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Ferroelectricity in Incommensurate Magnets

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In several systems (e. g. $Ni_3V_2O_8$ and $TbMnO_3$) there occurs a phase transition in which a new incommensurate magnetic order parameter appears simultaneously with the development of a uniform spontaneous electric polarization, P. Here I review the Landau theory which gives a phenomenological explanation (independent of the microscopic details) of this phenomenon. The key point is that although the quadratic term in P in the free energy is always stable (positive), a nonzero value of P is induced by a trilinear coupling of the $\sum_{kmn} a_{kmn} P_k M_m(q) M_n(-q)$, where subscripts label Cartesian components and $M(q)$ is the q-Fourier component of the magnetization. Using representation theory to identify the symmetry of the magnetically ordered phases, I identify the symmetry of this term which is consistent with crystal symmetry. This analysis shows that in the highest temperature magnetically incommensurate phase a nonzero value of P is not allowed (as observed) and also that in the lower temperature magnetically incomensurate phase a nonzero P can only appear in the direction which is observed by experiment. This theory indicates that a microscopic model must involve a trilinear interaction between a phonon displacement and two spin operators. A microscopic analysis of phonon distortions of the spin Hamiltonian reproduces these symmetries, as expected and indicates which gradients of the most general anisotropic exchange tensor can possibly come into play. Inelastic neutron scattering data on a $Ni_3V_2O_8$ powder sample and a symmetry analysis of the phonon spectrum enables us to speculate as to which phonon modes are crucial for this phenomenon. See PRL **95**, 087205 and cond-mats: 0508617, 0508730, 0510386, and 0510807 whose coauthors I hereby acknowledge.