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First-Order Phase Transitions in the Dark Sector

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SIMP dark matter can be realized through low-energy $SU(N_c)$ effective theories, where dark matter consists of the Goldstone bosons associated with the spontaneous breaking of chiral symmetry, the dark pions. The restoration of this symmetry in the early universe may proceed through a first-order phase transition (FOPT), capable of generating a stochastic background of gravitational waves observable by future experiments such as LISA, DECIGO, or BBO.

We show that a θ-term induced by instanton effects in QCD-like vacua, can trigger such a FOPT. The analysis is performed in a QCD-like theory with $N_c = 3$, using the linear sigma model with three coupled quark flavors, focusing on the vacuum structure for $\theta = 0$ and $\theta = \pi$, and the resulting gravitational-wave spectrum.

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