Spatial determination of magnetic avalanche ignition points

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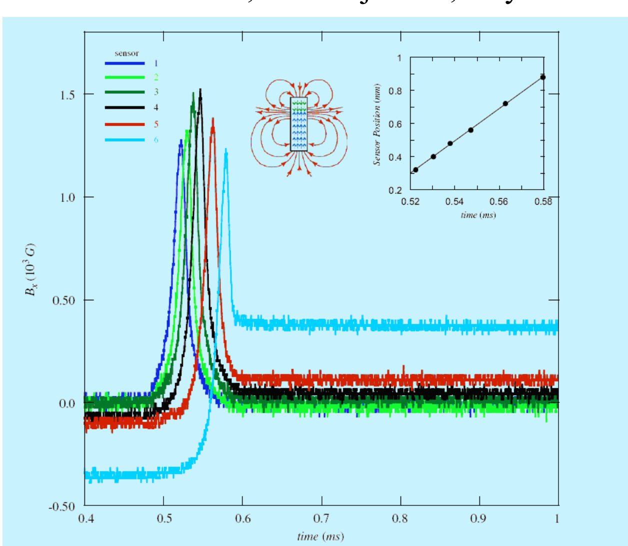
Recommended with a commentary by Albert Migliori, National High Magnetic Field Laboratory at Los Alamos National Laboratory.

Mn_{12}-acetate is a prototypical molecular magnet composed of 12 Mn atoms strongly coupled by exchange to form superparamagnetic clusters of spin $S=10$. Arranged in a centered tetragonal lattice, the spin of the Mn_{12} clusters is subject to strong magnetic anisotropy along the symmetry (*c* axis) of the crystal.

Start by arranging the field along the easy axis after having prepared (cooled) the crystal so the molecular magnets are magnetized in the opposite direction to the magnetic field. Remember that in zero field, the easy axis supports either possible magnetization direction with equal energy minima by symmetry. But with an applied field along *c*, one magnetization direction has lower energy than the other.

The fun starts by stressing the magnetic anisotropy with an external magnetic field. Increasing the magnetic field pushes the system toward instability, whereupon the magnetization switches, accompanied by lots of action. The primary probe to date has been a microscopic array of Hall bars [1] because, of all the possible ways for the magnetization to switch from unfavorable to favorable, this system rejects the dull and uninteresting. That is, there appears to be a nucleation site, and a propagation speed for reversal of magnetization. This "magnetic avalanche" takes the form of a thin interface between regions of opposite magnetization and propagates throughout the crystal with a constant, field-dependent speed ranging from 1 to 15 m/s. This phenomenon is likened to be analogous to the propagation of a flame front (deflagration) through a flammable chemical substance, or I conjecture, maybe even a detonation wave, something with some allure for those of us at LANL.



In analogy with detonation or burning, surface acoustic waves have been observed to trigger the "ignition" just below the instability threshold. Tunneling has been studied as the process that links the high potential energy before instability to the low potential energy after it [2]. With this most recent publication commented upon here, compelling evidence mapping out likely ellipsoidal propagation of the avalanche (how ellipsoidal depends on how the thermodynamic driver is coupled to such a magnetically anisotropic system?) using 2-D Hall bar arrays has strongly confirmed this beautiful behavior. In the figure, depicting the signal at several Hall bars as a function of time, the sense of the measurement is clear. Missing still is a thermal measurement to detect the entropy (heat) that must be sprayed away from the traveling interface. Can such a nicely controlled propagating disturbance be used to model other physical phenomena? Who knows, but last month's "Journal Club for Condensed Matter Physics" commentary by Bernard Nienhuis on "First passage times in complex scale-invariant media" suggests there may be more to this than seen so far.

Other references:

1. Propagation of Avalanches in Mn_{12}-Acetate: Magnetic Deflagration, Yoko Suzuki, M. P. Sarachik, E. M. Chudnovsky, S. McHugh, R. Gonzalez-Rubio, Nurit Avraham, Y. Myasoedov, E. Zeldov, H. Shtrikman, N. E. Chakov, and G. Christou, Phys. Rev. Lett. **95,** 147201 (2005).

2. Quantum Magnetic Deflagration in Mn_{12} Acetate, A. Hernandez-Minguez, J. M. Hernandez, F. Macia, A. Garcia-Santiago, J. Tejada, and P.V. Santos, Phys. Rev. Lett. **95,** 217205 (2005).