A simple approach to ferroelectric ferromagnets: the case of $BiMnO_3$

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We discuss a simple phenomenological Landau theory of phase transitions with two coupled single-component order parameters and compare the results with available experimental data. They correspond to the case of a ferroic system, in which ferromagnetic and ferroelectric transitions originally occur at temperatures T_M and T_f, respectively. For $T_f > T_M$ the magnetoelectric coupling strongly renormalizes the magnetic transition temperature, $T_M \to T_{RM}$, as well as generates an additional anomaly in ferroelectric subsystem at the ferromagnetic phase transition temperature T_{RM}. Full susceptibility tensor has also been determined. The concept of Arrot plot is generalized to the situation when both types of order coexist. The results are in good overall agreement with experimental data for the ferroelectromagnetic $BiMnO_3$. We also estimate the contribution of Gaussian fluctuations of both order parameters, that lead to corrections to the mean-field specific heat. Those corrections are still insufficient even though other quantities agree quite well with experiment.