Sub-GeV Dark Matter from a Conformal Phase Transition

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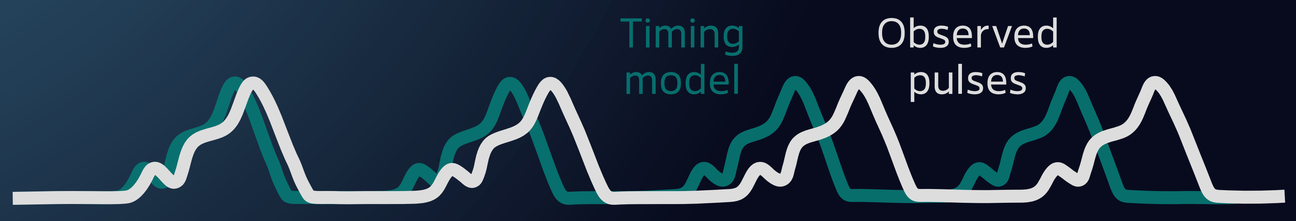
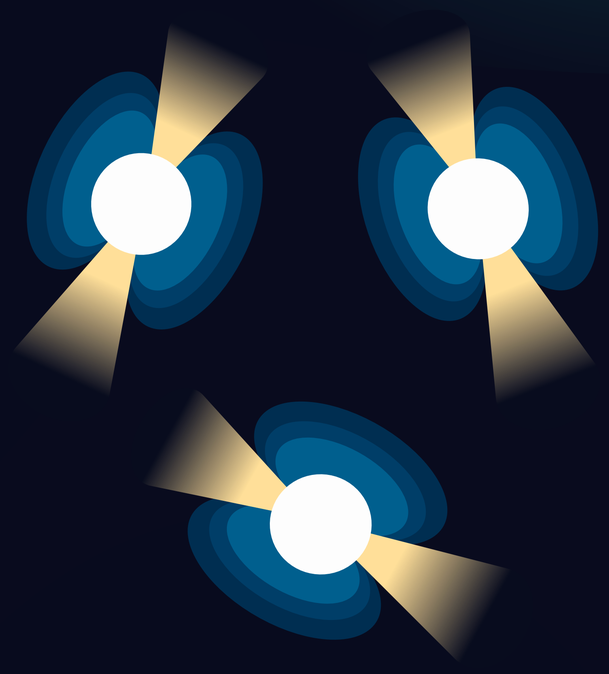
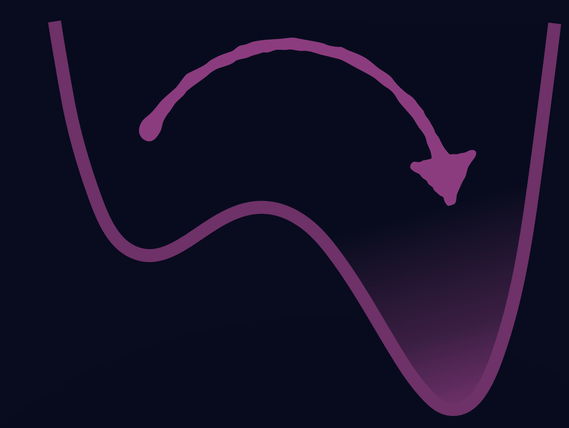


Pulsar timing arrays

In 2023, several pulsar timing arrays found $\approx 3\sigma$ evidence for a gravitational wave background at nHZ frequencies. The observed signal is stronger than the expected astrophysical background from merging supermassive black holes. We therefore study the possibility of additional contributions to the background from the early universe.

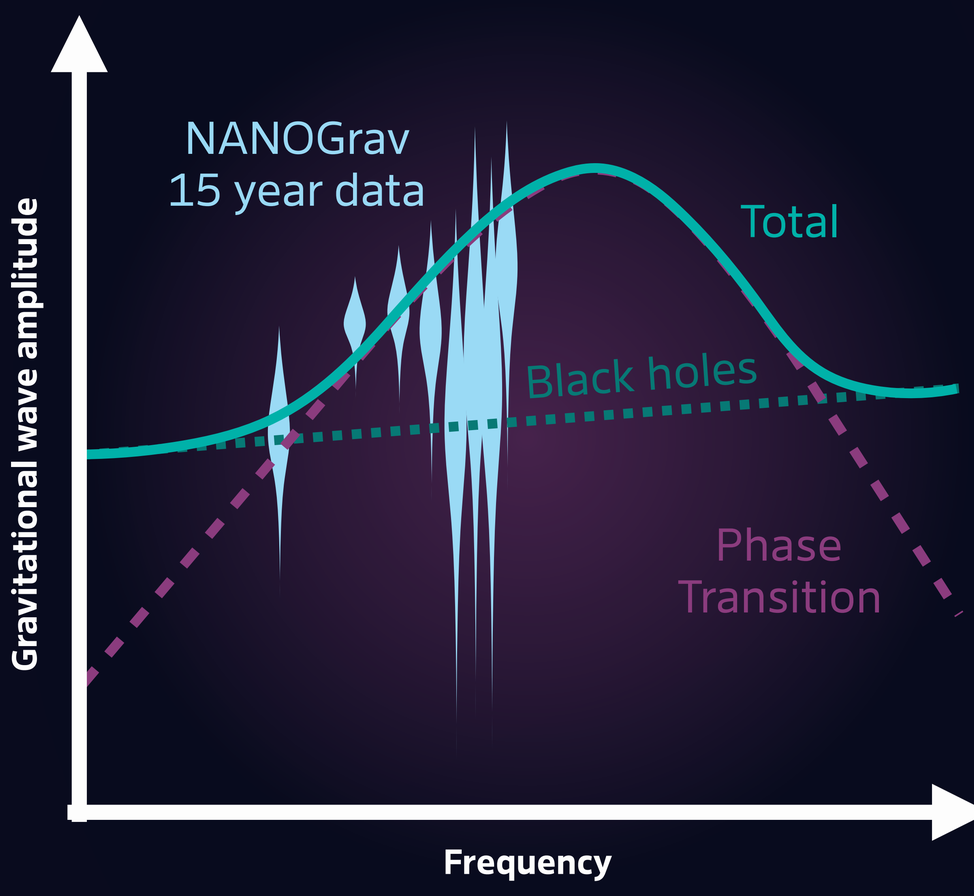


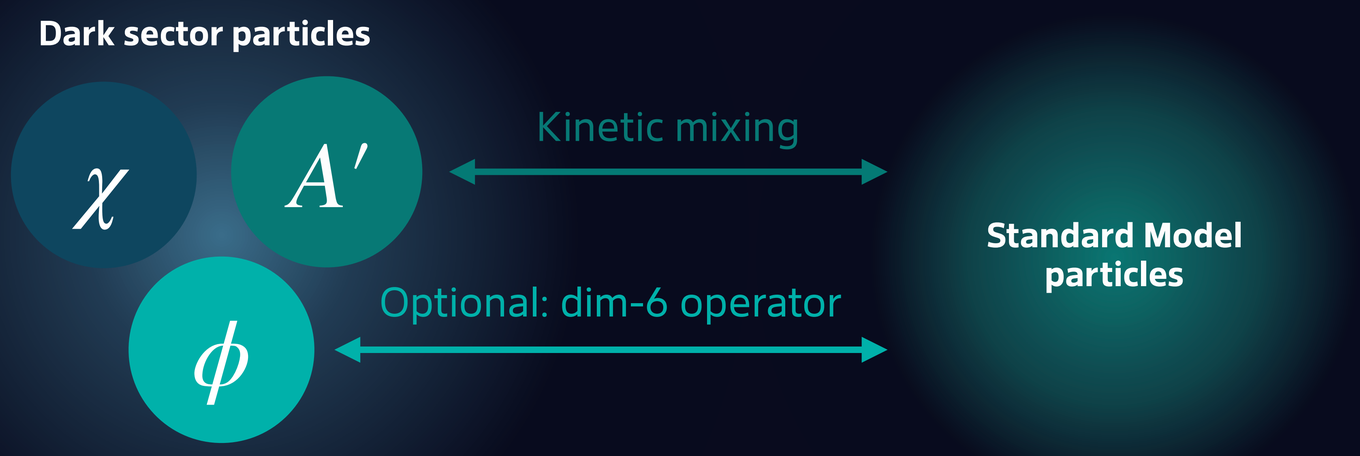
Galactic millisecond pulsars



First-order phase transition

We extend the SM by an additional U(1) gauge symmetry which breaks spontaneously at the 100 MeV scale. A dark matter fermion obtains its mass and is hence triggered to freeze out. The U(1) is conformally invariant at tree-level, such that the transition is supercooled and emits strong gravitational waves.





Dark sector constraints

The dark sector featuring the transition consists of three particles: A dark matter fermion χ, a dark photon A' and a dark Higgs ϕ. After the transition, the energy of the dark sector needs to be transferred to the Standard Model bath to circumvent constraints from BBN and the CMB. In our global fit, we also take constraints from dark matter self-interactions and beam-dump experiments into account. Dark matter direct and indirect detection constraints play no role.

Results

Both with and without the optional dim-6 operator to allow for an increased $\phi \to ee$ decay rate, we find points which explain the PTA signal and the observed dark matter abundance. Both scenarios can be tested by future beam-dump experiments like LDMX, which constrain the kinetic mixing parameter down to $\kappa \lesssim 10^{-4}$ for $m_{A'} \simeq \mathcal{O}(100\,\mathrm{MeV})$.

Scan me for a quick video summary!

Reference: S. Balan et al. „Sub-GeV dark matter and nano-Hertz gravitational waves from a classically conformal dark sector". ArXiv: 2502.19478 [hep-ph]. Accepted for publication in JCAP.

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