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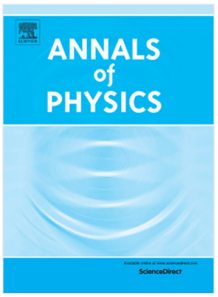

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Critical properties of scalar field theory with Lorentz violation: Exact treatment of Lorentz-violating mechanism

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Abstract

In this work, we compute analytically the infrared divergences of massless O(N) self-interacting scalar field theories with Lorentz violation, which are exact in the Lorentz-violating $K_{\mu\nu}$ coefficients, for evaluating the corresponding next-to-leading order critical exponents. For that, we apply three distinct and independent field-theoretic renormalization group methods. We find that the outcomes for the critical exponents are the same in the three methods and, furthermore, are identical to their Lorentz invariant counterparts. We generalize the results for all loop levels by employing a general theorem arising from the exact procedure and give the corresponding physical interpretation.

Keywords:
Exact calculation
All-loop renormalization
Lorentz violation

1. Introduction

The search for violations of Lorentz symmetry has grown in the last few years. The possible physical effects predicted by Lorentz-violating (LV) theories were established in research areas ranging from high energy physics [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19] to condensed matter theory [20, 21, 22]. Except to one work considering the breaking of the referred symmetry exactly [23], for our knowledge, the most of them treat this symmetry breaking mechanism in an approximated footing at first order [12, 13, 14, 15, 16, 18, 24, 25, 26] and just a few of them at second order [17, 19, 20, 21, 22] in a typical LV parameter. All these works were treated perturbatively in two parameters, some LV one and the loop level considered. While these problems were investigated at most at second order in the LV parameter, the same was not the case when dealing with the loop level in question. In fact, after an explicit analytic computation up to two- and three-loop order for the critical exponents ν and η, respectively, some degree of sophistication in a road to an all-loop order solution of the problem was attained when expressions for the same exponents at any loop level were obtained, although yet at second order in the LV parameter for ν and at first order in the same parameter for η. We present an exact solution of the problem valid for any values of LV parameter.

As the critical exponents are universal quantities, they do not depend on the microscopic details of the system but depend only on its dimension d, N and symmetry of some N-component order parameter (magnetization for magnetic systems) if the interactions of its constituents are of short- or long-range type. In this work, we propose to probe the effect of exact Lorentz symmetry breaking mechanism in the outcomes for the all-loop critical exponents for massless O(N) self-interacting scalar field theories with Lorentz violation. For that, we apply three distinct field-theoretic methods based on renormalization group and ϵ-expansion techniques. The systems studied here belong to the general O(N) universality class and are distinct systems as a fluid and a ferromagnet, whose critical behaviors are characterized by the same set of critical exponents. The referred universality class is a generalization of the specific

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