JCCM-Apr06-02

The Blue Fog State of Magnetization : Helical Spin Crystal in MnSi

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http://arxiv.org/cond-mat/0602529

Recommended and Commentary by Chandra Varma,

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It is very satisfying to come across non-trivial symmetry based explanation of well done experiments which have given extraordinary results with much ensuing discussion. This appears now to have happened to the neutron diffraction results in the itinerant magnet $MnSi$ which have been around for several years. At low pressures and temperatures this metal displays a spin-spiral state with a period of 180 Angstroms oriented along the 111 direction. This has been understood to be due to the weak Dzyaloshinskii - Moriya spin-orbit interaction in the crystal due to its lack of a center of inversion. The orientation (111) is fixed by the even weaker crystalline anisotropy. Under pressure there is a weak first order transition: the diffraction pattern changes. The intensity becomes diffuse over a sphere in q-space of about the same period as before but with peaks in the 110 direction. This is quite reminiscent of the Blue-fog phase seen in diffraction experiments in certain cholesteric liquid crystals which Brazovskii and collaborators had explained with beautiful symmetry arguments in the 80's.

One might think that under pressure the favored crystalline anisotropy changes but the authors show that 110-direction is always a saddle point. In looking elsewhere to account for the observations, the most natural place are the fourth-order interaction energy terms between spirals of the same pitch oriented in different directions $\hat{q}$. There follows a clever way of re-writing this interaction in terms of a minimum number of parameters to describe interaction among six different $\hat{q}$'s. The number 6 is inspired by the number of different 110 Bragg vectors which are actually observed. The end result is that the 6 different spirals phase themselves to provide a body centered structure with a lattice constant equal to the pitch of the spiral provided some inequalities in the coupling constants are satisfied. In addition the state breaks time-reversal symmetry with an order parameter $< M_x M_y M_z > \neq 0$. The magnetization direction in a cross-section of the unit cell in a plane parallel to a side of the

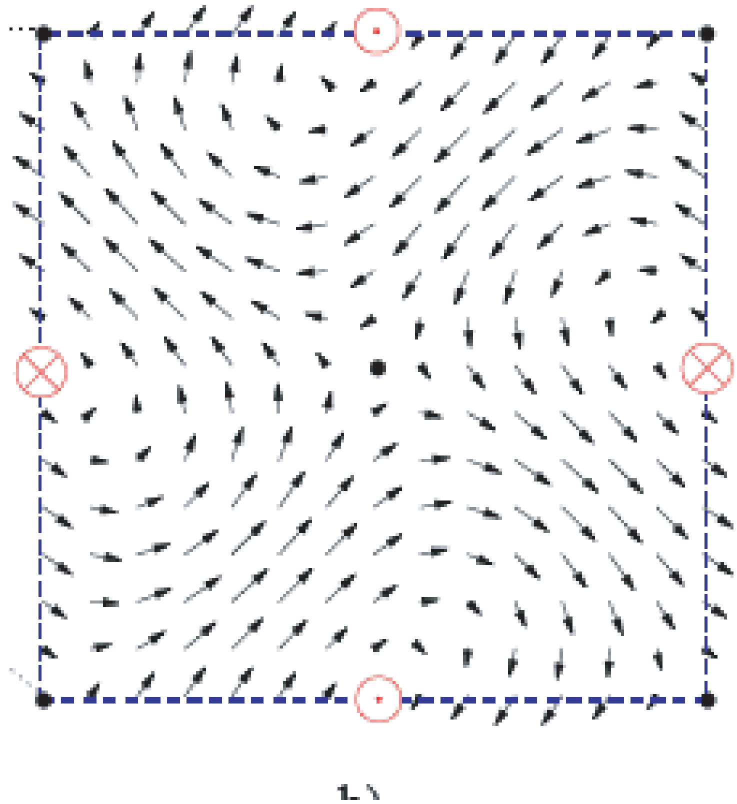

FIG. 1: Magnetization pattern on a cross-section of the bcc unit cell described in the text.

cube about 1/3 of the unit-cell size from the face of the cube is reproduced from the paper below.

The magnetization points into the plane at the red-dot and out of it at the red-cross. It is zero on 3 lines going through the center of the cube; one of these lines intersects the cross-section shown at the black dot. I think the whole pattern is very pretty.

There is a nice prediction in the paper for samples in which a single magnetic domain can be stabilized: a linear in field magneto-resistance and a quadratic in field Hall effect. There are some questions not fully answered: Why the almost uniform distribution of the intensity over the sphere? The authors point to defects and the small stiffness of the structure but if the experimental results do indeed give a uniform distribution (this issue is foggy), there must be a more subtle explanation.