Gravitational waves from spin-one dark matter

Camilo Garcia Cely

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In collaboration with Iason Baldes
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Dark matter as massive dark gauge bosons

General idea

- Hypothesis: Dark matter are massive gauge bosons. Phase transition in the Early Universe.

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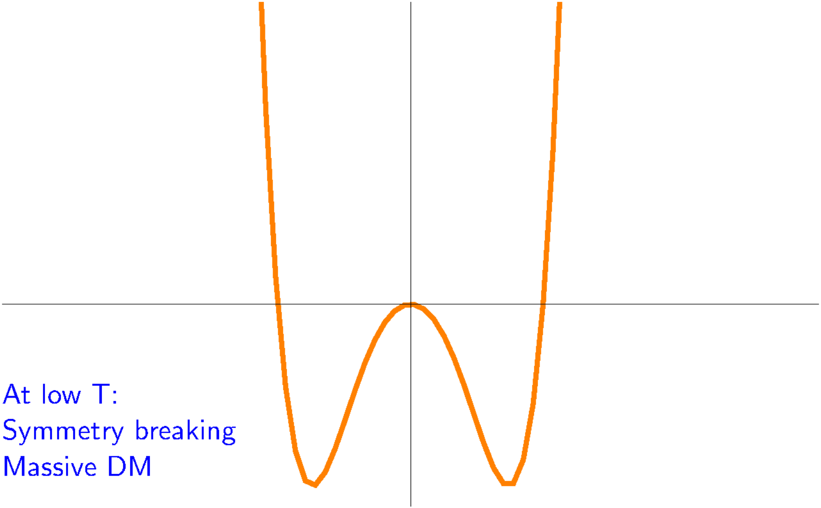
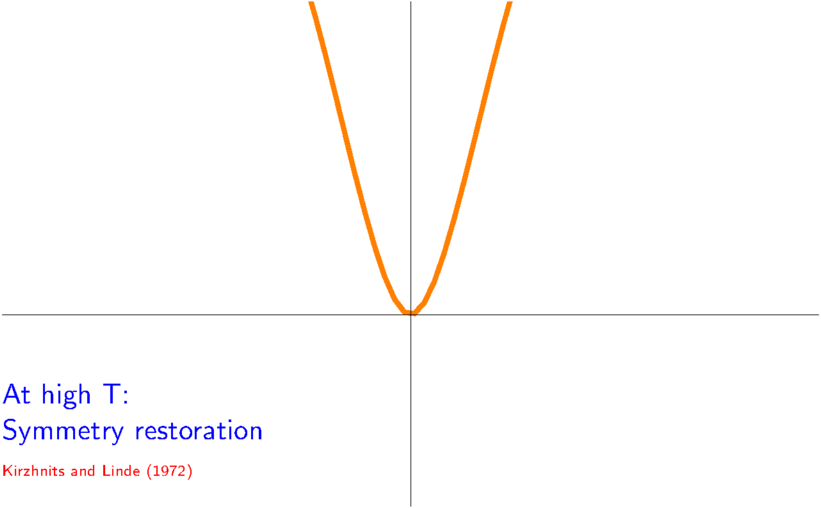
- First order $\rightarrow$ they produce gravitational waves.

First-order phase transition



At low T:
Symmetry breaking
Massive DM

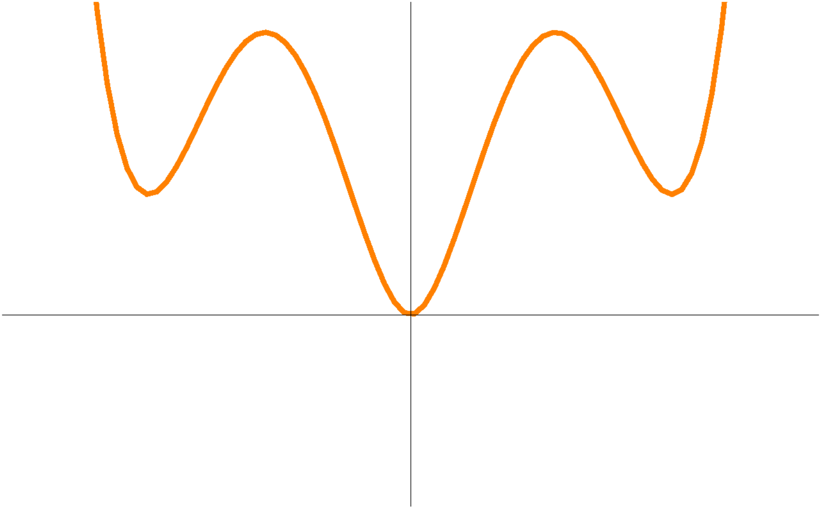
First-order phase transition



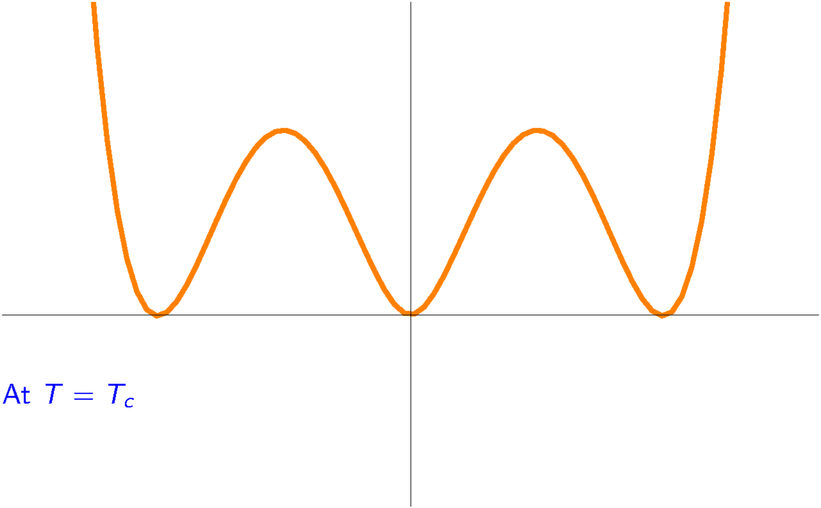
At high T:
Symmetry restoration

Kirzhnits and Linde (1972)

First-order phase transition

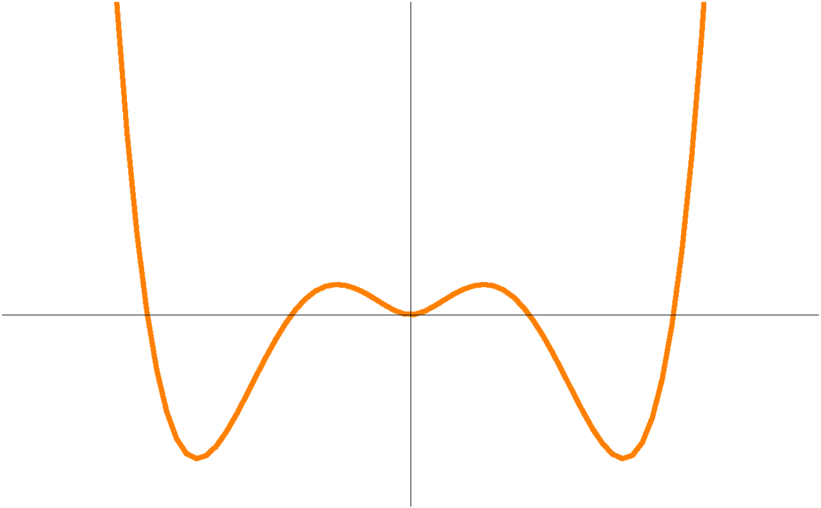


First-order phase transition

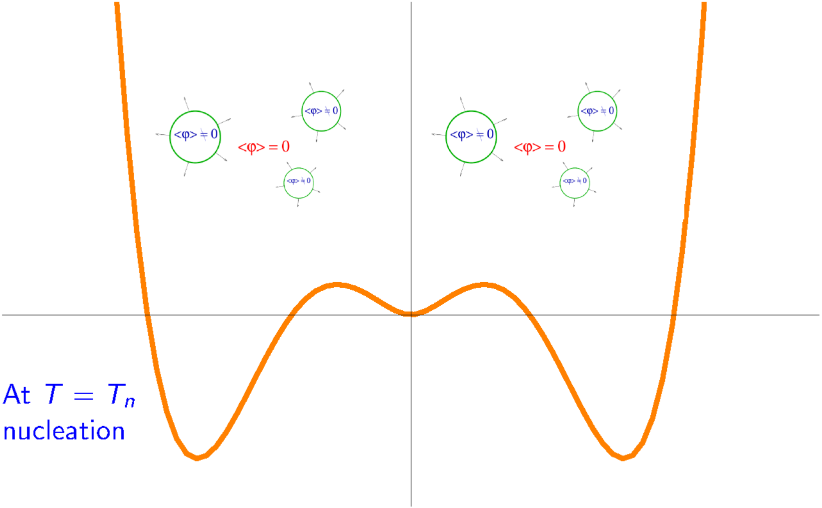


At $T = T_c$

First-order phase transition

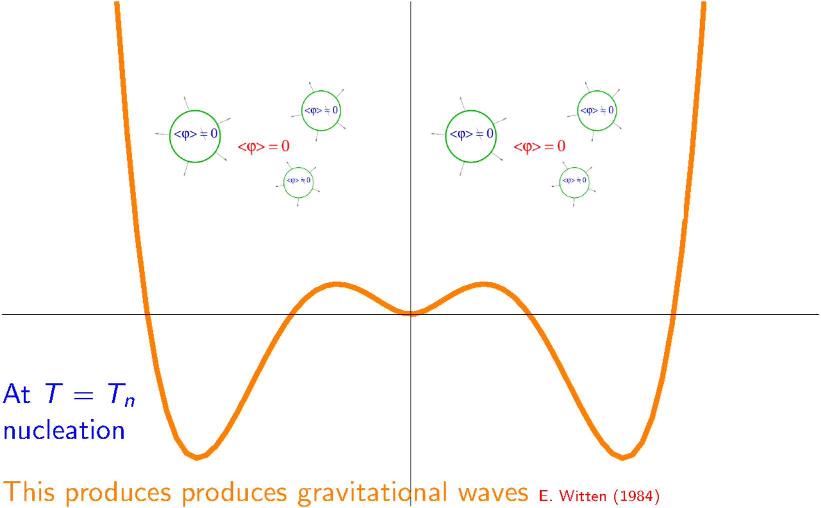


First-order phase transition



At $T = T_n$
nucleation

First-order phase transition



At $T = T_n$
nucleation

This produces produces gravitational waves E. Witten (1984)

First-order phase transition

At low T:
Massive DM
GWs redshift.

First-order phase transition

$m_{\mathrm{DM}} \sim 1$ TeV
$\rightarrow f \sim 10^{-2}$ Hz

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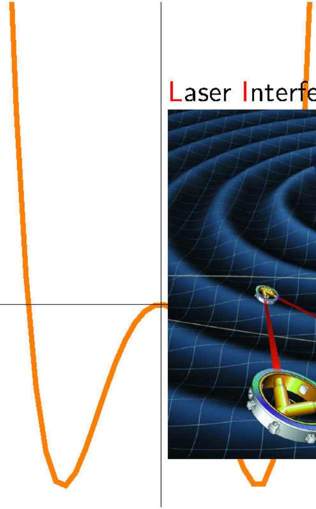
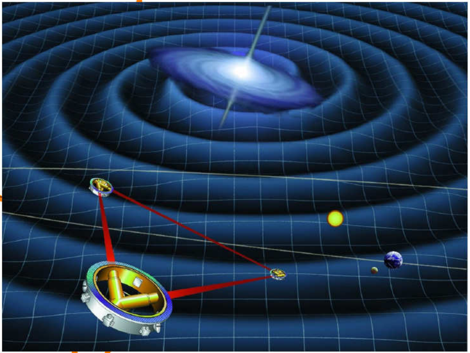


Laser Interferometer Space Antenna



Caprini et al (2015)

Focus on a scenario based on a $SU(2)_D$ group

Field	$SU(3)$	$SU(2)$	$U(1)_Y$	$SU(2)_D$
H	1	2	$\frac{1}{2}$	0
H_D	1	1	0	2

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Local $SU(2)_D$ $\rightarrow$ Global $SO(3)$
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Dark doublet H_D $\rightarrow$ Higgs-like h_D

Hambye (JHEP 2009)

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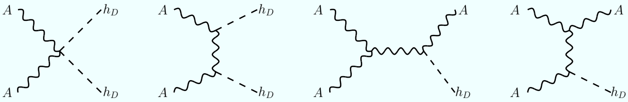
High temperatures		Low temperatures	

Hambye (JHEP 2009) Phase transition in the Early Universe!!!!!!!!!!!

Four parameters

- DM mass
- Higgs-like mass
- mixing angle. Direct detection in Xenon1T: $\theta \lesssim 0.1$.
- vev (or g_D) are set by the relic density (via freeze-out):

$$\begin{cases} g_D \approx 0.9 \times \sqrt{\frac{m_A}{1\,\mathrm{TeV}}} \\ v_\eta \approx 2.2\,\mathrm{TeV} \times \sqrt{\frac{m_A}{1\,\mathrm{TeV}}} . \end{cases}$$



GW spectrum

Phase transition parameters

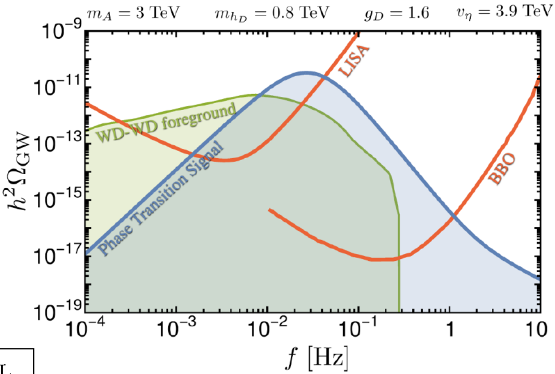
$T_n = 0.48$ TeV

$\eta_n = 3.8$ TeV

$\alpha = 0.29$, ~(latent heat)

$\beta/H = 290$ ~(fq. scale)

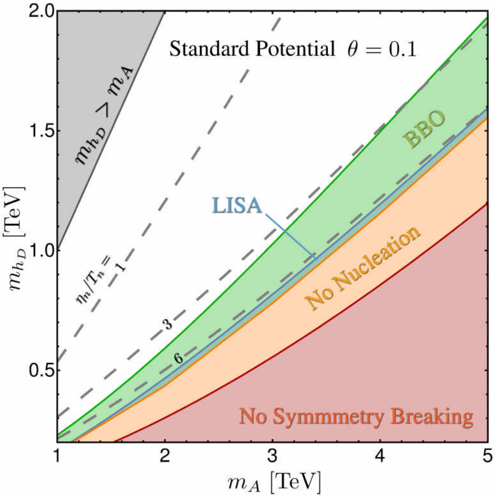
	SNR	SNR_{FGL}
LISA	15	1.8
BBO	3.7×10^5	2.3×10^3



PRELIMINARY

Parameter space for SNR>5.

$$\mathrm{SNR} = \sqrt{t_{\rm obs} \int \left[\frac{h^2\Omega_{\rm GW}(f)}{h^2\Omega_{\rm sens}(f)}\right]^2 df}$$



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Radiative effects break the $SU(2)_D$ symmetry Coleman-Weinberg (1973)
λ_2 runs to negative values.

PRELIMINARY

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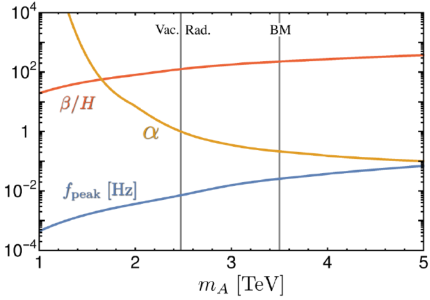

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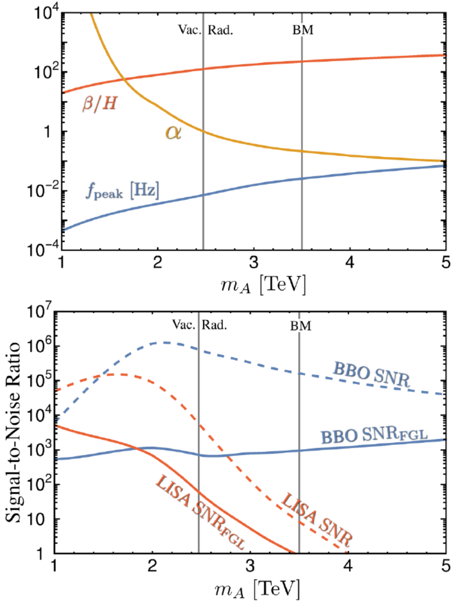

Conclusions

- We have explored the possibility of DM from a hidden $SU(2)_D$ gauge group. This implies a phase transition that will result in detectable gravitational waves.
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Thanks for your attention