newly discovered function of ZBP1 contribute to biological and pathological processes involving cell migration? Such processes occur, for example, during embryonic development, infiltration of tissues by immune cells, wound healing and metastasis. Finally, does ZBP1 also act as a translational repressor in polarized neurons? If so, it will be exciting to discover whether it is involved in processes such as neurite outgrowth, axon guidance and synaptic plasticity, which underlie learning and memory. ■

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CONDENSED-MATTER PHYSICS

Focus on the Fermi surface

Peter Littlewood and Šimon Kos

The electrical resistance of some manganese oxides takes a tumble when they become magnetic. Close examination confirms the interplay of conduction electrons and lattice vibrations that contributes to this effect.

Certain manganese oxides (manganites) exhibit an intriguing effect known as 'colossal magnetoresistance'. Below a certain critical temperature, these materials become ferromagnetic — showing the spontaneous alignment of electron spins that accounts for the magnetic attraction of materials such as iron — and this is accompanied by a drastic reduction in electrical resistance. On page 474 of this issue, Mannella and colleagues[1] describe the electronic properties of a two-layer manganite compound, $La_{1.2}Sr_{1.8}Mn_2O_7$ (LSMO), revealing that the interaction of electrons and lattice vibrations known as phonons is crucial to colossal magnetoresistance. The results also bring to light unexpected similarities between the electronic structures of manganites and superconducting copper oxides.

In a metallic material such as a manganite, electrons fill quantum-mechanically allowed energy states singly from the lowest possible energy upwards. (This is a consequence of the Pauli exclusion principle, which holds that no two electrons may share the same quantum state.) The energy of the most highly occupied state is known as the chemical potential, or Fermi energy. The electronic energy states in a solid with a periodic lattice structure also have a well-defined momentum; when components of these momenta in the three spatial dimensions are plotted against each other, the occupied states form a characteristic shape bounded by a so-called Fermi surface. Only electrons in states near the Fermi surface — those with the highest momenta — contribute to conduction. According to a central tenet of quantum mechanics, known as Heisenberg's uncertainty relation, how sharply defined these energy states are is a measure of the degree to which electrons scatter on the lattice or on each other. So a good metal, with a low electrical resistance (little scattering), will have a sharply delineated Fermi surface.

Mannella and colleagues[1] provide the first experimental observation of the Fermi surface in a manganite. The technique they use, photoemission spectroscopy, is based on the photoelectric effect, in which light striking a metallic surface behaves as if it were a particle, knocking out a loosely bound electron. The electron's momentum and energy can be probed directly using this method, and the photoelectric effect has been a workhorse of experimental condensed-matter physics since it was first explained by Albert Einstein 100 years ago (for which he won the Nobel Prize in Physics in 1921).

The authors show that the Fermi surface of LSMO becomes more sharply defined when the material is cooled into the ferromagnetic state, indicating that its resistance has fallen. The result fits in with our understanding of colossal magnetoresistance as the suppression, induced by the onset of ferromagnetic order, of an interaction between electrons and phonons (the quanta of lattice vibrations)[2] that increases resistance. This bundling of electron and lattice properties can itself be treated as a physical entity moving through the lattice — a 'quasiparticle' known as a polaron. Scanning tunnelling microscopy measurements of LSMO support this picture[3], showing images of polarons trapped by occasional impurities.

Mannella and colleagues' results also indicate that the spectral weight of the sample (loosely, the proportion of the total number of energy states that exist at the Fermi surface) is very small, explaining why these states have not been observed previously. In addition, the measured energy spectrum at the Fermi surface is not isotropic, but depends strongly on the direction: electrons propagate readily (albeit with a velocity five times smaller than expected) in a direction that is diagonal to the square lattice of manganese atoms, but poorly along the axes of the lattice.

The reduced spectral weight and velocity seem to imply that, even in the metallic state, in which conduction electrons supposedly move freely throughout the lattice, electrons and phonons are interdependent. The results are puzzling, because at low temperatures manganites such as LSMO are good metals with an isotropic conductivity. The shape of the Fermi surface itself — with large parts that are nearly parallel, or 'nested' — supplies one possible interpretation. Nesting provides a channel through which an electron can be scattered between different parts of the Fermi surface; in this case it is scattered by a phonon, but in general it could also be scattered by magnetic fluctuations, should these exist. Scattering would reduce the electronic spectral weight around the Fermi energy and induce a gap in the energy spectrum.

The spectrum measured by Mannella *et al.* is very similar to that of the mysterious 'pseudogap' phase seen in high-temperature cuprate superconductors. This intriguing fact suggests that such a gap is a generic feature of the oxides of transition metals — rather than being a facet only of cuprate superconductors, as had been assumed. A further widespread belief is that phonons play no role in the high-temperature superconductivity seen in cuprates, despite the fact that interactions between electrons and phonons underlie conventional, low-temperature superconductivity. But it has been shown[4–6] that phonons affect various properties of the electrons in these superconductors, especially in the pseudogap phase. Mannella *et al.*[1] provide yet another incentive to examine the role of phonons more carefully. ■

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