Gravitational Waves from Dark Phase Transitions at Strong Coupling

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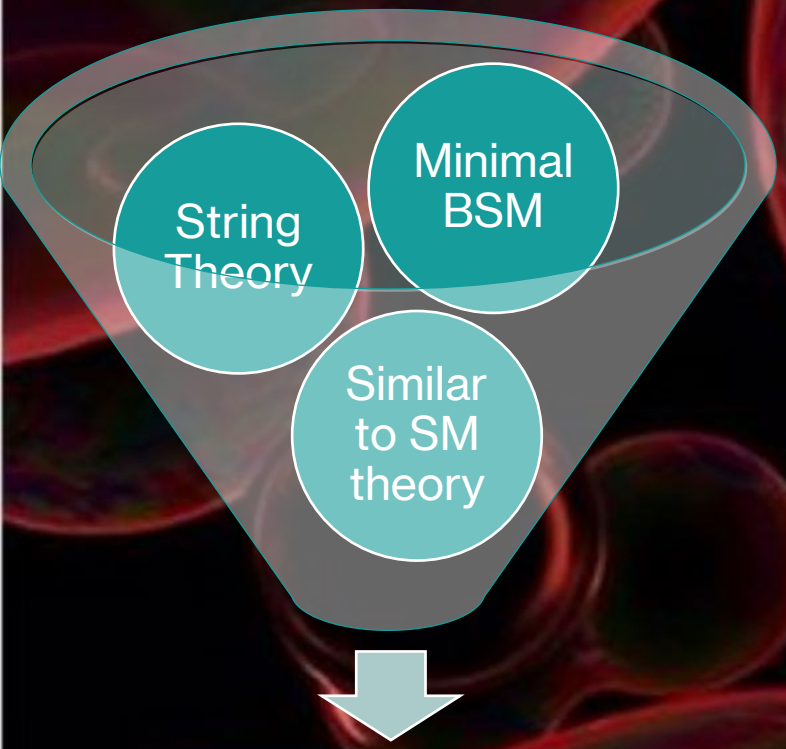
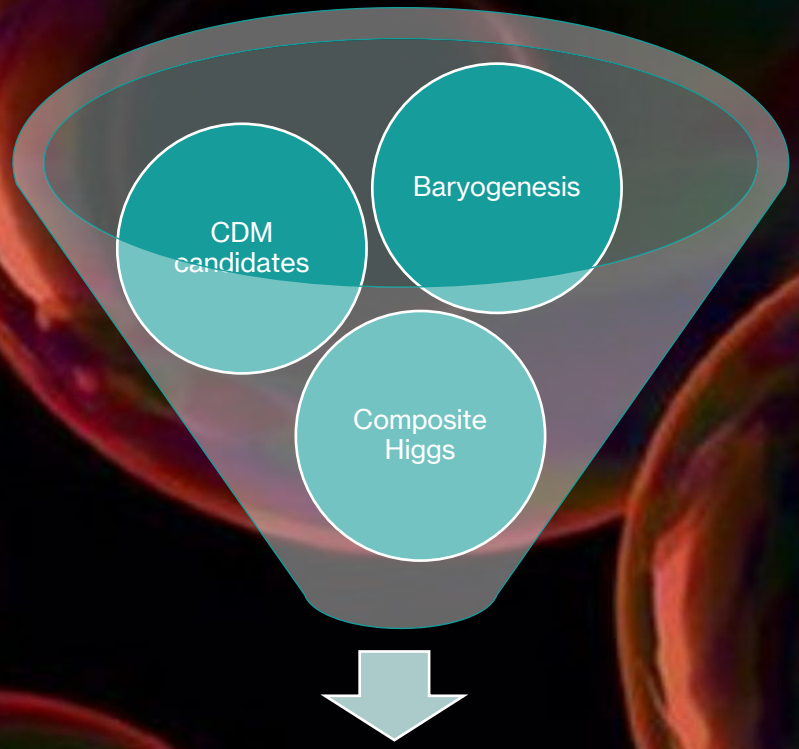
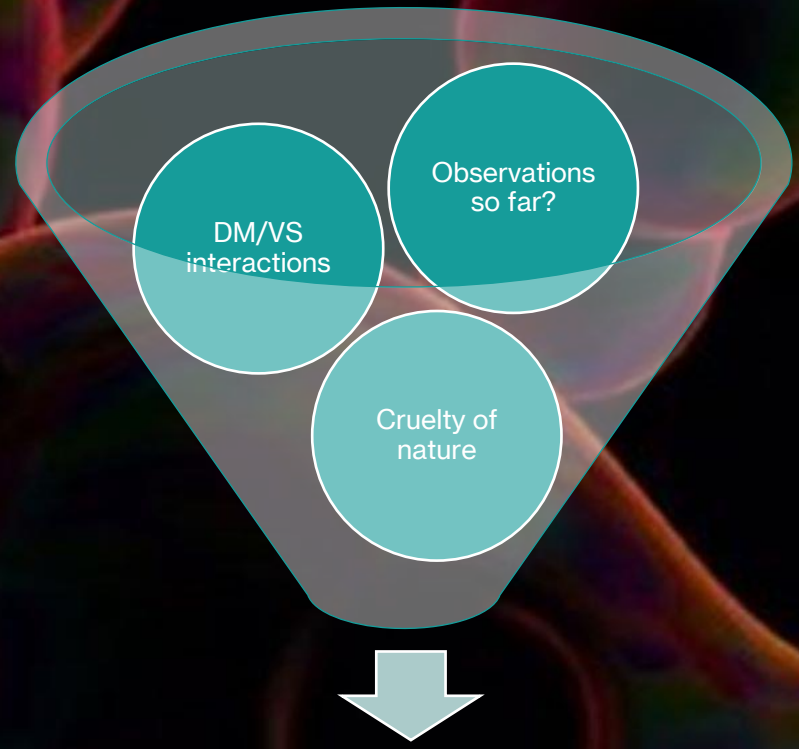
Dark SU(N) Yang-Mills Theory



Theoretically appealing

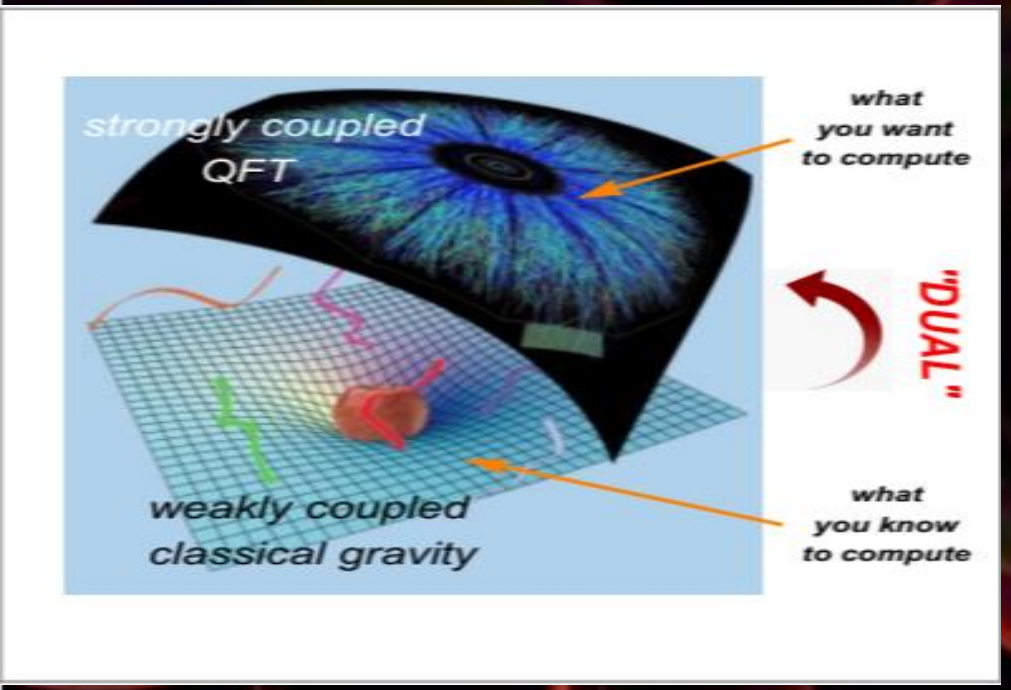


Particle physics phenomenology



GW searches in dark sectors

How to proceed with FOPTs at strong coupling?



- Lattice QCD Data for SU(3) YM with $n_f = 0$.
- The AdS/CFT Correspondence for theoretical control.

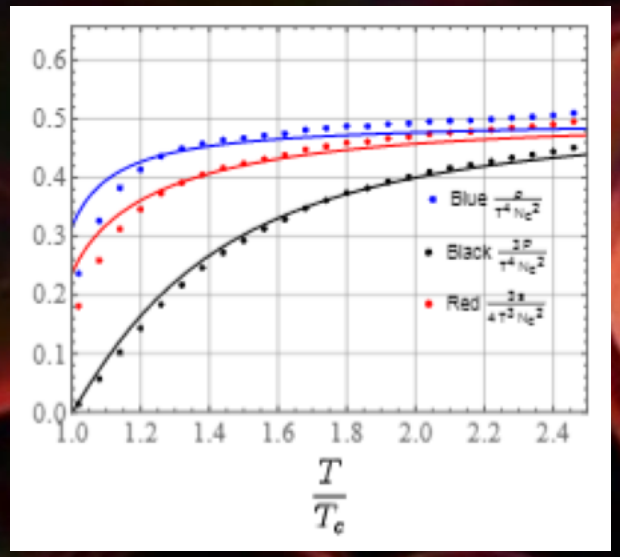
We will make use of Improved Holographic QCD

$$\mathcal{S}_5 = -M_p^3 N_c^2 \int d^5 x \sqrt{g} \left(R - \frac{4}{3}(\partial\Phi)^2 + V(\Phi) \right) + 2M_p^3 \int_{\partial\mathcal{M}} d^4 x \sqrt{h} \mathcal{K}$$

- AdS5 Einstein Dilaton Gravity
- Radial 5-D coordinate r
- Scalar field $\lambda = e^{\Phi}$
- Different Geometries
- 4D CFT
- RG Scale
- T'hooft coupling $\lambda_t = N_c g_{YM}^2$
- Phases of YM theory

Main Idea: Use the AdS/CFT correspondence to construct a 4D CFT which resembles SU(3) Yang Mills Theory.

Thermodynamics, Effective Action, and PT Parameters



Interpolate between BBH and SBH

Violate the condition $T_h \neq T$

1. BH not in thermal eq.
2. Conical singularity

Regularize with spherical cap

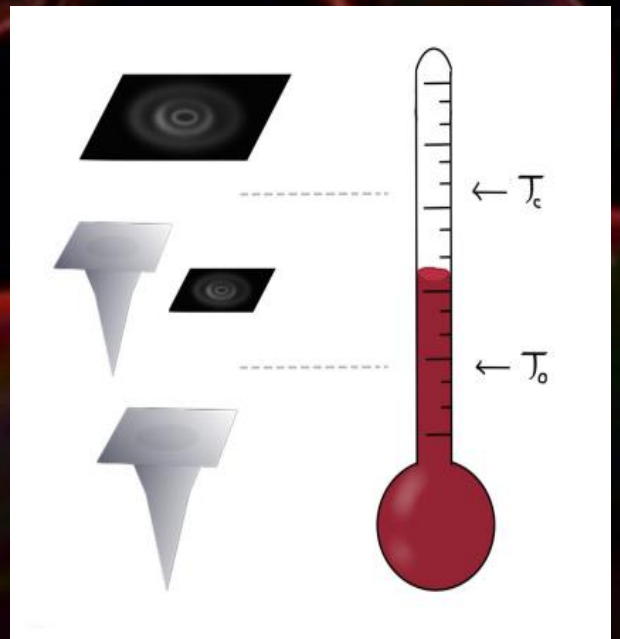
Kinetic term normalization: $c\frac{N_c^2}{16\pi^2}\left(\vec{\nabla}\lambda_h\right)^2$

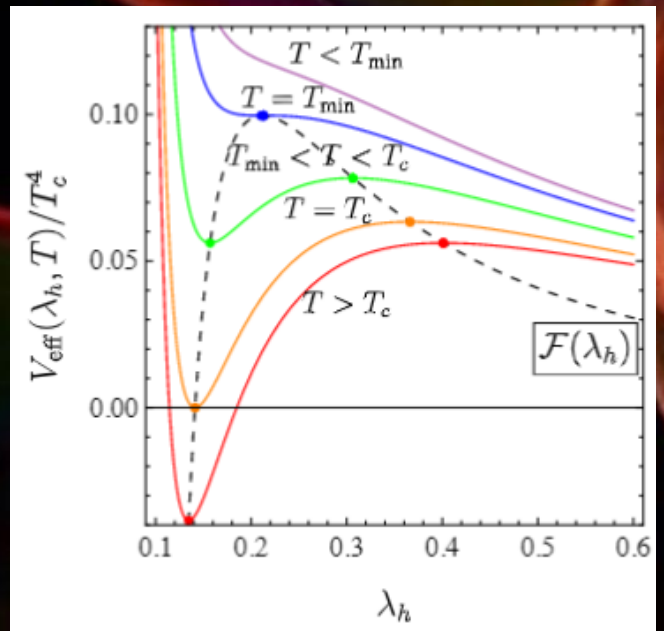
Effective action for $\mathcal{O}(3)$ tunneling configurations

$$\mathcal{S}_B = \frac{4\pi}{T}\int dr\ r^2\left[c\frac{N_c^2}{16\pi^2}\left(\partial_r\lambda_h(r)\right)^2 + V_{\text{eff}}(\lambda_h(r),T)\right]$$

Bubble Nucleation Rate

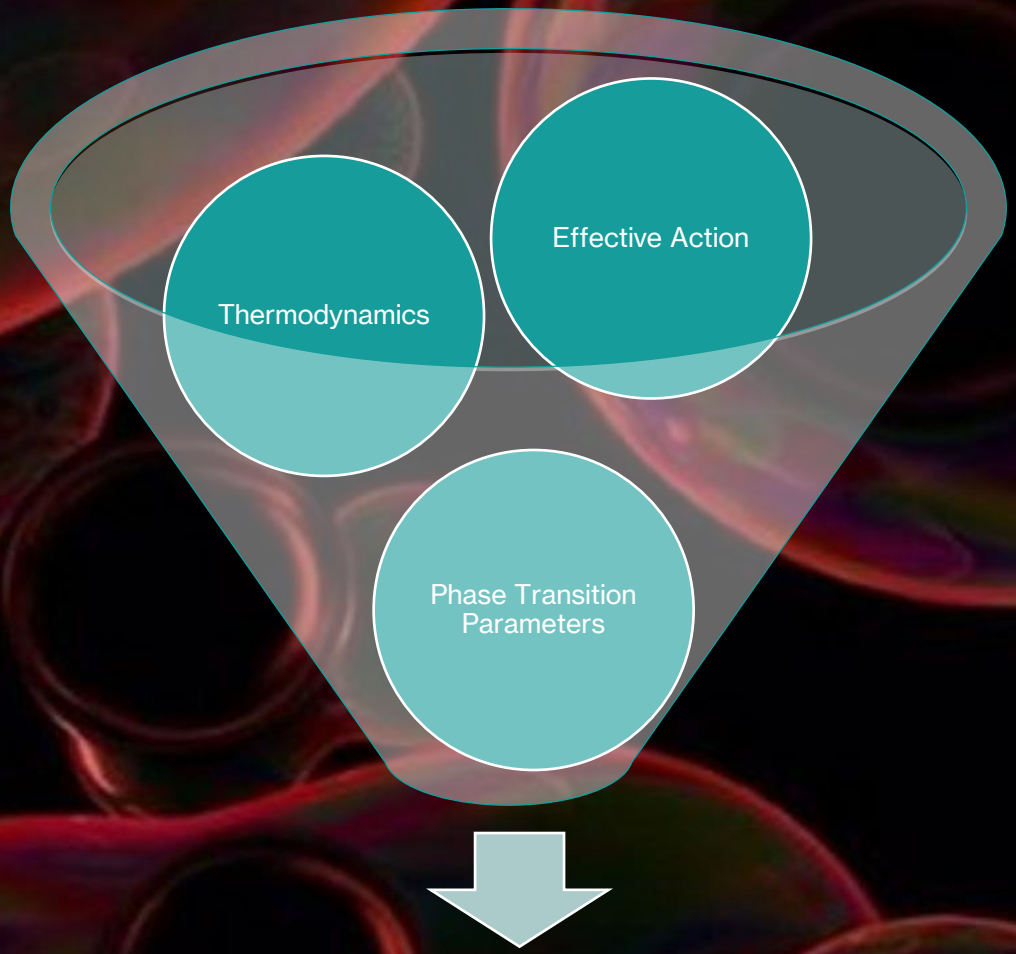
$\Gamma = T^4\left(\frac{\mathcal{S}_B}{2\pi}\right)^{3/2} e^{-\mathcal{S}_B}$, Nucleation $\Gamma \approx H^4$.

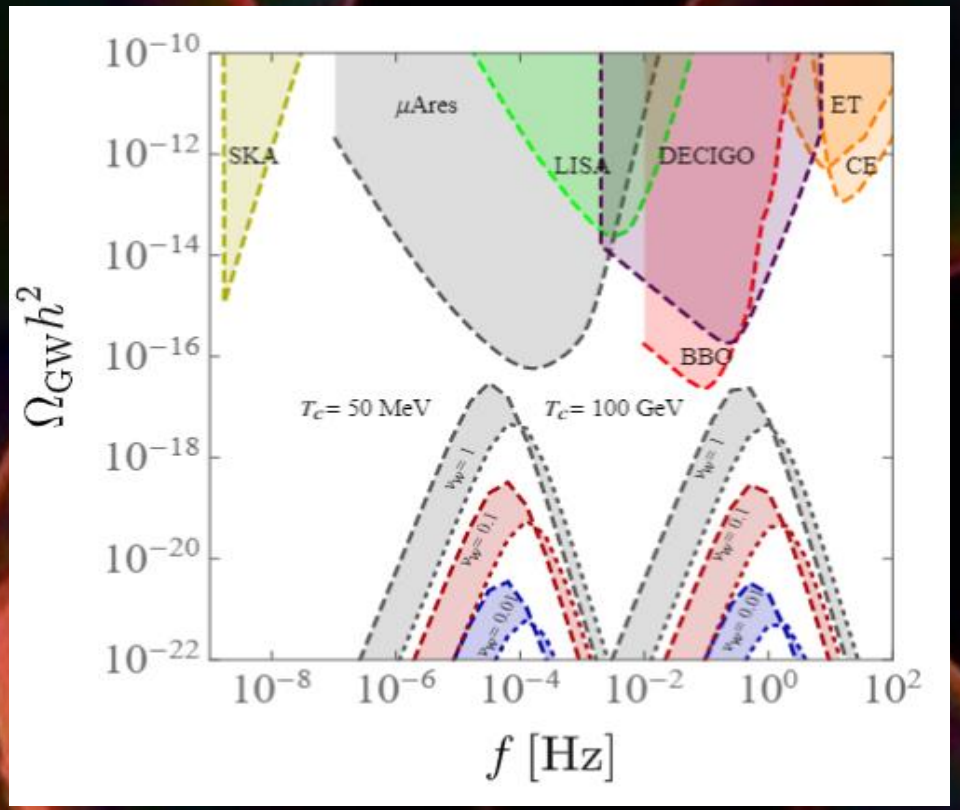




	α	$\beta/H(v_w = 1)$	$\beta/H(0.1)$	$\beta/H(0.01)$
$T_c = 50$ MeV	0.343	9.0×10^4	8.6×10^4	8.2×10^4
100 GeV	0.343	6.8×10^4	6.4×10^4	6.1×10^4

The output results of SU(3) Yang-Mills





Gravitational Waves

Conclusions/Ongoing work/Outlook

Conclusions

1. Dark Confining Gauge Sectors are interesting!
2. These theories ”naturally” predict FOPTs
3. Gravitational waves of such theories can be quiet small

Ongoing work

1. Bubble wall velocity estimate
2. Kinetic term computation.
3. Phenomenology of Large N SU(N)

Outlook

1. Inclusion of an Axion.
2. Incorporate quarks.
3. GW correlation to different quark phases