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Renormalized mean-field form of the static spin correlator and approximate nature of the quantum-to-classical correspondence

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The quantum-to-classical correspondence (QCC) in spin systems is the phenomenon that the static correlator of quantum spin models agree with their classical counterpart at a different temperature within QMC error bars in bold-line diagrammatic Monte-Carlo. The quantum fluctuations appear to only "heat up" the system. Currently, the QCC is a purely empirical observation. We show that the QCC is exact until 3rd order perturbation theory in any dimension and for all spin lengths, and universally breaks down at fourth order. The QCC thus never holds exactly. We give a model dependent equation for the correspondence in 3rd order perturbation theory. Furthermore, we uncover why the QCC can be observed in the first place. We show that whenever QCC is observed, the static correlator of quantum and classical models can be approximated by a renormalized mean-field correlator. This is due to a partial cancellation of 1J-irreducible diagrams that contribute to deviations from the renormalized mean-field correlator. With this new insight, we are able to reproduce the spin structure factor for $K_2Ni_2(SO_4)_3$ where a QCC was previously observed.

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