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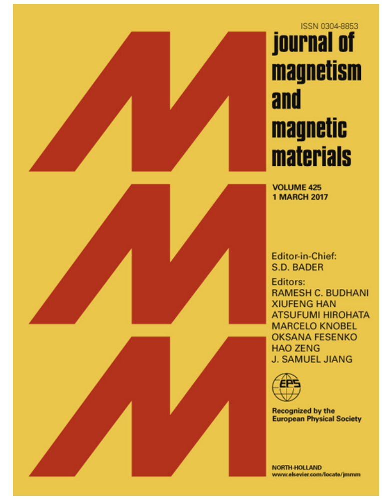

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Spontaneous Magnetic Order in Complex Materials: Role of Longitudinal Spin-Orbit Interactions

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Abstract

We show that the longitudinal spin-orbit interactions (SOI) critically determine the fate of spontaneous magnetic order (SMO) in complex materials. To study the magnetic response of interacting electrons constituting the material, we implement an extension of the Hubbard model that faithfully accounts for the SOI. Next, we use the double-time Green functions of quantum statistical mechanics to obtain the spontaneous magnetization, $M_{\rm sp}$, and thence ascertain the possibility of SMO. For materials with quenched SOI, in an arbitrary dimension, $M_{\rm sp}$ vanishes at finite temperatures, implying the presence of the disordered (paramagnetic) phase. This is consistent with and goes beyond the Bogolyubov's inequality based analysis in one and two dimensions. In the presence of longitudinal SOI, $M_{\rm sp}$, for materials in an arbitrary dimension, remains non-zero at finite temperatures, which indicates the existence of the ordered (ferromagnetic) phase. As a plausible experimental evidence of the present SOI-based phenomenology, we discuss, *inter alia*, a recent experimental study on $Y_4Mn_{1-x}Ga_{12-y}Ge_y$, an intermetallic compound, which exhibits a magnetic phase transition (paramagnetic to ferromagnetic) upon tuning the fraction of Ge atoms and thence the vacancies of the magnetic centers in this system. The availability of Ge atoms to form a direct chemical bond with octahedral Mn in this material appears to quench the SOI and, as a consequence, favours the formation of the disordered (paramagnetic) phase.

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