Spin dynamics and sliding density-wave in $Sr_{14}Cu_{24}O_{41}$ ladders

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$Sr_{14}Cu_{24}O_{41}$ ladder compounds contain linear fragments of copper oxide planes. In contrast to the two-dimensional antiferromagnetic cuprates the spin $\frac{1}{2}$ two-leg ladders have short-range magnetic order and a spin gap. Holes doped into these ladders pair and superconduct at high doping concentrations, while insulators are known to result from low hole concentrations. The competition between insulating states and superconductive pairing has emerged as a key feature of the high-T_c problem, but the character of the insulating states has remained elusive. Here, using transport and Raman scattering data, we identify the insulating state of self-doped two-leg spin ladders of $Sr_{14}Cu_{24}O_{41}$ as a weakly pinned, sliding density wave. This collective density-wave state exhibits a giant dielectric response, non-linear conductivity, and persists to well above room temperature [1].

Our results have quantitative parallels with sliding density wave transport phenomena observed in established charge/spin density wave materials, yet there is a number of important microscopic differences from conventional weak-amplitude charge- and spin-density waves. The density wave correlation in $Sr_{14}Cu_{24}O_{41}$ is a high temperature phenomena that we observe up to the highest measured temperature, above 630 K. Such high temperature correlations can not be supported by phonons and suggest that the charge/spin correlations arise from strong spin exchange interactions with characteristic energy scale $J \simeq 1300$ K [2]. Theoretical calculations for a doped two-leg spin ladder suggest that the holes are paired in a state of approximate d-wave symmetry with a few lattice spacings in size. The superconducting condensation of bound pairs is competing with a crystalline order of these pairs in a density wave state.

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References

[1] G. Blumberg et al., Science **297**, 584 (2002).
[2] A. Gozar et al., Phys. Rev. Lett. **87**, 197202 (2001).