

Nano-Hertz GWs and sub-GeV dark matter from a classically conformal phase transition

Jonas Matuszak

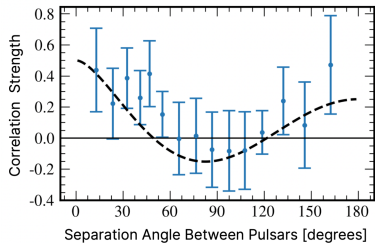
Sowmiya Balan, Torsten Bringmann, Felix Kahlhöfer, Carlo Tasillo

[arxiv:2502.19478](https://arxiv.org/abs/2502.19478)

4. June 2025

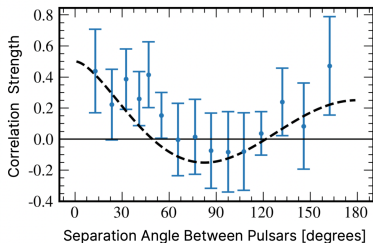
Pulsar Timing Arrays and the GW Background

NANOGrav 15 year data release

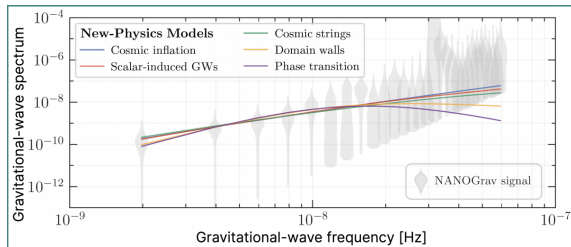


Pulsar Timing Arrays and the GW Background

NANOGrav 15 year data release



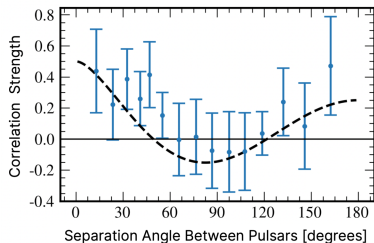
- Pulsar timing arrays found evidence of a stochastic GW background
- Astrophysical source: inspiralling black hole binaries
- Data allows for BSM sources of signal



Figures: [arxiv:2306.16213](https://arxiv.org/abs/2306.16213), [arxiv:2306.16219](https://arxiv.org/abs/2306.16219)

Pulsar Timing Arrays and the GW Background

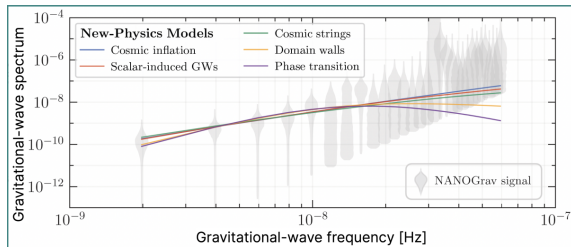
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Question:

Can we have a GW signal *and* dark matter from a first-order phase transition?



Figures: [arxiv:2306.16213](https://arxiv.org/abs/2306.16213), [arxiv:2306.16219](https://arxiv.org/abs/2306.16219)

Dark Sector Phase Transition Recipe

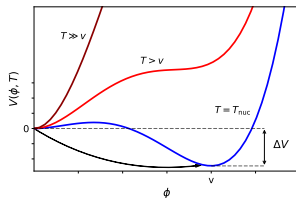
$U(1)'$ dark sector

Ingredients:

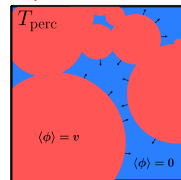
- Scalar field Φ : Dark Higgs
- Gauge boson A'_{μ} : Dark photon
- Fermionic DM candidate χ
- Classically conformal potential: $V(\Phi) = \lambda|\Phi|^4$

Cook at high $T \gg v_{\phi}$

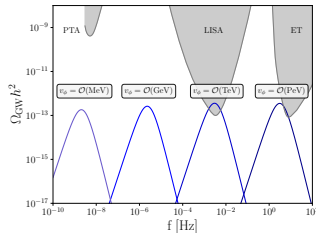
- Let cool until symmetry breaks $\langle \phi \rangle \neq 0$
 \Rightarrow Mass generation + stochastic GW signal



Symmetry breaking



Bubble collision & Sound Waves



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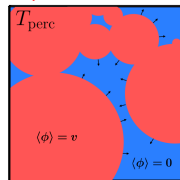
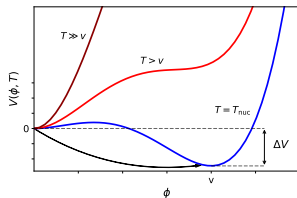
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Sub-GeV dark matter

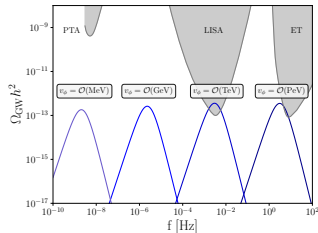
Mass scale of $\mathcal{O}(100)$ MeV required for a GW signal at nHz frequencies.



Symmetry breaking



Bubble collision & Sound Waves



Cosmological and Collider Constraints

Is this model consistent with data?

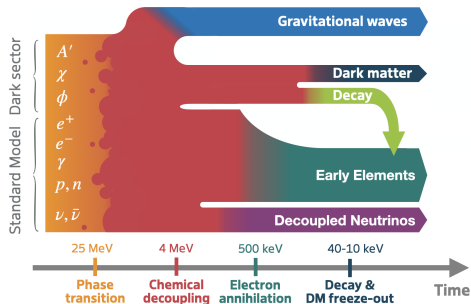
Freeze-out: $\mathcal{L}_{\text{int}} \supset -\kappa e A'_\mu \sum_f q_f \bar{f} \gamma^\mu f$

Cosmological Constraints

- BBN: Light element abundances ${}^4\text{He}$ and D
- CMB constraints: N_{eff}

Accelerator constrains:

- Missing energy searches: NA64
- Future: Belle II, NA64 μ , LDMX



Cosmological and Collider Constraints

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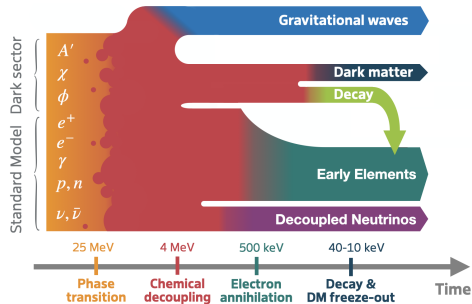
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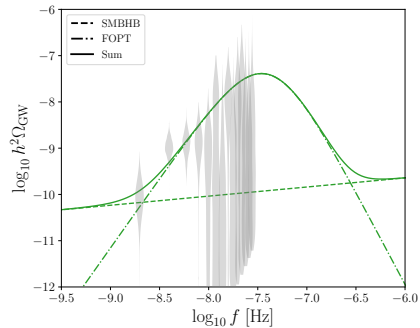
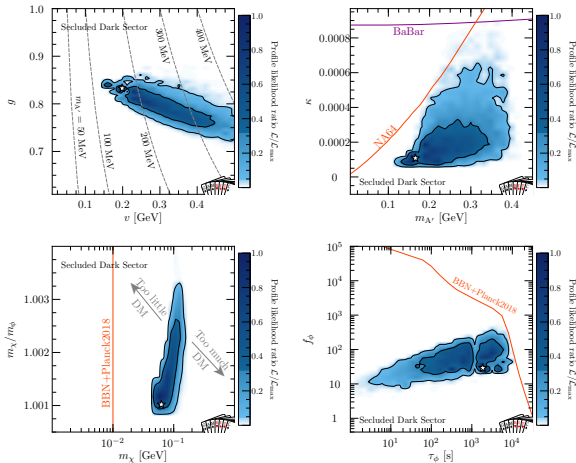
Global fit with GAMBIT arxiv:1705.07908

- Parameters: $m_{\text{DM}}, m_{A'}, \text{vev}, \kappa$ ($\gamma_{\text{SMBHB}}, A_{\text{SMBHB}}$)
- Combined likelihood:

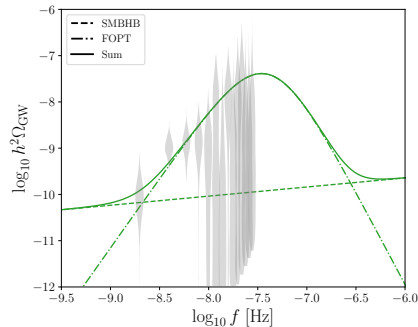
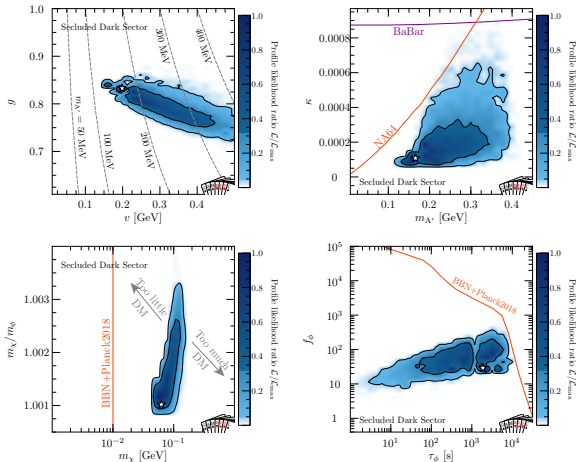
$$\mathcal{L}_{\text{tot}} = \mathcal{L}_{\text{PTA}} \times \mathcal{L}_{\Omega_{\text{DM}} h^2} \times \mathcal{L}_{\text{BBN,CMB}} \times \mathcal{L}_{\text{BC}} \times \mathcal{L}_{\text{Coll}}$$



Global Fit with GAMBIT



Global Fit with GAMBIT



Results:

We find viable parameter space fitting the PTA data and reproducing the observed DM relic abundance while avoiding current constraints.