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Formation of chiral soliton lattice

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The Chiral Soliton Lattice (CSL) is a lattice structure composed of domain walls aligned in parallel at equal intervals, which is energetically stable in the presence of a background magnetic field and a finite (baryon) chemical potential due to the topological term originated from the chiral anomaly. We study its formation from the vacuum state, with describing the CSL as a layer of domain-wall disks surrounded by the vortex or string loop, based on the Nambu-Goto-type effective theory. We show that the domain wall nucleates via quantum tunneling when the magnetic field is strong enough. We evaluate its nucleation rate and determine the critical magnetic field strength with which the nucleation rate is no longer exponentially suppressed. We apply this analysis to the neutral pion in the two-flavor QCD as well as the axion-like particles (ALPs) with a finite (baryon) chemical potential under an external magnetic field. In the former case, even though the CSL state is more energetically stable than the vacuum state and the nucleation rate becomes larger for sufficiently strong magnetic field, it cannot be large enough so that the nucleation of the domain walls is not exponentially suppressed and promoted, without suffering from the tachyonic instability of the charged pion fluctuations. In the latter case, we confirm that the effective interaction of the ALPs generically includes the topological term required for the CSL state to be energetically favored. We show that the ALP CSL formation is promoted if the magnetic field strength and the chemical potential of the system is slightly larger than the scale of the axion decay constant.

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