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A New Magnetic Phase in Hole-Doped $BaFe_2As_2$: Implications for the Origin of Nematicity[1]

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Establishing the origin of nematic order has emerged as one of the most important goals of research into iron pnictides and chalcogenides, because of its implications for the origin of their unconventional superconductivity [1]. It is well known that superconductivity emerges when antiferromagnetism is suppressed with doping or pressure. Across the phase diagram, the magnetic transition occurs just below, or is coincident with, a structural phase transition from tetragonal (C_4) to orthorhombic (C_2), or nematic, symmetry. A symmetry analysis indicates that the C_2 transition is electronically driven, but it could be due either to orbital interactions that then induce magnetic stripe order or to magnetic interactions that then induce orbital order. In the latter, magnetic fluctuations from interactions between the hole pockets at $Q = 0$ and the electron pockets at $Q_X = (\pi, 0)$ and $Q_Y = (0, \pi)$ break the Ising X/Y symmetry before time-reversal symmetry is broken. As part of a comprehensive neutron diffraction study of the phase diagram of hole-doped $BaFe_2As_2$ [2], we have recently observed an entirely new magnetic phase that occurs close to the suppression of the C_2 phase, in which the spins reorient along the c-axis and C_4 symmetry is restored [3]. This reentrant C_4 transition has now been observed in other hole-doped compounds as well. In spin-nematic theory, a restoration of C_4 symmetry is predicted to occur when doping weakens Fermi surface nesting, favoring an order parameter that involves Q_X and Q_Y simultaneously, so our observations provide evidence for magnetically-driven models of nematicity.

[1] R. M. Fernandes, *et al.* Nat. Phys. **10**, 97 (2014);
[2] S. Avci *et al.* Phys. Rev. B **88**, 094510 (2013);
[3] S. Avci *et al* Nat. Comm. **5**, 3845 (2014)

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