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The uses of the SO(5)/SO(2) Stiefel sigma model for the unified Zhang's model

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We investigate the critical behavior and phase structure of nonlinear sigma models on real Stiefel manifolds SO(N)/SO(N-k), with particular focus on the SO(5)/SO(2) model and its relation to the $SO(5)$-based Zhang model of competing antiferromagnetic and superconducting orders. The Stiefel model is characterized by two effective interaction coupling constants, which give rise to a tetracritical regime implying, in particular, the appearance of the phase with coexistence of antiferromagnetic and superconducting orders. We analyze the scaling behavior and properties of the four phases using both Hamiltonian and Lagrangian formulations. In particular, we determine quasiparticle masses and apply these to characterize the symmetry breaking in different phases, including the mixed phase where the two orders coexist. As one of our main results we present the determination of "transverse" critical exponents for the tetracritical point. These exponents complement the previously obtained critical exponents in the (T)-direction and provide a more complete characterization of the associated universality classes. Note that the transverse critical exponents are obtained for the general class of Stiefel models SO(N)/SO(N-k). We further examine the electron–hole asymmetry, which is not intrinsically incorporated in the Zhang model but emerges naturally in the Stiefel model framework. For the SO(5)/SO(2) model, the resulting carrier charge has the physically relevant sign, in contrast to the SO(5)/SO(3) Stiefel model which, in addition, does not exhibit tetracritical behavior. The obtained results establish an important connection between the critical structure (and phases) of Stiefel sigma models and the phenomenology of competing antiferromagnetic and superconducting orders.

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