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Electronic liquid-crystal phases, symmetry breaking and Fermi-surface reconstruction in $YBa_2Cu_3O_{6+x}$[1]

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The physics of underdoped cuprates is governed by strong correlations and phase competition, and its understanding remains one of the challenges of condensed-matter research. Here we will discuss our systematic doping- and temperature-dependent neutron-scattering investigation of the spin correlations in underdoped $YBa_2Cu_3O_{6+x}$ (YBCO) in the context of various proposed symmetry-breaking phases. In YBCO6.45 ($T_c = 35$ K), we observe the spontaneous onset of a one-dimensional, incommensurate (IC) modulation of the low-energy (< 10 meV) spin excitations below $T \sim 150$ K, Hinkov *et al., Science* **319**, 597 (2008). We interpret our finding as the occurrence of an electronic liquid-crystal phase breaking $C4$-symmetry, as predicted by Kivelson *et al., Nature* **393**, 550 (1998). Below $T \sim 30$ K, we observe the onset of quasi-static spin-correlations with the same IC geometry as the low-energy spin excitations. Their intensity is doubled by the application of a magnetic field of 15 T. First of all, this resolves a long-standing discrepancy with the $La_{2-x}(Sr,Ba)_xCuO_4$ family where field-dependent, IC quasi-static spin correlations were reported before (Lake *et al., Nature* **415**, 299 (2002)). More importantly, our results show how the recently reported quantum oscillations in high magnetic fields in $YBa_2Cu_3O_{6.5}$ (Doiron-Leyraud *et al., Nature* **447**, 565 (2007)) can be understood in terms of a Fermi-surface reconstruction induced by IC spin modulations. In the lack of experimental evidence for such IC modulations, this mechanism has not been pursued in the past, although it was discussed as a straightforward explanation for Fermi-surface reconstruction. Finally, we will discuss YBCO with a T_c of 10 K. Compared to the previous example, there is an enhancement of the quasi-static spin-correlations. In addition, there is indication for incipient commensurate AF order in reminiscence of the AF parent compound.

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