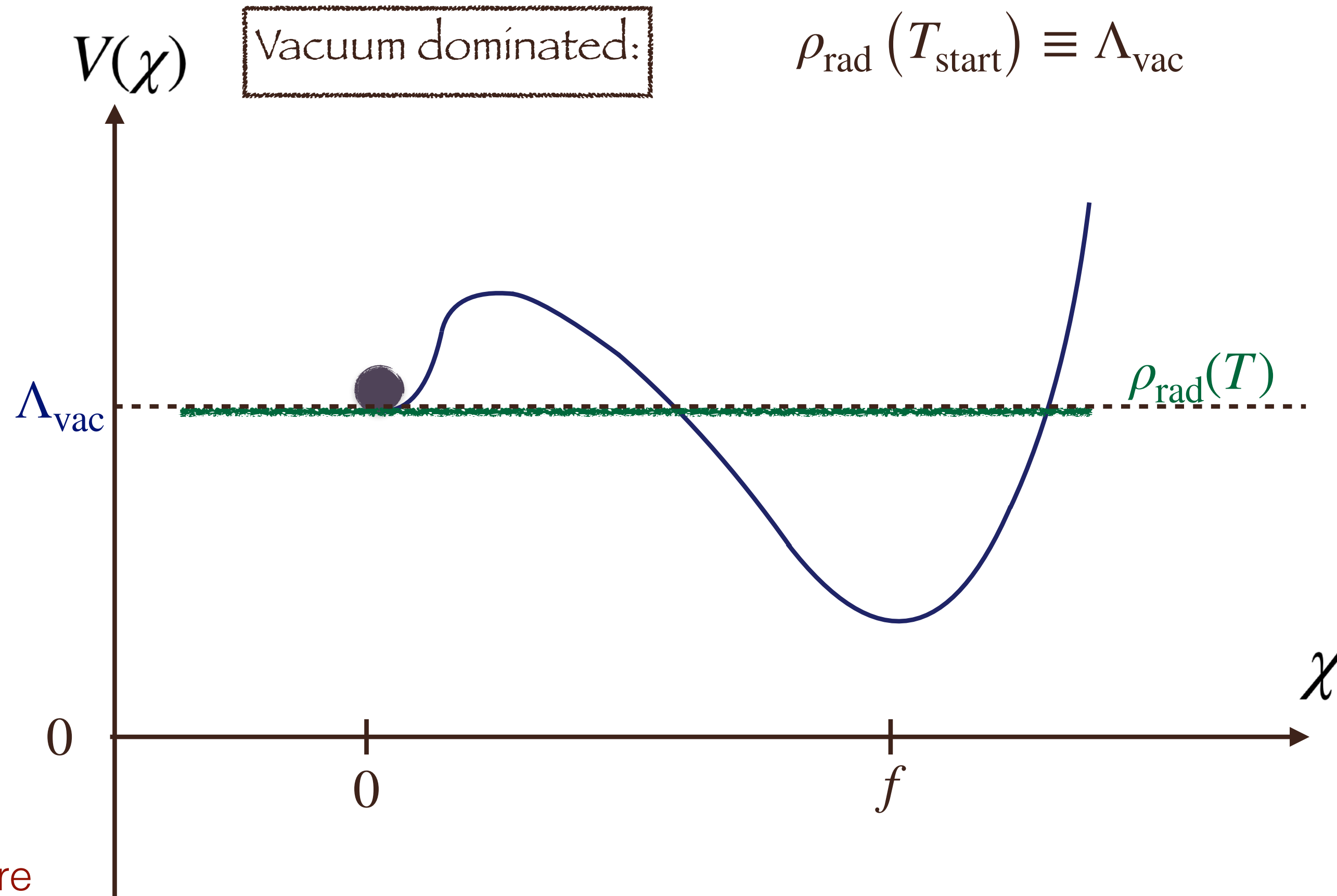
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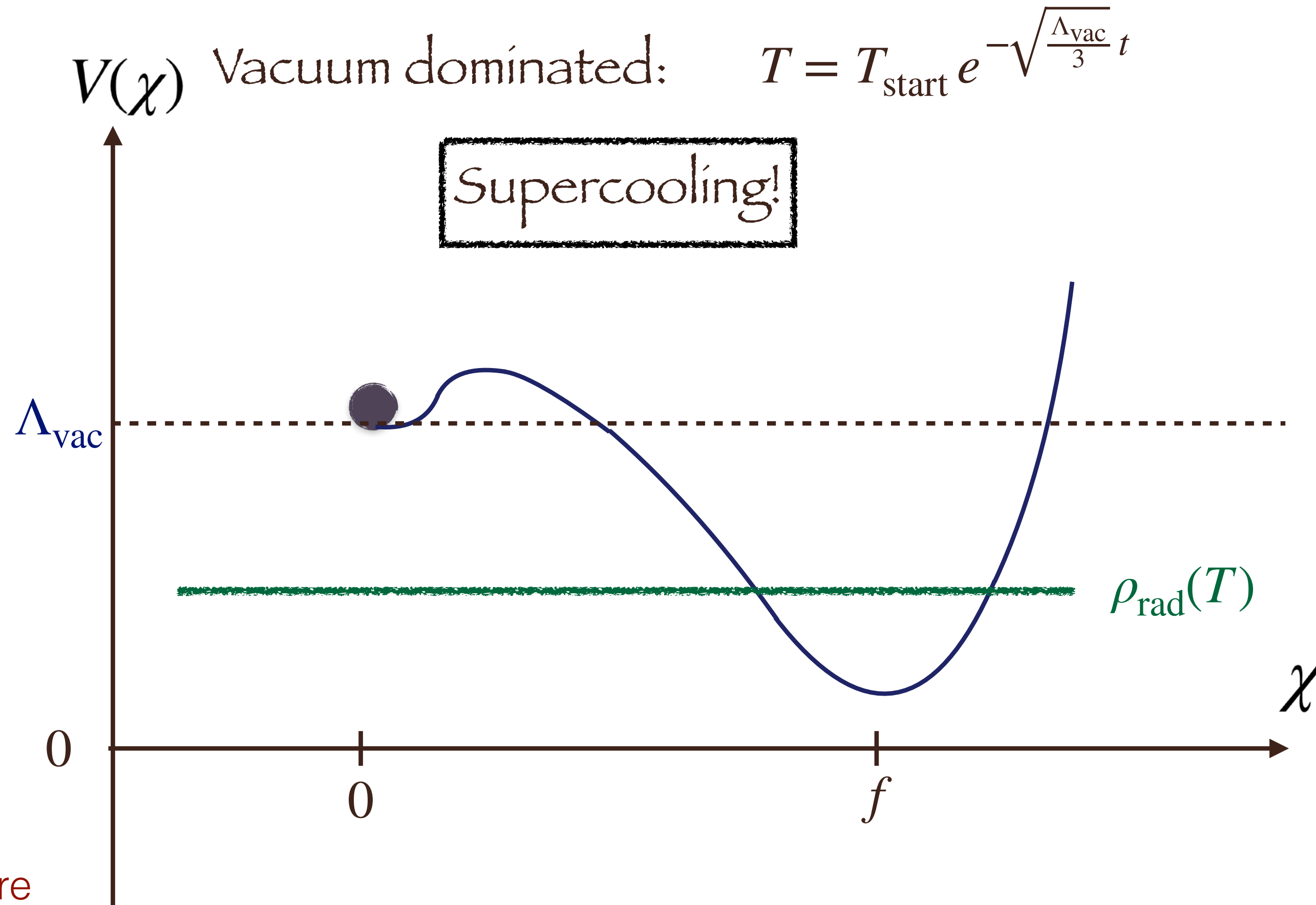
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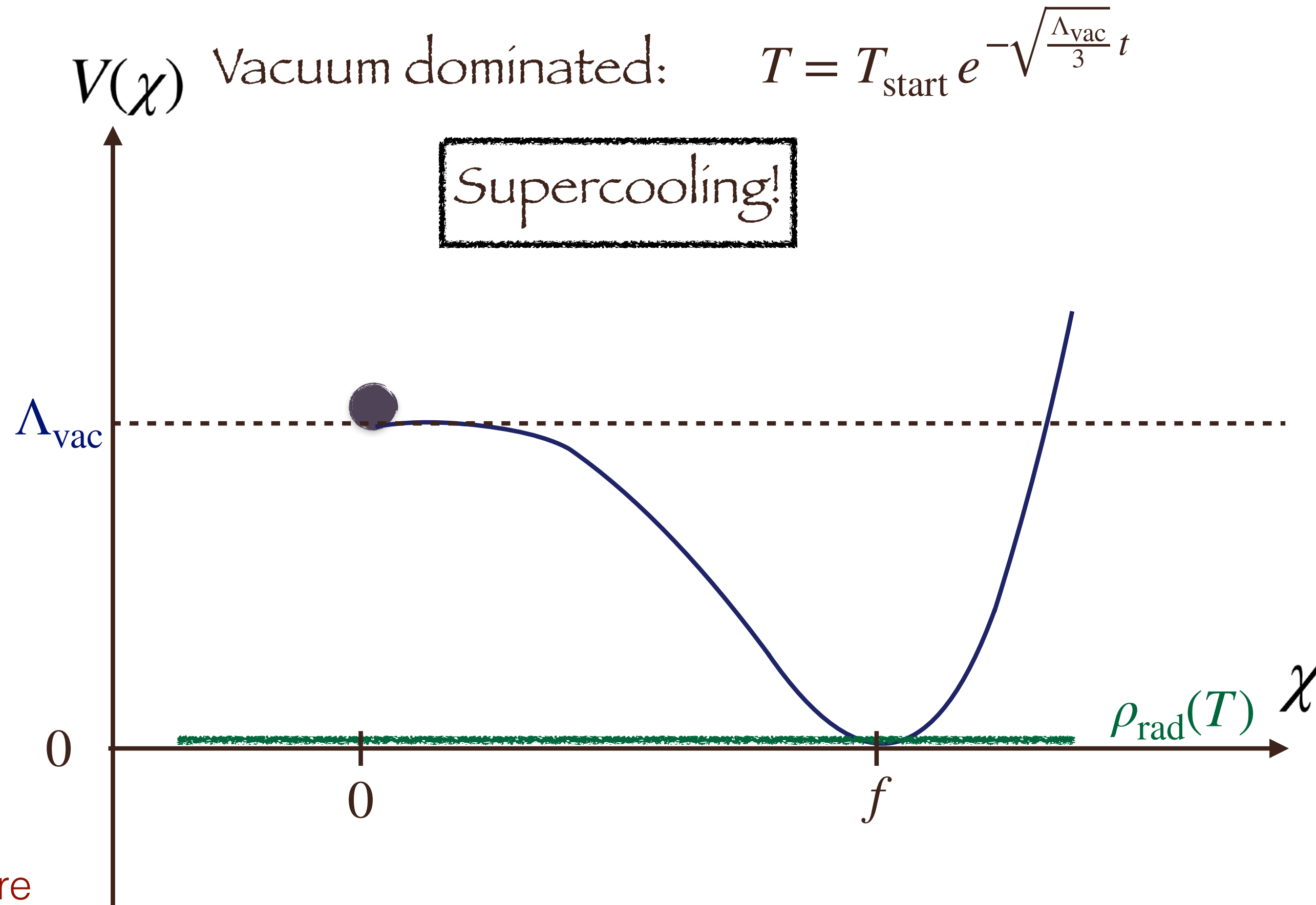
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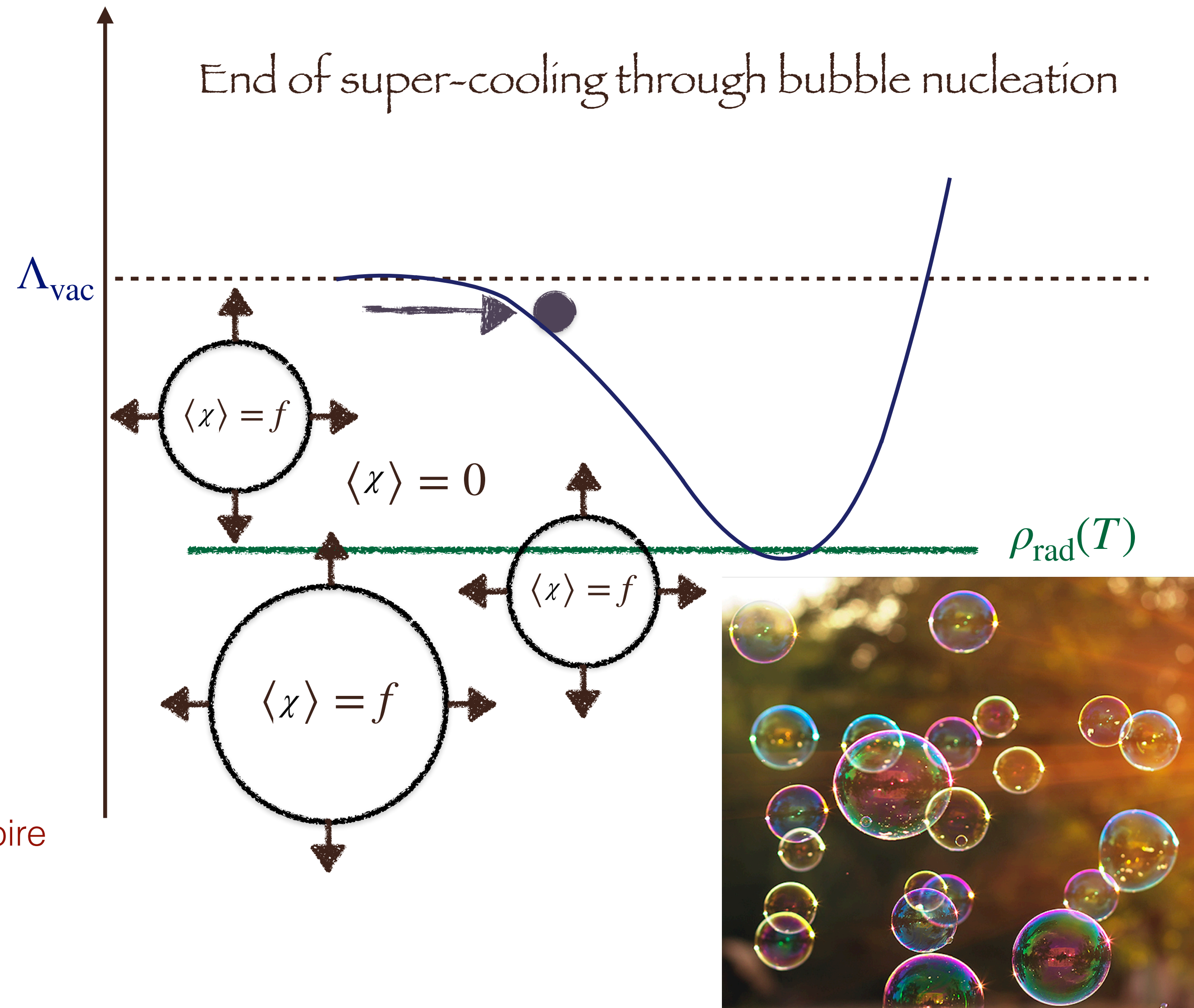
Vacuum Energy Domination from phase transition



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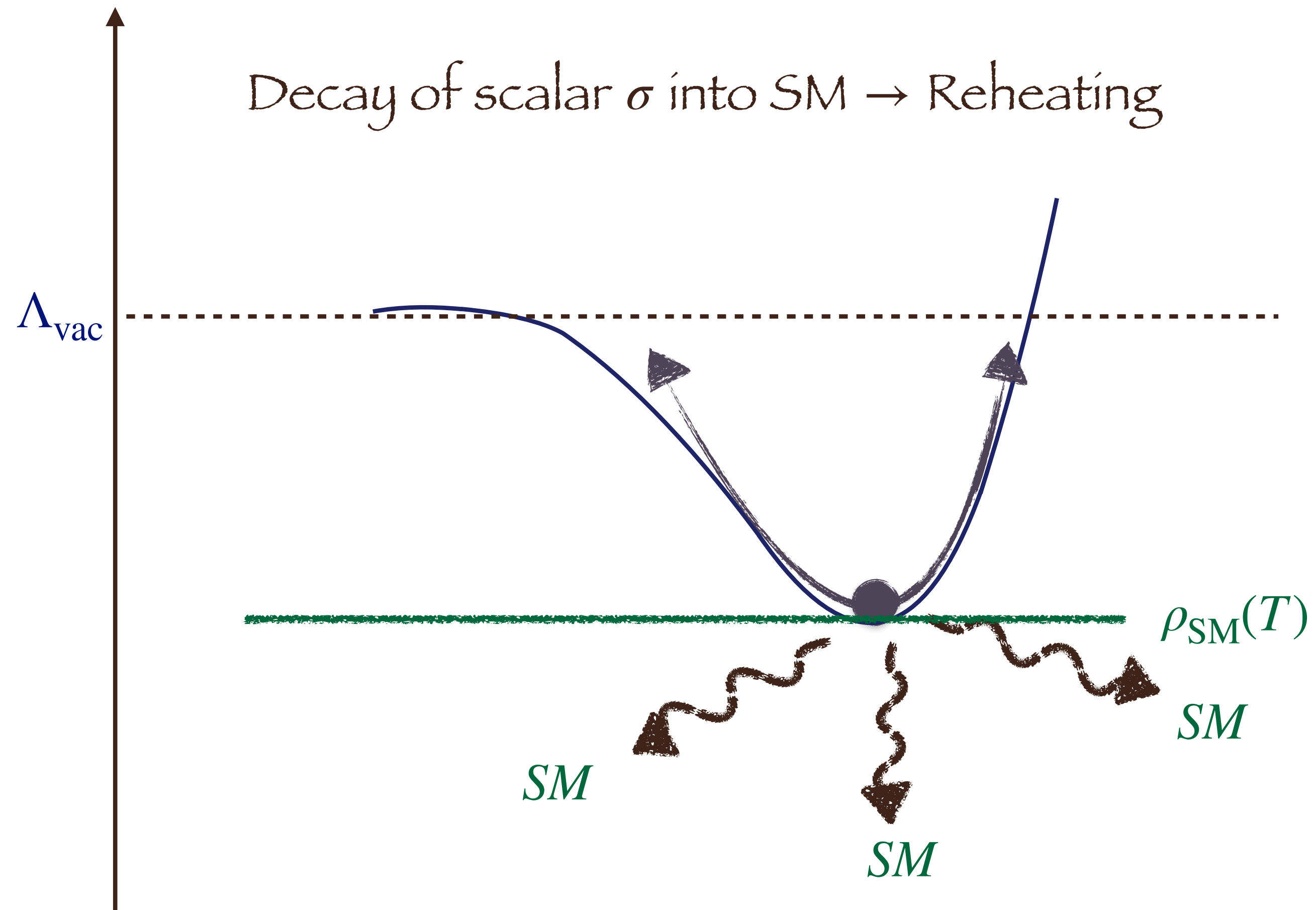
$$H \equiv \frac{\dot{a}}{a} = \frac{1}{M_{\text{Pl}}} \sqrt{\rho_{\text{rad}} + \Lambda_{\text{vac}}} \quad \rho_{\text{rad}} \approx T^4$$

End of Vacuum Energy Domination



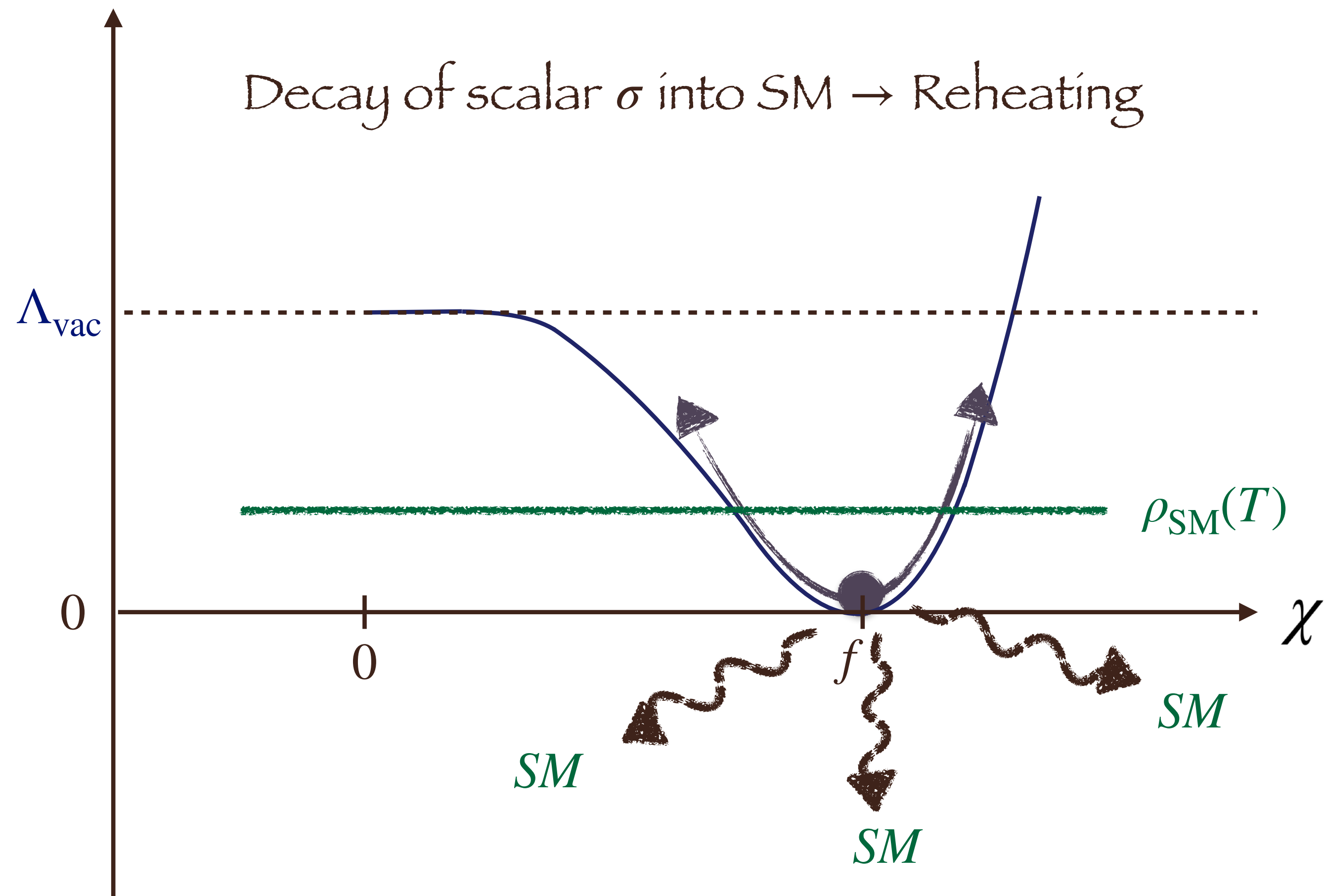
animation by Yann Gouttenoire

End of Vacuum Energy Domination



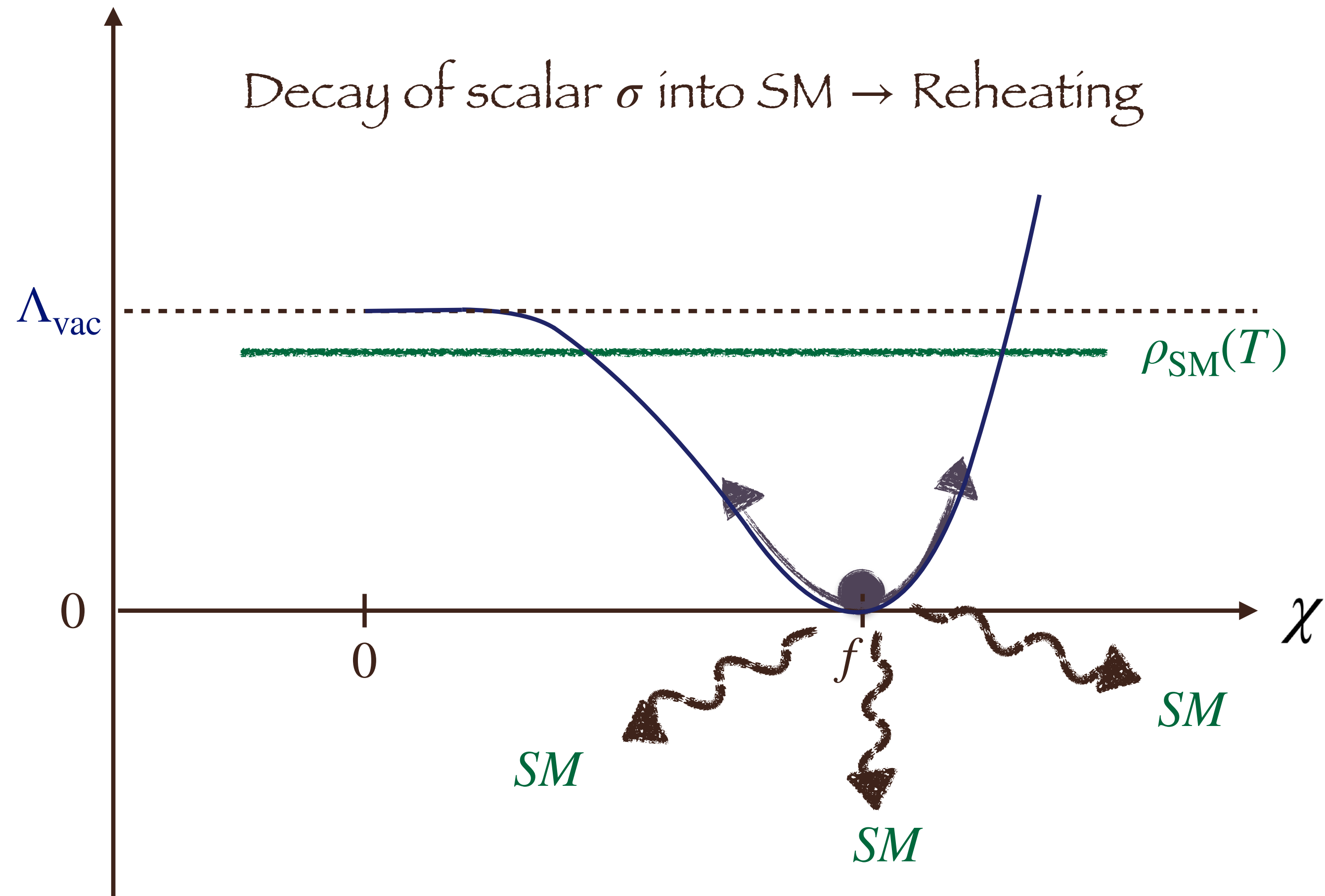
animation by Yann Gouttenoire

End of Vacuum Energy Domination



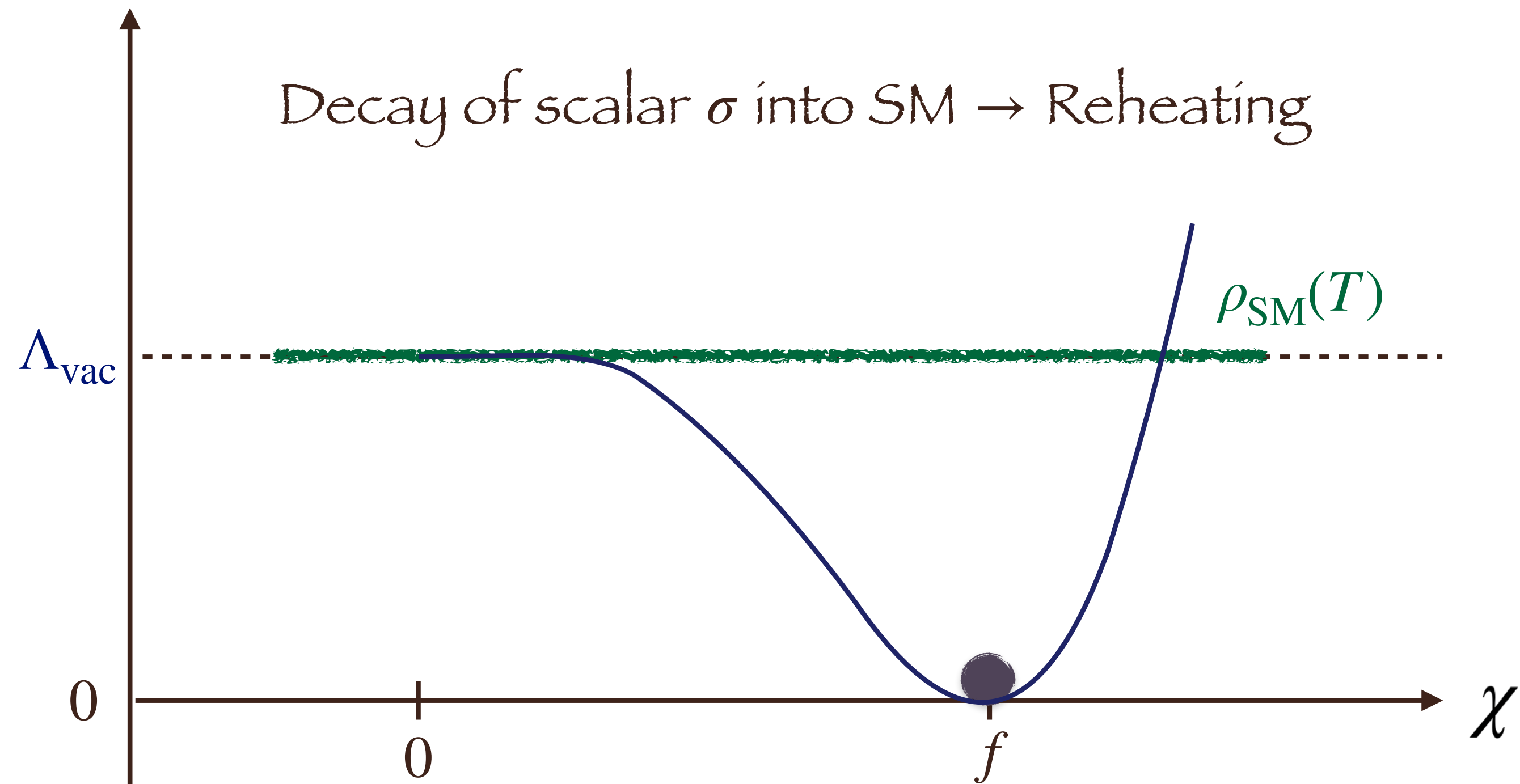
animation by Yann Gouttenoire

End of Vacuum Energy Domination



animation by Yann Gouttenoire

End of Vacuum Energy Domination



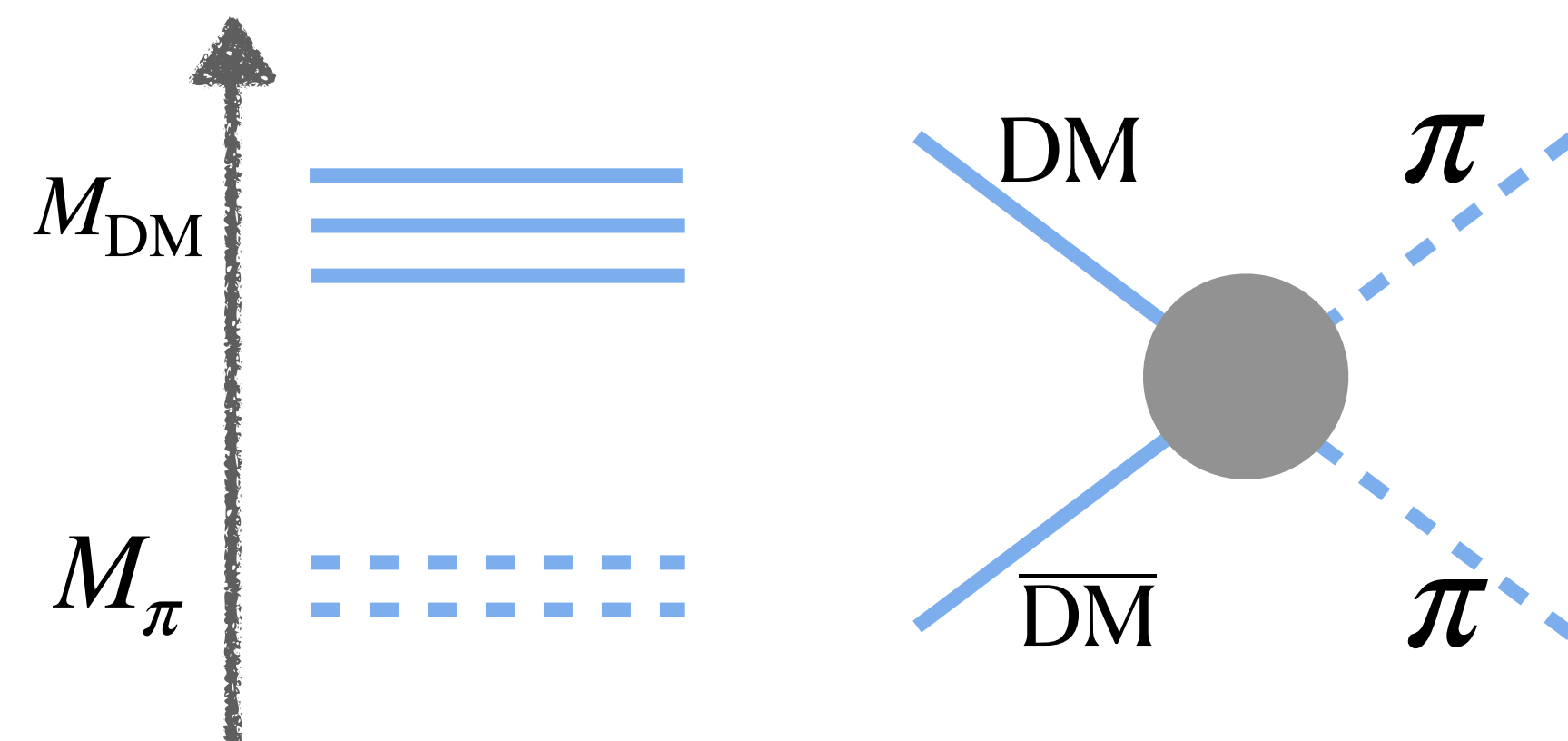
animation by Yann Gouttenoire

Net effect: dilution by

$$D^{\text{SC}} = \left(\frac{a_{\text{end}}}{a_{\text{start}}} \right)^3 \sim \left(\frac{f}{T_{\text{nuc}}} \right)^3$$

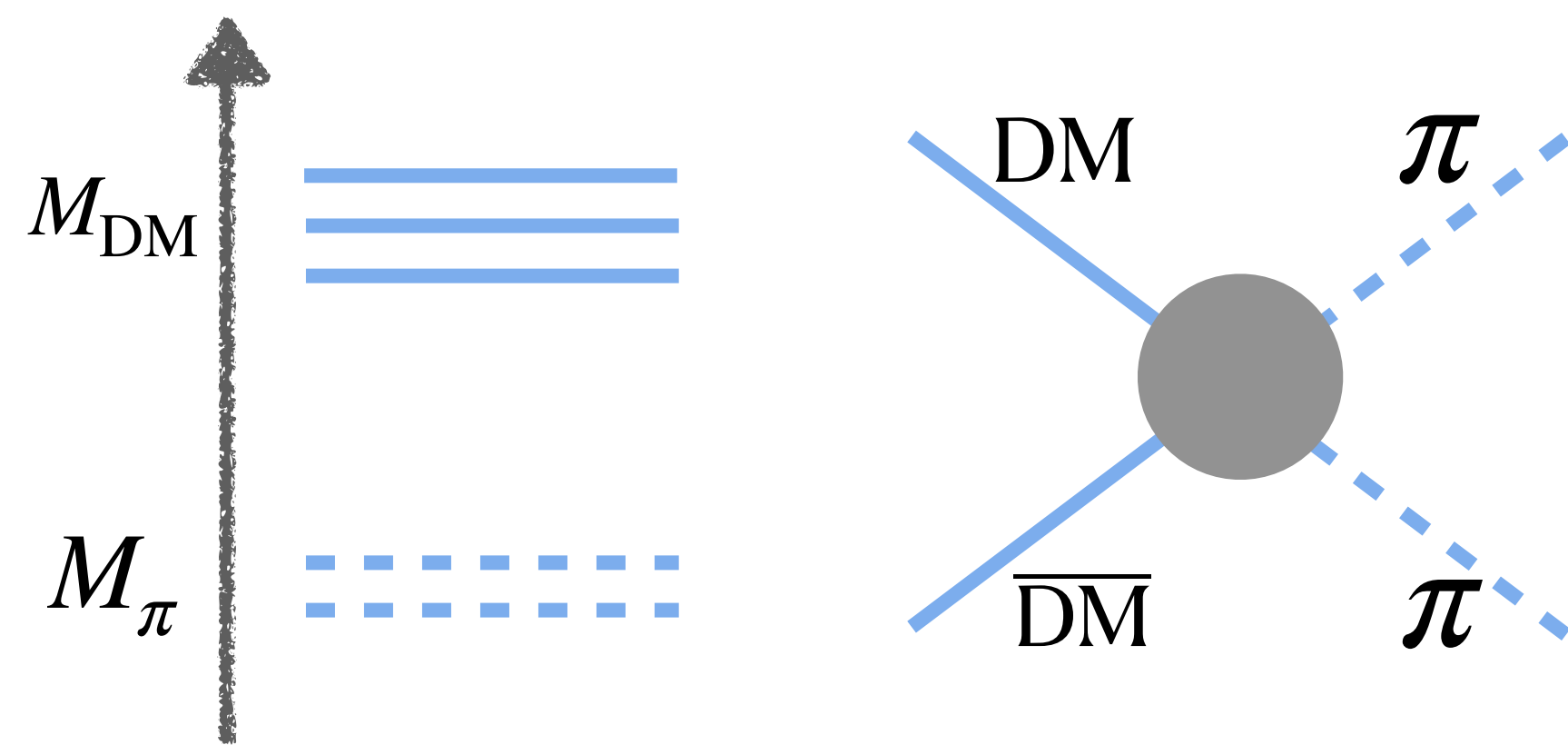
Vacuum Energy Domination & Secluded DM

These Phase Transitions predicted
in some confining theories

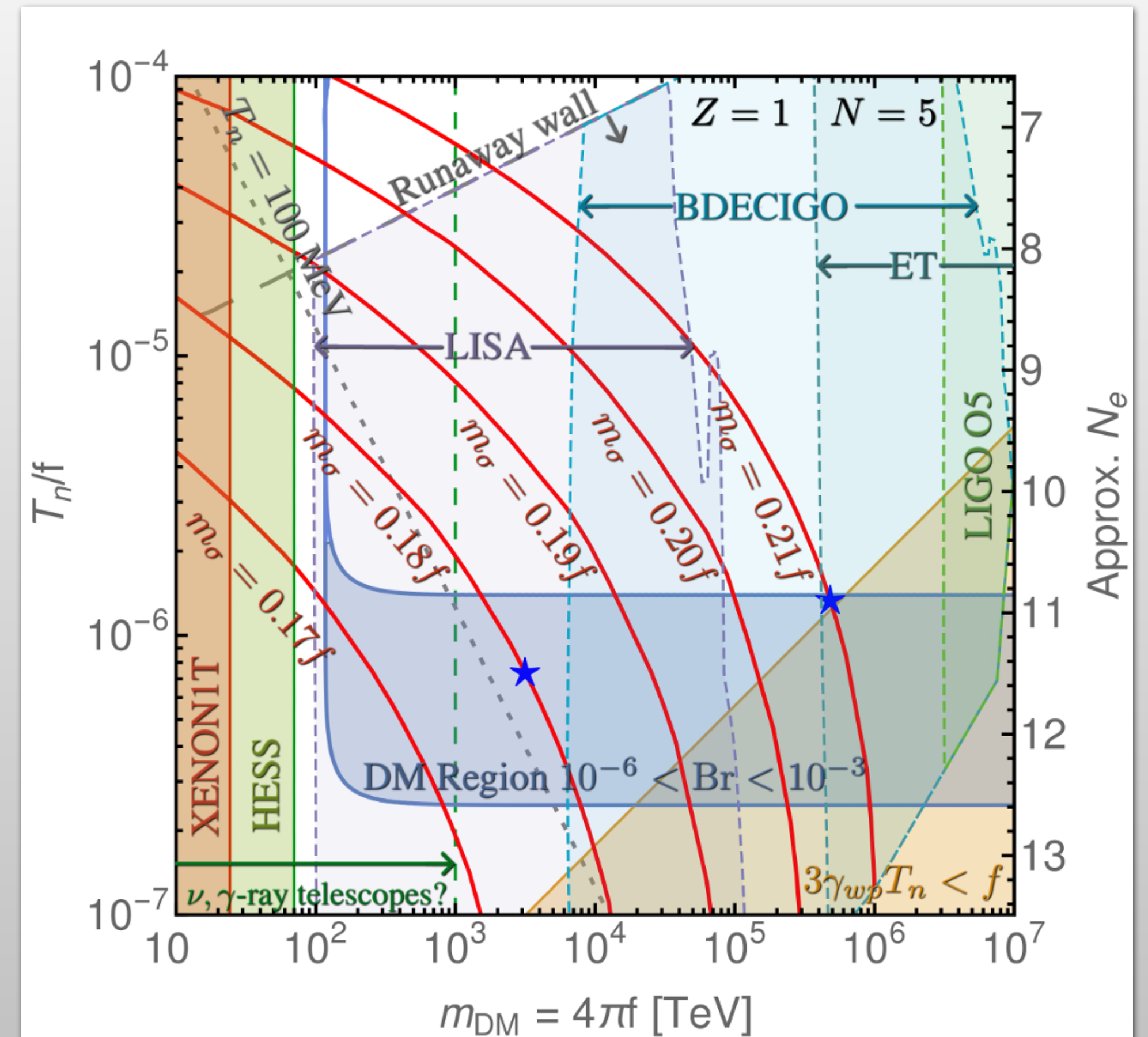


Vacuum Energy Domination & Secluded DM

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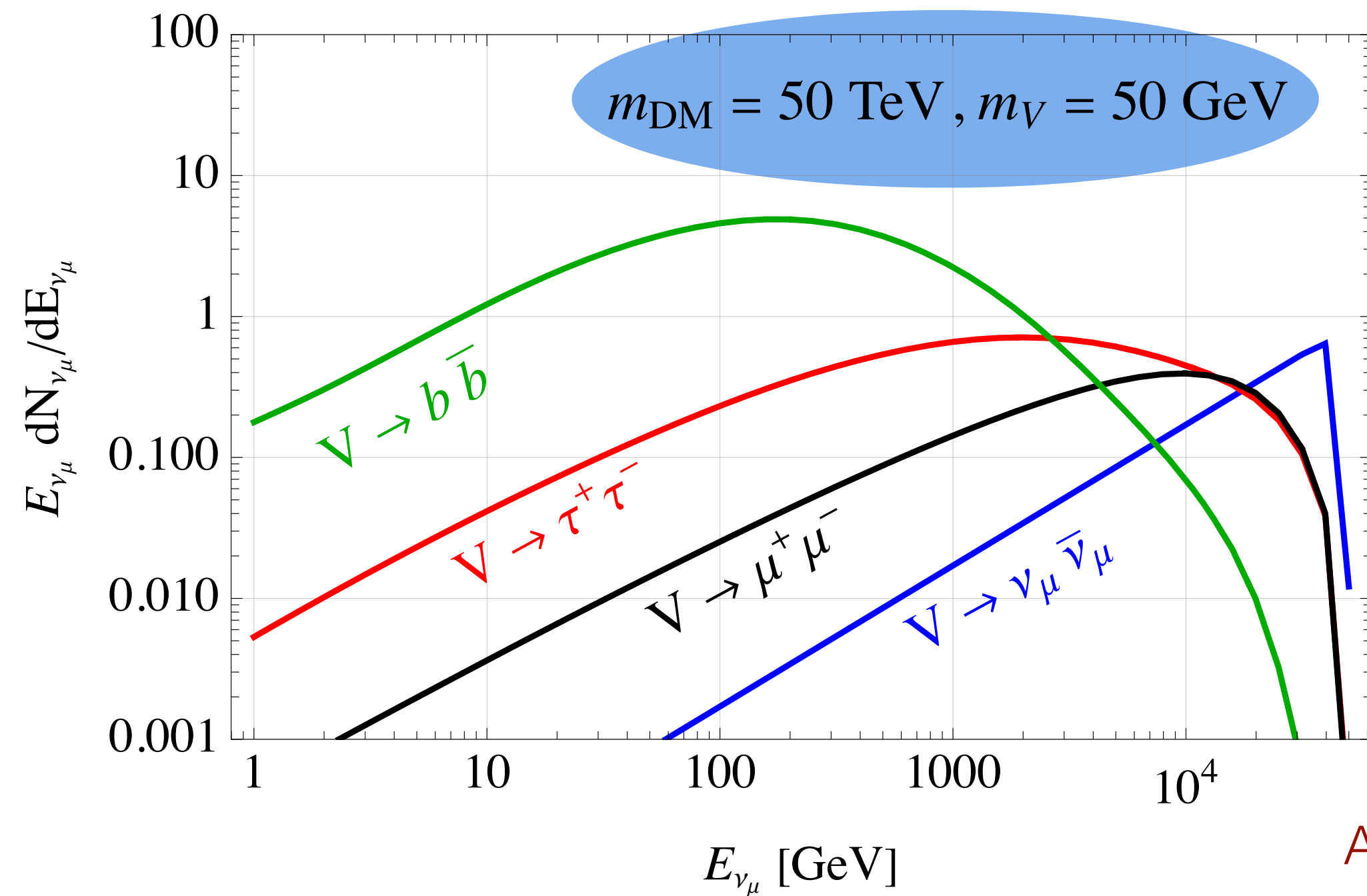
Cosmic Rays + Gravity Waves!



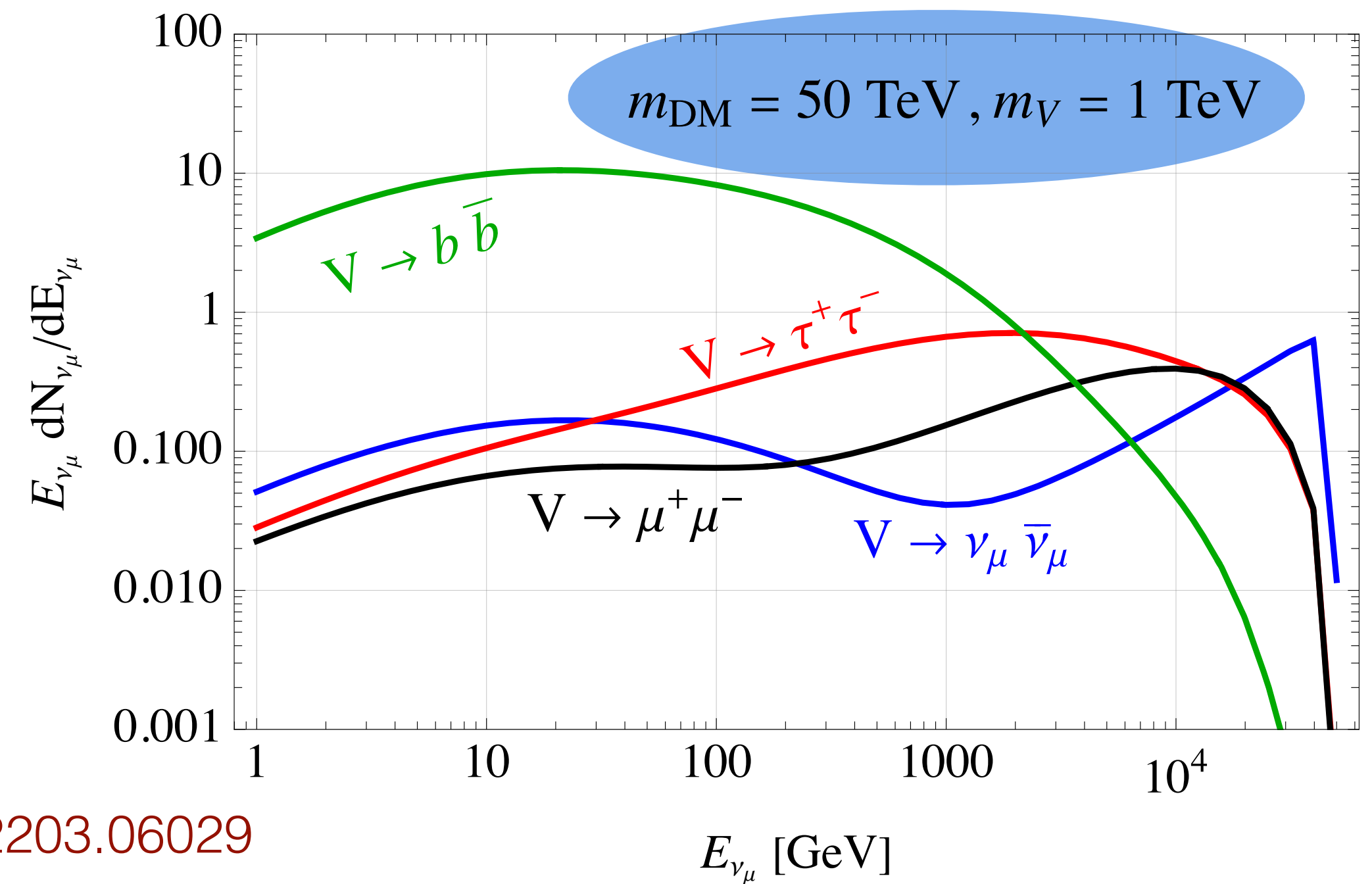
Baldes Gouttenoire FS 2007.08440, +Servant 2110.13926

At Neutrino Telescopes

Neutrino Spectra from Secluded DM



ANTARES 2203.06029

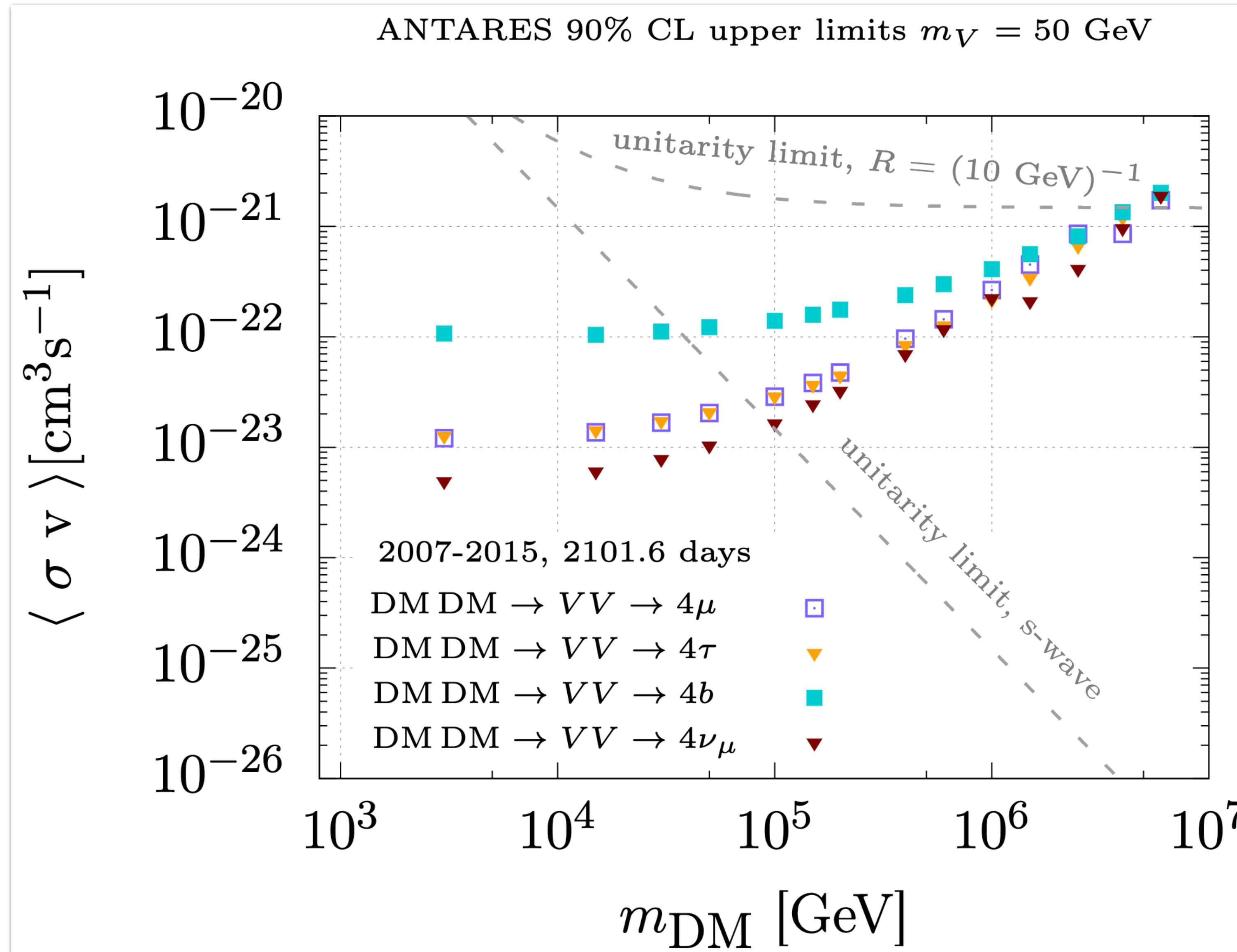


1. Can be predicted with `PPPC` or `Pythia`, mediator mass matters!

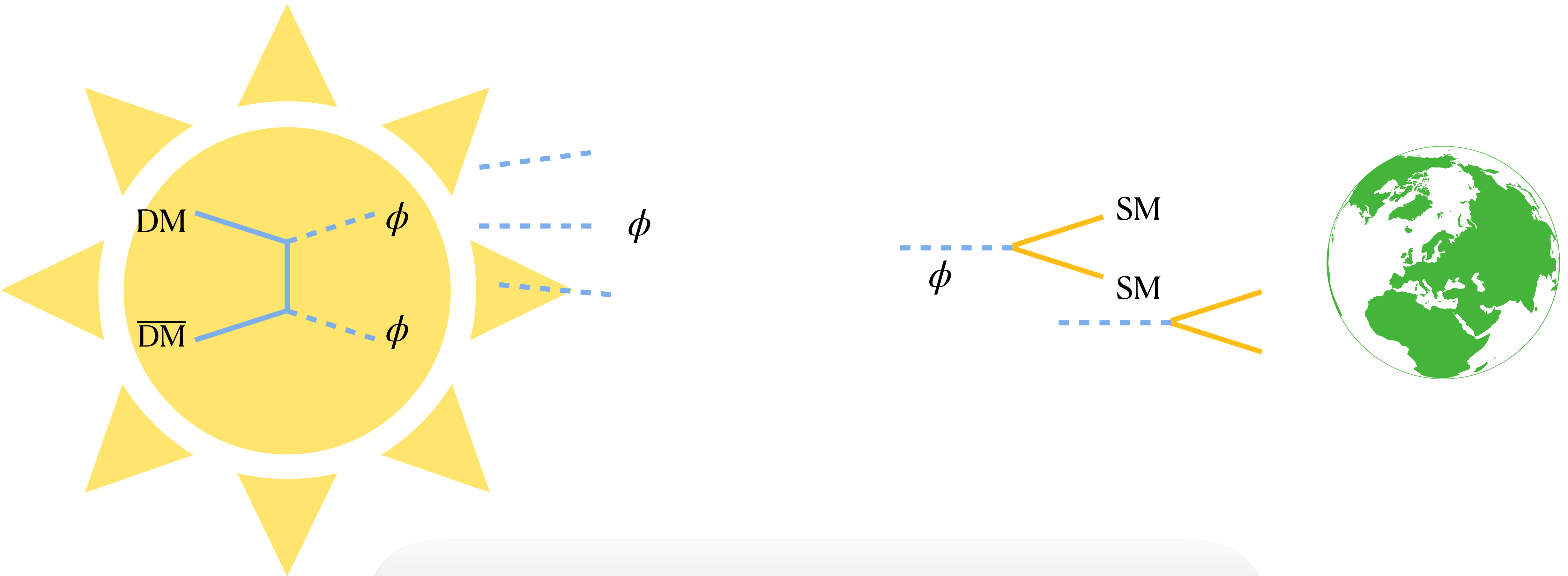
2. Either dedicated searches, or **make data public & usable**

ANTARES search for Secluded DM

ANTARES 2203.06029



Bonus: Secluded DM from the Sun



=/ works only for limited lifetimes of ϕ

=) can test direct detection of $M_{DM} \gg \text{TeV}$

Balaji Petraki Sachdeva FS
in progress

Why Secluded Dark Matter?

