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Spontaneous Symmetry Breaking in Rindler frame and AdS space

The phenomenon of spontaneous symmetry breaking (SSB) is one of the cornerstone paradigms of modern physics. In this work, we address fundamental questions related to the role of observers and curvature in phase transitions associated with SSB. Our study involves scalar field theory with $\lambda\phi^4$ interaction and the linear sigma model (LSM) at leading order in $1/N$. Employing these models, we explore two distinct scenarios with different symmetry groups and perturbation approaches. The scalar field theory with $\lambda\phi^4$ interactions involves a discrete Z_2 symmetry and perturbation in small λ. At the same time, the LSM features a continuous N-dimensional rotation group $O(N)$ and perturbation in $1/N$, which includes a more non-linear structure. By general covariance, it is clear that a set of inertial observers would perceive the mechanism of SSB as universal. However, the situation is not so straightforward when we consider this phenomenon from the perspective of a uniformly accelerating observer. We demonstrate that the spontaneously broken symmetries can be restored from the viewpoint of an accelerating observer but only above a certain critical value of acceleration, thereby establishing that SSB is indeed an observer-dependent phenomenon. In the analysis, we introduce proper renormalization methods for calculating the one-loop effective potential in the Rinlder frame in arbitrary dimensions. Also, our findings support the ontic nature of the Unruh effect.

To study the role of curvature, we focus on SSB in the Anti–de Sitter (AdS) space using LSM in the large N limit. We calculate a closed-form expression for the renormalized one-loop effective potential in various dimensions. In four-dimensional AdS space, the vacuum state of the theory is degenerate, and one needs to consider the global vacuum for studying SSB. We show that the $O(N)$ symmetry is spontaneously broken in three-dimensional AdS space, and there is no SSB in four-dimensional AdS space for LSM in large N limit. As we have a quantum gravity theory in AdS space (AdS/CFT correspondence), our results may help better understand SSB using AdS/CFT correspondence.

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