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How baryons appear in low-energy QCD: Domain-wall Skyrmion phase in strong magnetic fields

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Low-energy dynamics of QCD can be described by pion degrees of freedom in terms of the chiral perturbation theory (ChPT). A chiral soliton lattice (CSL), an array of solitons, is the ground state due to the chiral anomaly in the presence of a magnetic field larger than a certain critical value at finite density. Here, we show in a model-independent and fully analytic manner (at the leading order of ChPT) that the CSL phase transits to a domain-wall Skyrmion phase when the chemical potential is larger than the critical value $\mu_{\rm c} = 16\pi f_\pi^2/(3m_\pi) \sim 1.03\,\text{GeV}$ with the pion's decay constant f_π and mass m_π, which can be regarded as the nuclear saturation density. There spontaneously appear stable two-dimensional Skyrmions or lumps on a soliton surface, which can be viewed as three-dimensional Skyrmions carrying even baryon numbers from the bulk despite no Skyrme term. They behave as superconducting rings with persistent currents due to a charged pion condensation, and areas of the rings' interiors are quantized. This phase is in scope of future heavy-ion collider experiments.
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