Leptophilic Dark Matter from Gauged Lepton Number

Phenomenology and Gravitational Wave Signatures

arXiv:1809.09110

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in collaboration with Pedro Schwaller

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Gauged Lepton Number

[Schwaller, Tait, Vega-Morales (2013)]

SM + RH-ν

+ $U(1)_\ell$ lepton number gauge group	$\Longrightarrow$	Z' gauge boson
+ spontaneous lepton number breaking	$\Longrightarrow$	scalar field ϕ
+ anomaly cancellation	$\Longrightarrow$	4 exotic leptons DM candidate

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Phenomenology

- LEP: $m_{Z'} > 200\,\text{GeV},\ v_\Phi > 1880\,\text{GeV}$
- LHC: Z' searches, Higgs measurements,
  exotic lepton searches
- DM: relic density, direct/indirect detection
- 1st order phase transition $\Longrightarrow$ GW

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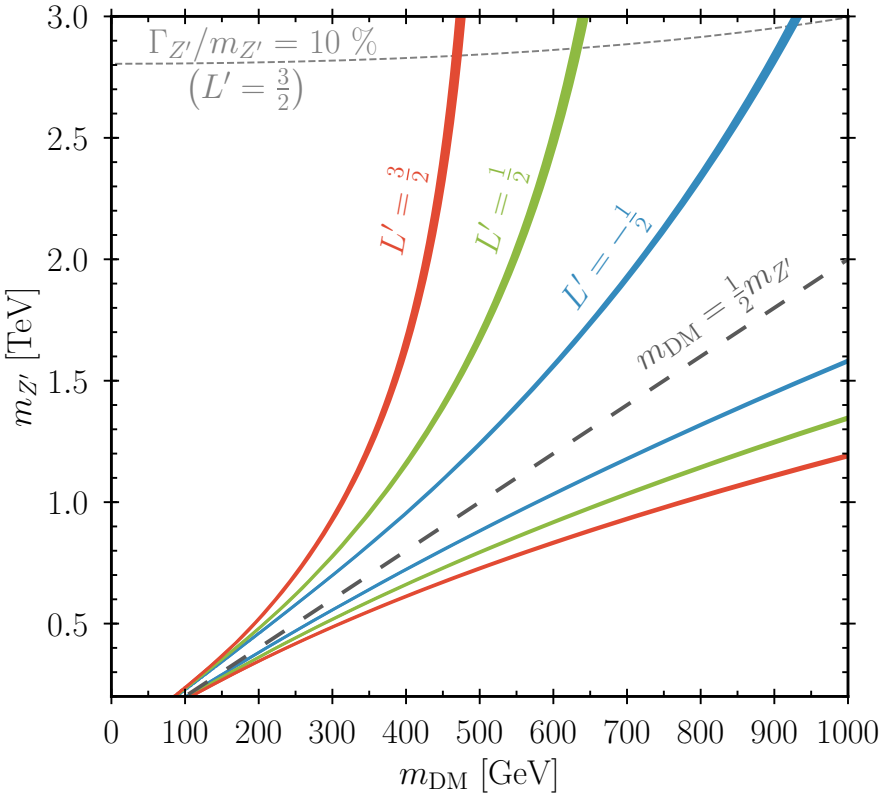
- LEP: $m_{Z'} > 200\,\text{GeV}$, $v_\Phi > 1880\,\text{GeV}$ $\Longrightarrow$ $v_\Phi = 2\,\text{TeV}$
- LHC: Z' searches, Higgs measurements, exotic lepton searches $\leftarrow$ see 1809.09110
- DM: relic density, direct/indirect detection $\leftarrow$ next slide
- 1st order phase transition $\Longrightarrow$ GW $\leftarrow$ main focus

Dark Matter

DM candidate: mostly SM singlet, chiral couplings to Z'

Relic Density



Dark Matter

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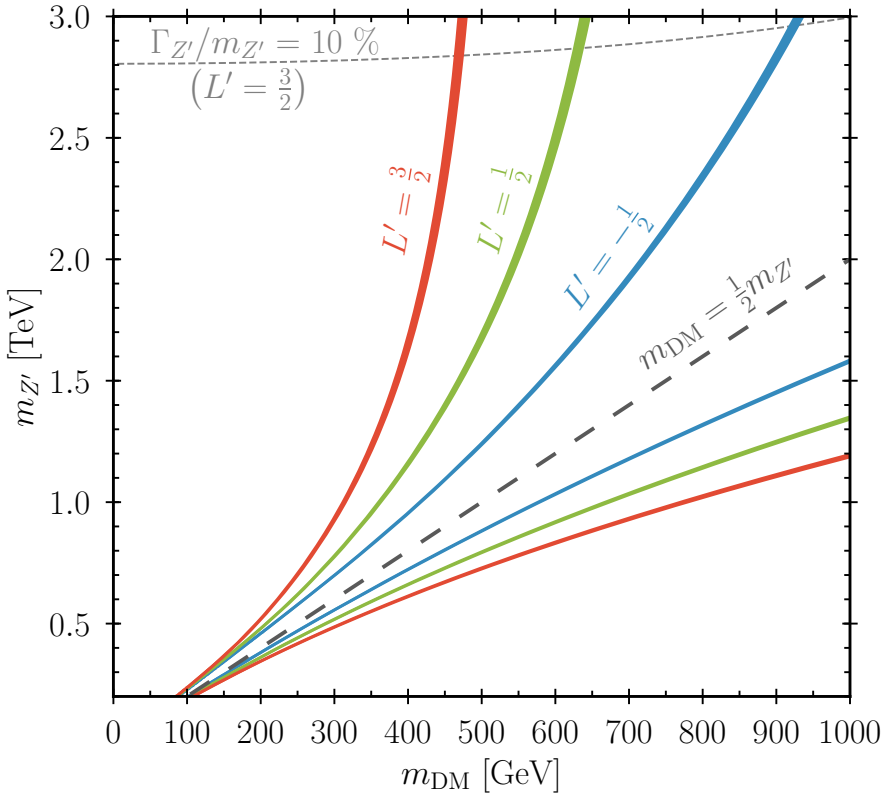
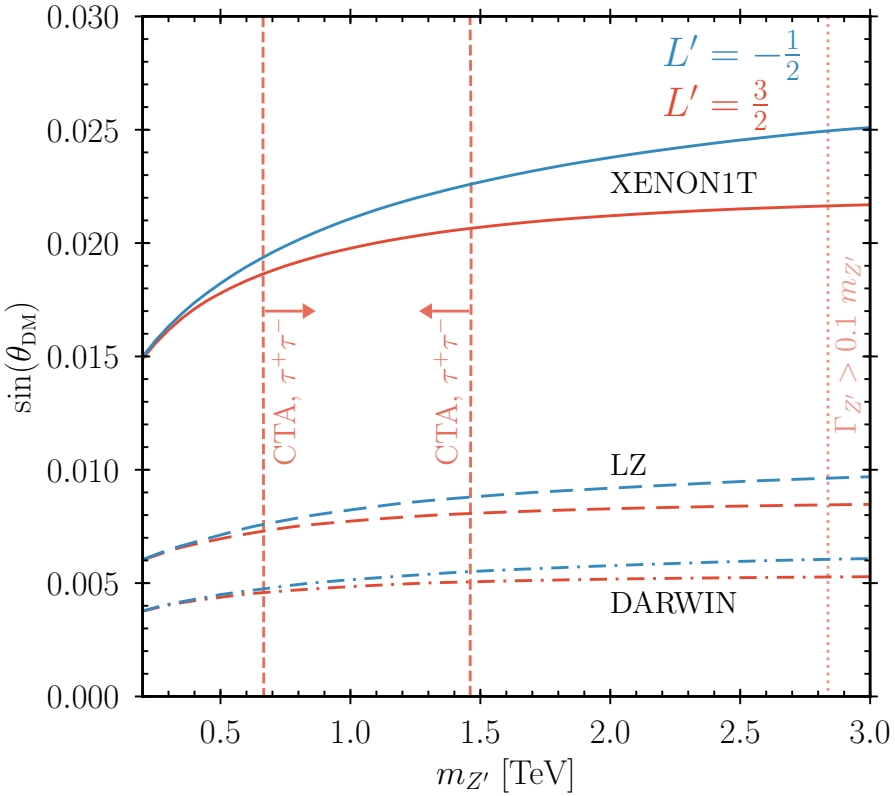
doublet admixture: $\nu_{\text{DM}} = \cos\theta_{\text{DM}}\ \nu_S + \sin\theta_{\text{DM}}\ \nu_D$

Relic Density



Direct Detection



Cosmological Phase Transitions

finite-T corrections restore symmetry at high T

$\Longrightarrow$ symmetry breaking phase transition in the early Universe

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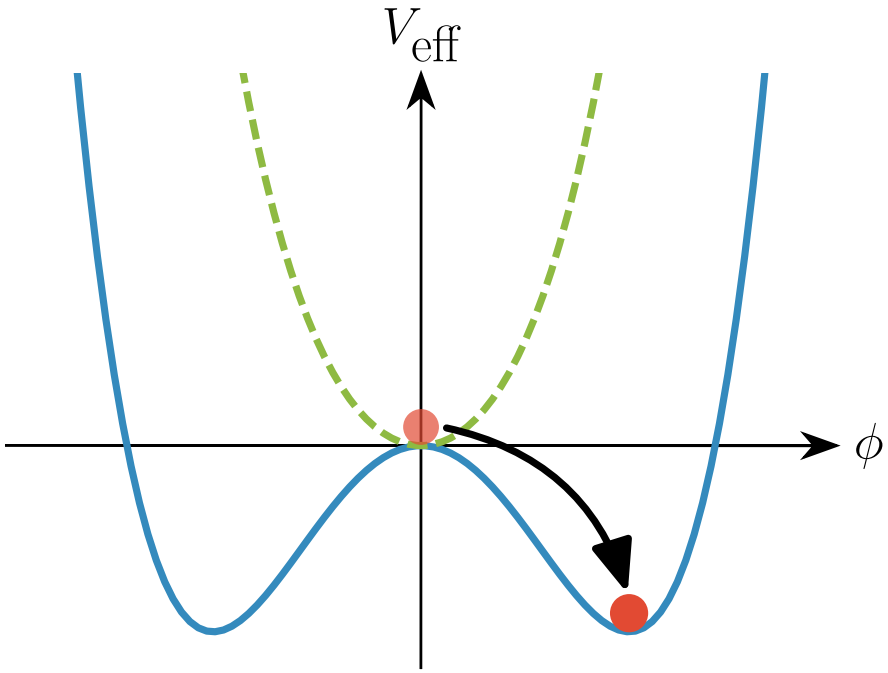
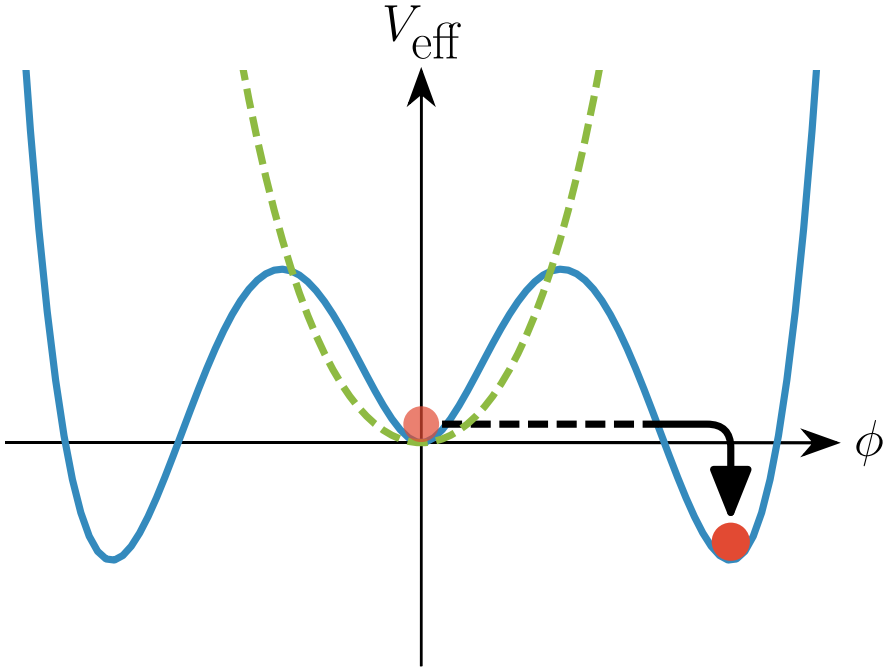


1st-order:



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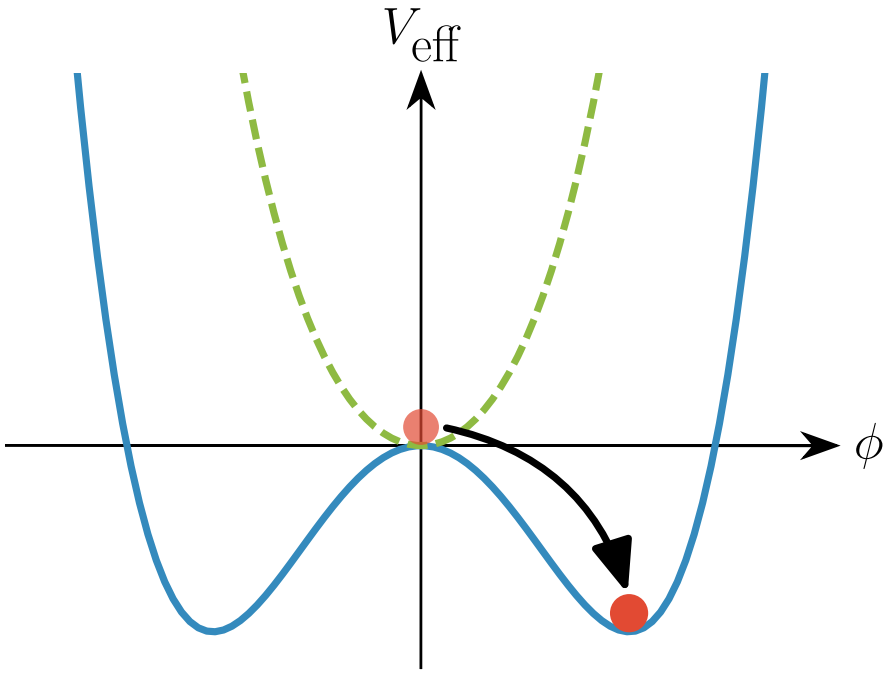

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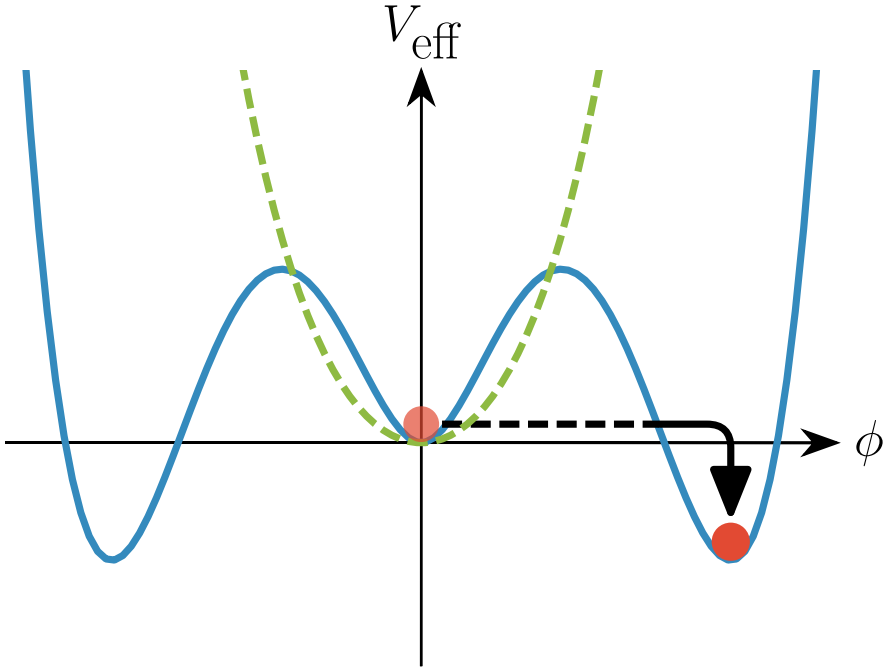


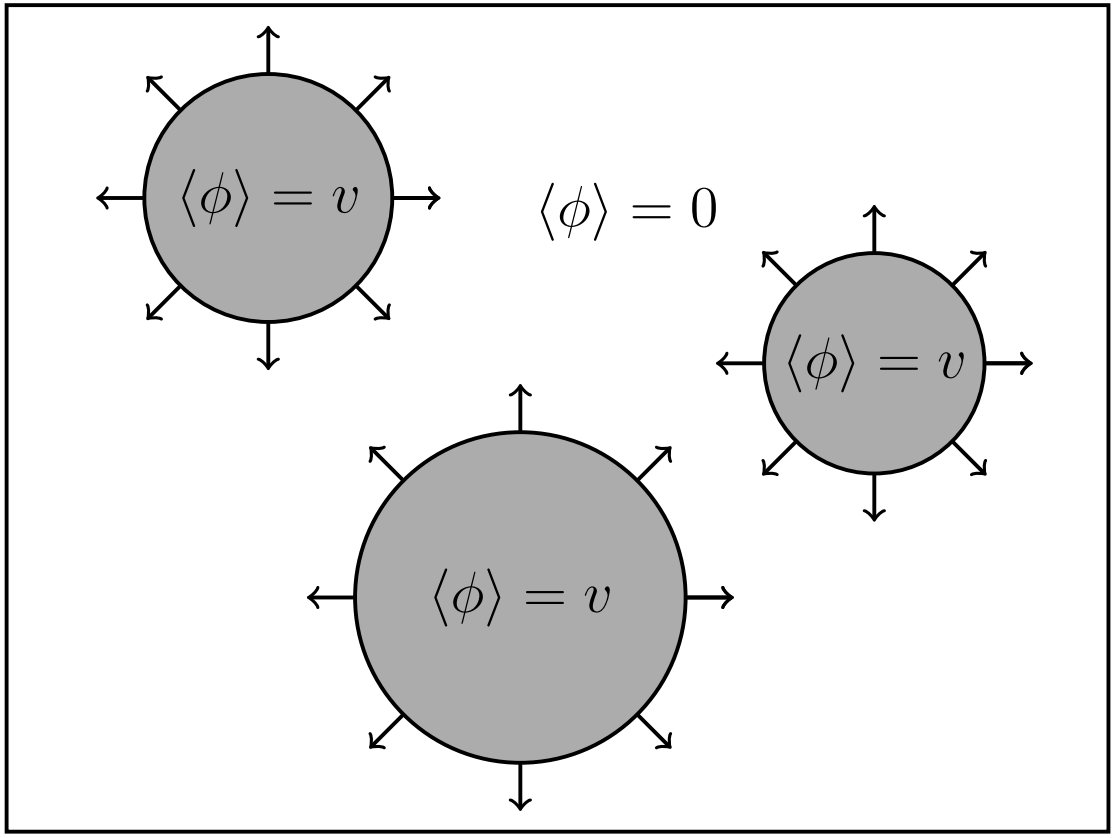
Gravitational Waves only from 1st-order Transition!

1st-Order Phase Transition

high- and low-T minima separated by barrier

$\Longrightarrow$ 1st-order PT via tunneling

$\Longrightarrow$ bubble nucleation



Nucleation Temperature

- nucleation rate $\longleftrightarrow$ Hubble expansion
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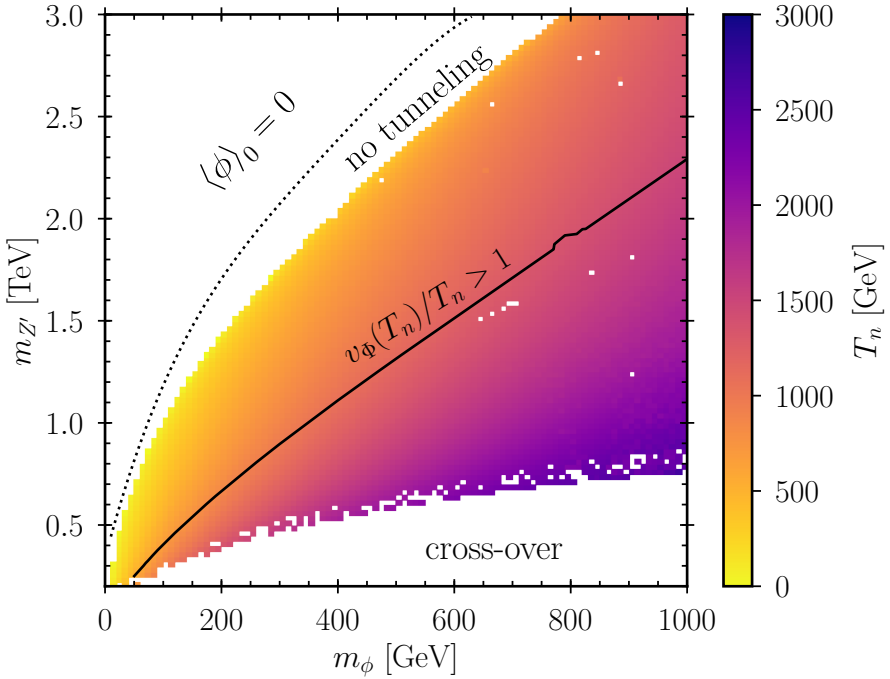

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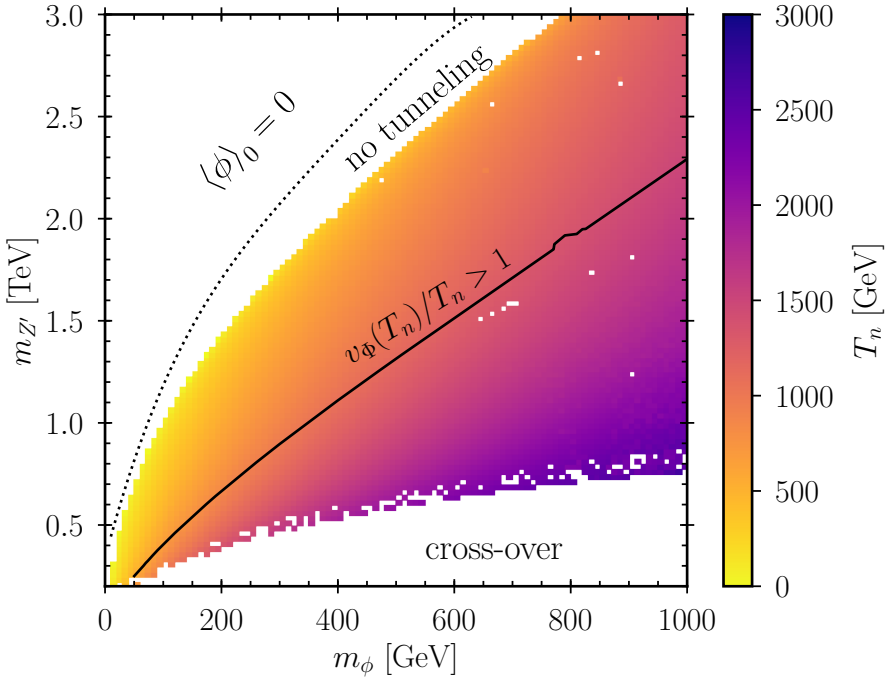
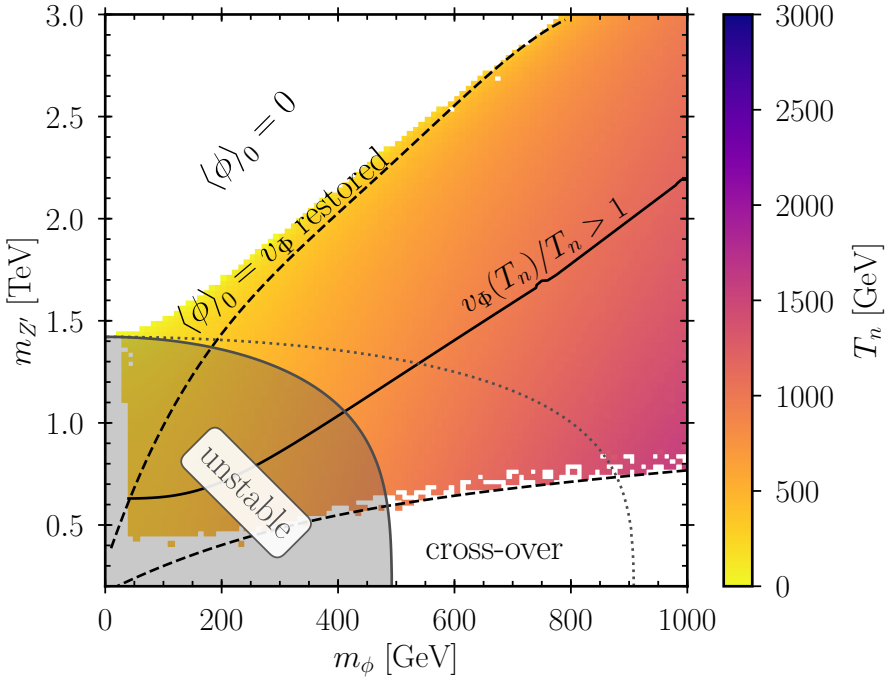


without dark leptons

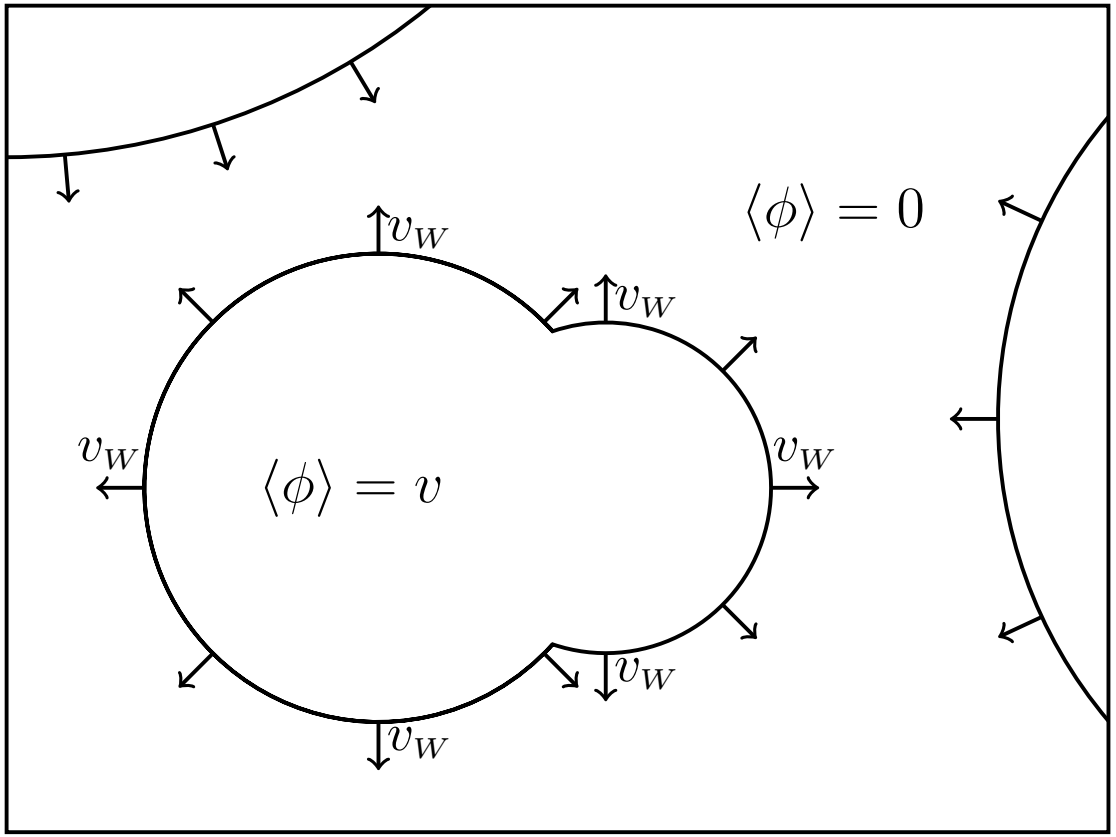


$m_{\mathsf{DM}} = 500$ GeV, $m_{\mathsf{HL}} = 1$ TeV

Gravitational Waves

GW spectrum: $h^2\Omega_{\mathsf{GW}}(f) \simeq h^2\Omega_\phi(f) + h^2\Omega_{\mathsf{sw}}(f) + h^2\Omega_{\mathsf{turb}}(f)$

- $h^2\Omega_\phi(f)$: collision of bubble walls



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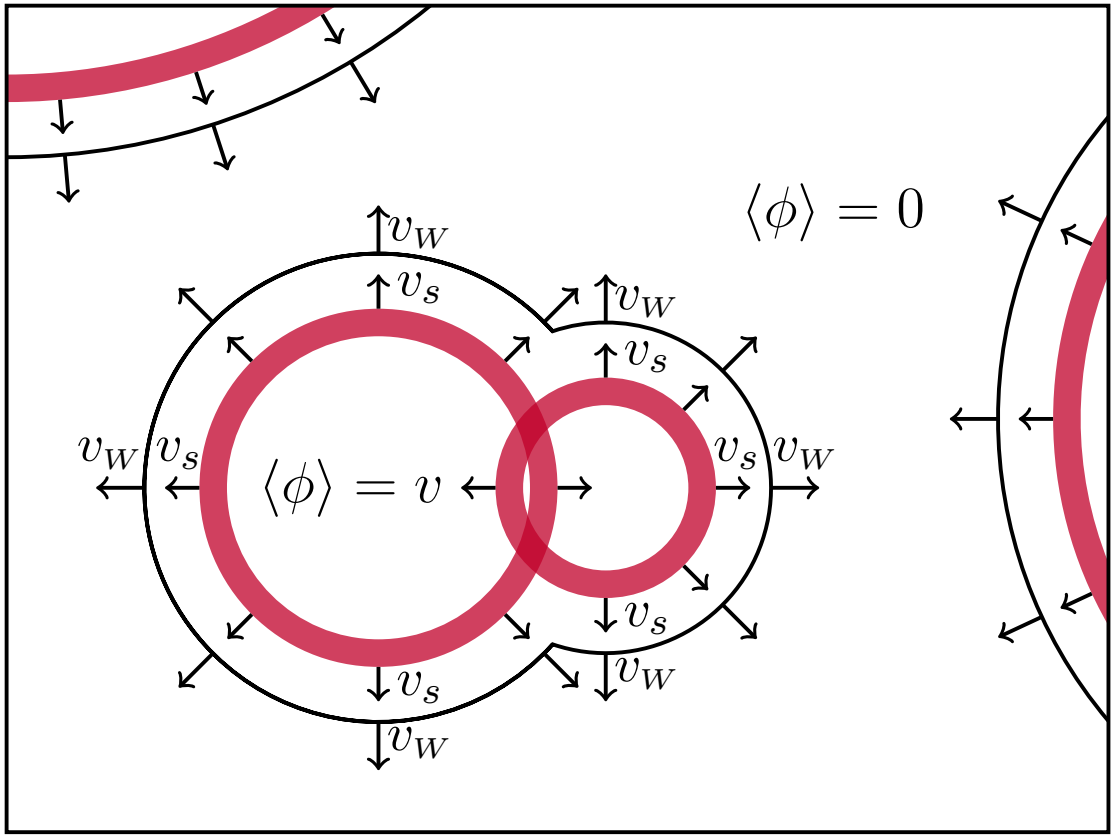
- $h^2\Omega_{\mathsf{sw}}(f)$: sound waves in the plasma



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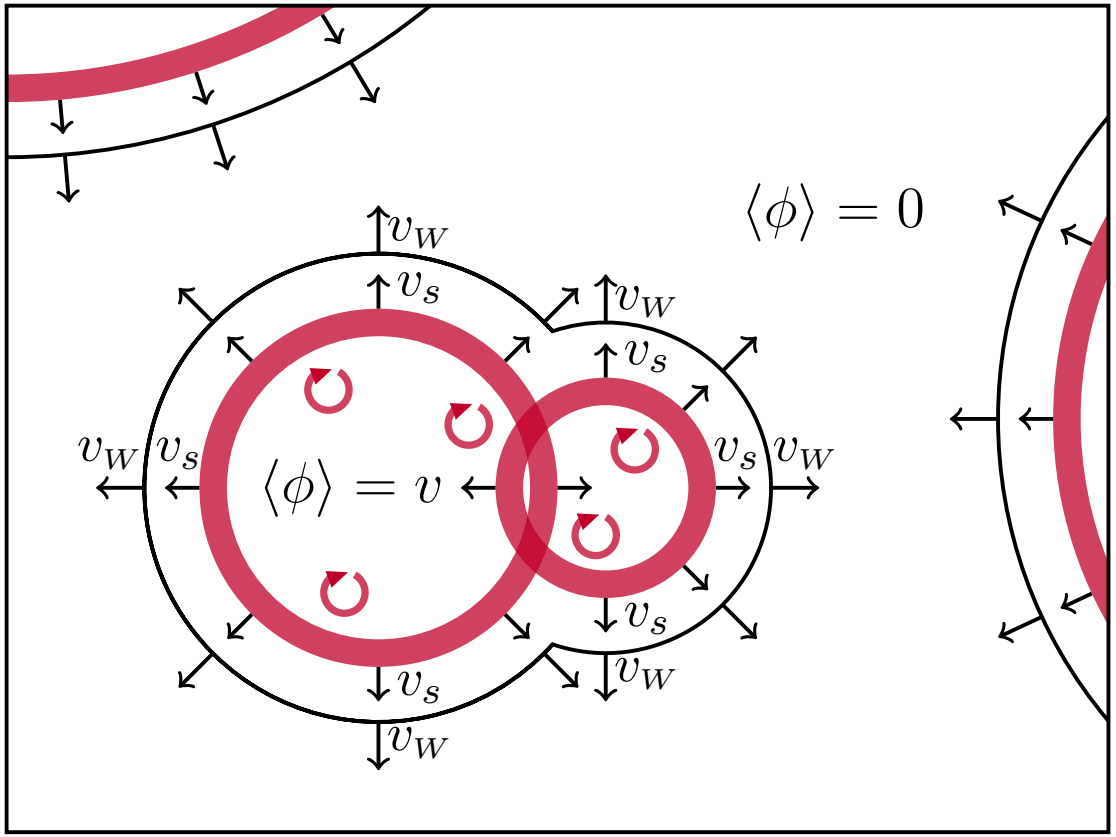
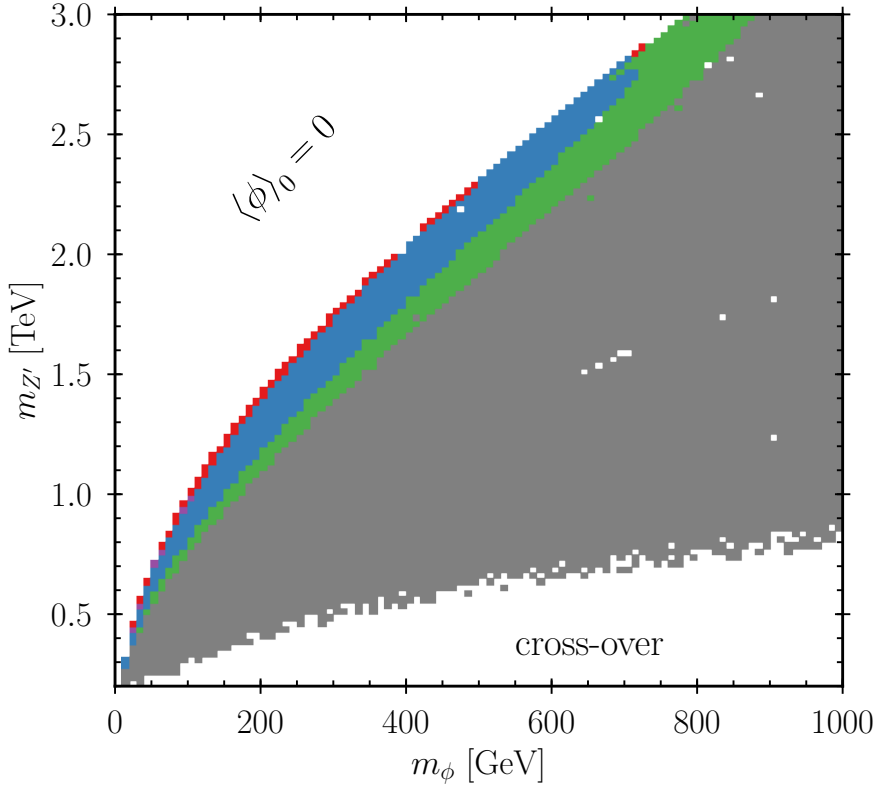
- $h^2\Omega_{\text{sw}}(f)$: sound waves in the plasma
- $h^2\Omega_{\text{turb}}(f)$: turbulence, vortical fluid motion



Detectability

neglecting dark leptons



LISA B-DECIGO DECIGO BBO

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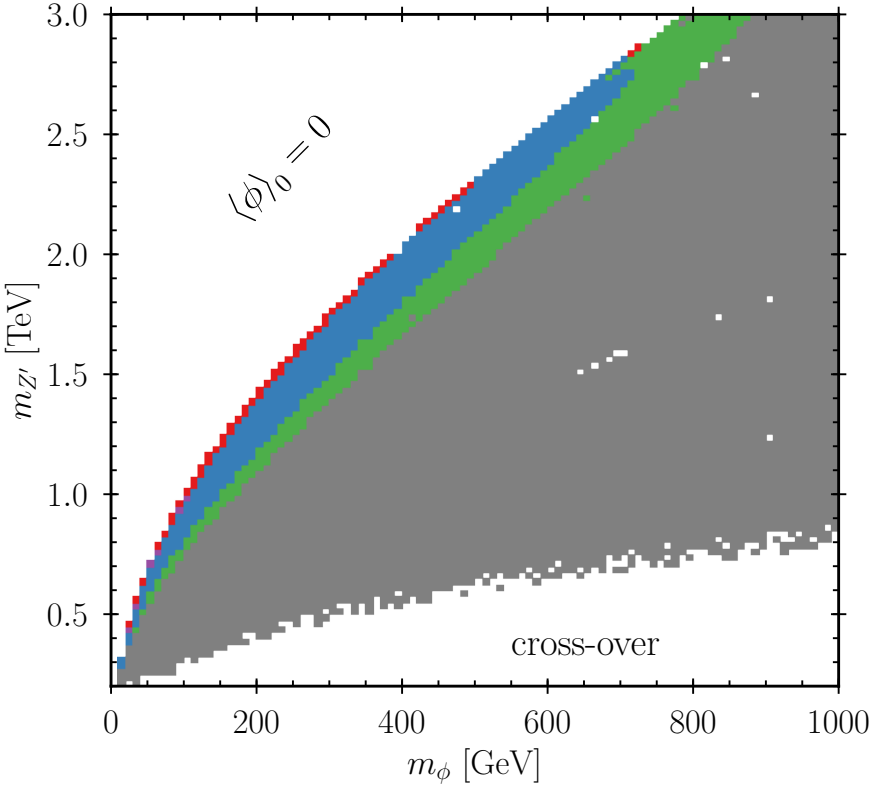
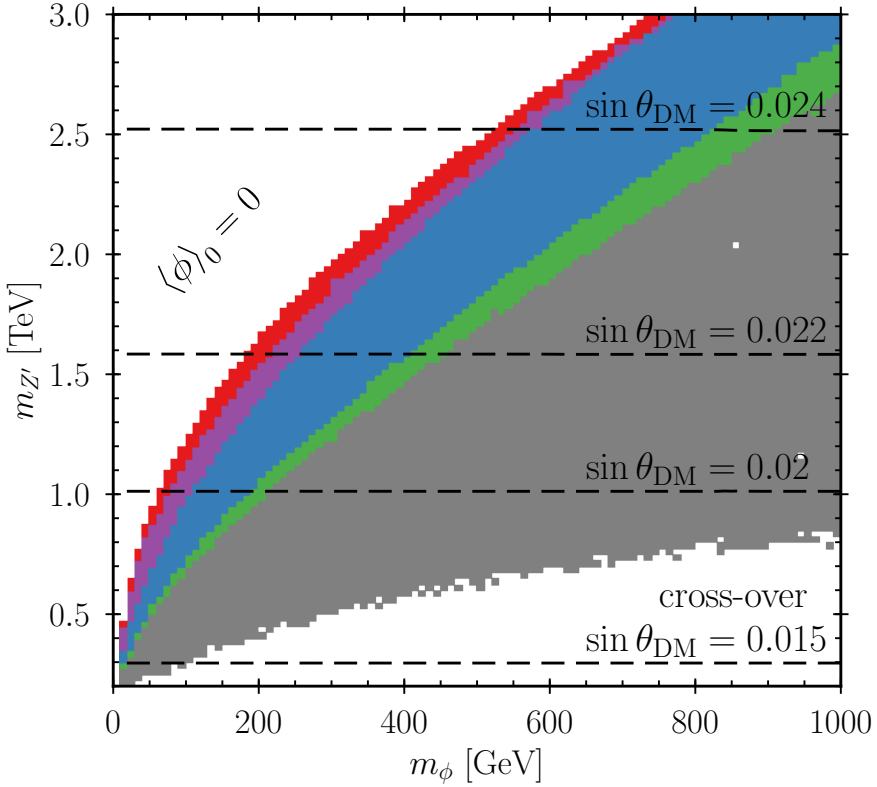


including dark leptons



$h^2\Omega_{\rm DM} = 0.1198,\ m_{\rm HL} = 1.5 \times m_{\rm DM}$

LISA B-DECIGO DECIGO BBO

Summary

- SM + $U(1)_\ell$ + vector-like leptons (provide DM candidate)
- Constraints:

  LEP-2: $v_\Phi > 1880$ GeV
  LHC: Higgs measurements, Z' searches
  Direct Detection: mixing angles

- ℓ breaking PT can be 1st order
- generated stochastic GW background can be probed by future experiments (LISA, B-DECIGO, DECIGO, BBO)
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Thank you for your attention!