Asymmetry of critical exponents above and below second-order transitions with continuous symmetries

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It has widely been believed that the critical exponents are symmetric above and below every continuous phase transition. We report our recent study on the critical exponents of the $O(N)$ symmetric ϕ^4 model with continuous symmetry, which clearly exhibit a counterexample to the statement. The Nambu-Goldstone mode and three-point vertices, which emerge in the ordered phase, make the longitudinal susceptibility diverge and the exponent γ' undefinable accordingly, thus suggesting the presence of asymmetry in the exponents of the model. We have calculated the fixed points and critical exponents above and below the transition on an equal footing based on a functional renormalization-group formalism which also satisfies Goldstone's theorem automatically. Despite the divergence of the longitudinal correlation length, one can define a characteristic length $\xi_{\rm J}$ called "Josephson length" in the ordered phase, which separates the critical region $G_{\parallel}(k) \propto k^{-2+\eta}$ from the Goldstone region $G_{\parallel}(k) \propto k^{-4+d}$ well inside the ordered phase. Our renormalization-group analysis reveals that one can define the exponent ν' in terms of the Josephson length as $\xi_{\rm J} \propto (T_c - T)^{-\nu'}$. Moreover, ν' acquires a value different from ν above the transition due to the emergence of three-point vertices in the ordered phase. The N dependence of the exponents will be discussed in detail.