Comment on "Crystal Field Model of the Magnetic Properties of URu_2Si_2"

Santini and Amoretti [1] have proposed that the 17 K transition in URu_2Si_2 is due to the ordering of certain uranium ion quadrupole moments. In order to account for the magnetic order (i.e., spin-flip scattering) observed using polarized neutrons [2], they proposed that a magnetic ordering accompanies the quadrupolar ordering as a secondary effect, but did not give any explanation of how this secondary effect is produced.

In this Comment, we note first that it is not possible to induce magnetic ordering at a continuous (or second order) phase transition as a secondary order parameter by the usual mechanism; this rules out the possibility that a magnetic secondary order parameter (in the usual sense of this term) could be the required secondary effect. Second, we consider ways in which the appearance of magnetic order might be consistent with the phase transition due primarily to quadrupolar ordering.

If Q is the order parameter describing the quadrupolar order, and η is to be a secondary order parameter induced at a continuous phase transition, the appropriate Ginzburg-Landau free energy must have the form

$$F = AQ^2 + BQ^4 + a\eta^2 + g\eta Q^2,$$

where $A = \alpha(T - T_c)$, $B > 0$, and $a > 0$. A minimization of F with respect to η yields $\eta = -gQ^2/2a$, showing that the secondary order parameter η varies as the square of the quadrupolar order parameter. However, if η is a magnetic order parameter, it changes sign under time reversal, and the coefficient g must therefore be zero in the above free energy. Hence, magnetic ordering cannot be induced as a secondary order parameter in the usual way.

In order for magnetic order to be induced with the quadrupolar order therefore, either (1) the 17 K phase transition must be discontinuous [the available evidence suggests that the transition is continuous—e.g., see Fig. 3 of [3]] or (2) there must be two successive phase transitions (only one transition has been observed—e.g., see [3]). It has also been suggested (3) that two distinct phases with nearly identical transition temperatures exist in different regions of the crystal. Until experimental evidence reveals that (1), (2), or (3) actually occurs, the proposal of [1] (which is distinct from that of the following reply) must be regarded as being in disagreement with at least some aspects of the current experimental understanding of URu_2Si_2. Clearly, the problem of the magnetic properties of URu_2Si_2 remains an open one.

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M. B. Walker
Department of Physics
University of Toronto
Toronto, Ontario
Canada M5S 1A7

W. J. L. Buyers
AECL Research
Chalk River, Ontario
Canada K0J 1J0

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[1] P. Santini and G. Amoretti, Phys. Rev. Lett. **73**, 1027 (1994).
[2] M. B. Walker, W. J. L. Buyers, Z. Tun, W. Que, A. A. Menovsky, and J. D. Garrett, Phys. Rev. Lett. **71**, 2630 (1993).
[3] A. de Visser, F. E. Kayzel, A. A. Menovsky, J. J. M. Franse, J. van den Berg, and G. J. Nieuwenhuys, Phys. Rev. B **34**, 8168 (1986).

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