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Quantum Yang-Mills vacua in expanding Universe: Do we live in a time crystal?

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The dynamical cancellation of the vacuum energy of the QCD sector in the infrared regime is a relevant problem for both particle physics and cosmology. We find an argument related to the existence of Z2-symmetry for the renormalization group flow derived from the bare Yang-Mills Lagrangian, and show that the cancellation of the vacuum energy may arise motivated both from the renormalization group flow solutions and the effective Yang-Mills action. At the cosmological level, we explore the stability of the electric and magnetic attractor solutions, both within and beyond the perturbation theory, and find that thanks these latter the cancellation between the electric and the magnetic vacua components is achieved at macroscopic space and time separations. This implies the disappearance of the conformal anomaly in the classical limit of an effective Yang-Mills theory while a local breakdown of time-translation invariance highlights the formation of a time-crystal grounds-state as a result of the QCD phase transition. A new type of non-perturbative non-local configurations in the Yang-Mills vacua, space-time instanton-like objects separated by domain walls, is emerged and their properties and implications (e.g. for gravitational-wave echoes of the QCD transition) are discussed.

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