DMR MRSEC Program

Materials Research Science and Engineering Centers (Princeton MRSEC 1420541)

Controllable electron flow in quantum wires (IRG-1)

Princeton MRSEC investigator **Yazdani** detected channels of conducting electrons that form between two quantum states on the surface of a bismuth crystal (from the lab of Princeton MRSEC investigator **Cava**) subjected to a high magnetic field. These two states consist of electrons moving in elliptical orbits with different orientations. The researchers found that the current flow in these channels can be turned on and off, making these channels a new type of controllable quantum wire.

The team further found that at the boundary, the conducting channels formed a valley-polarized domain wall, between two regions on the crystal where the electron orbits switched orientations abruptly. While the larger number of lanes would seem to suggest better conductivity, the repulsion between electrons counter-intuitively causes them to switch lanes, change direction, and get stuck, resulting in insulating behavior. With fewer channels, electrons have no option to change lanes and must transmit electrical current even if they have to move "through" each other—a quantum phenomenon only possible in such one-dimensional channels.

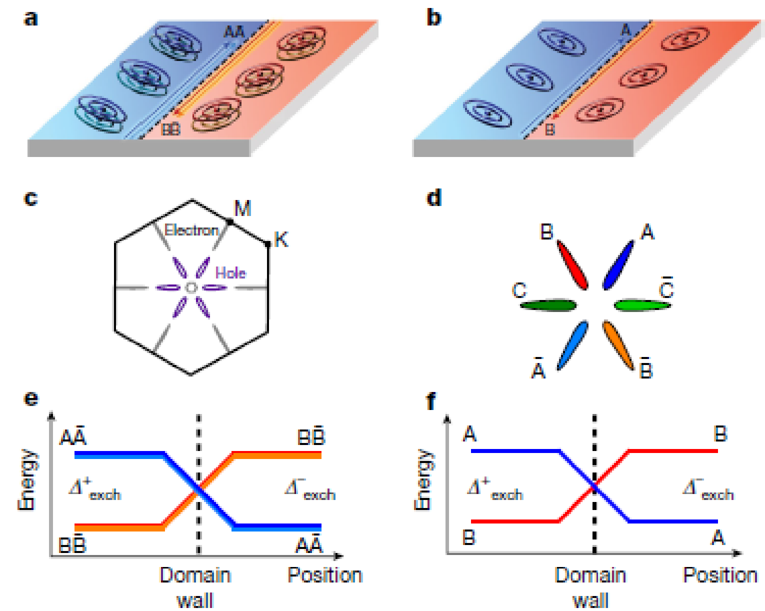

Fig. 1 | Boundary modes in a quantum Hall valley system. **a, b**, Schematic of nematic domain walls between different broken-valley-symmetry quantum Hall states at effective filling factors $\bar{\nu} = 2$ (**a**) and $\bar{\nu} = 1$ (**b**), with Landau orbits denoted by the ellipses on either side. The expected valley flavour and degeneracy of the counter-propagating modes along the boundary depend on the filling factor as shown. **c**, Brillouin zone of the Bi(111) surface, depicting multiple electron and hole valleys. **d**, Fermi surface in momentum space (***k***-space) of six-degenerate hole valleys, labelled to match different broken symmetry states discussed throughout the paper. Note the 90° rotation between the real-space Landau orbit orientation (shown in **a**, **b**), and the ***k***-space valley anisotropy. **e**, **f**, Gapless modes expected to connect topologically distinct phases on either side of the domain wall, with corresponding valley flavours and degeneracies indicated in the case of $\bar{\nu} = 2$ (**e**) and $\bar{\nu} = 1$ (**f**).

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"Interacting multi-channel topological boundary modes in a quantum Hall valley system," M. T. Randeria[1], K. Agarwal[1], B. E. Feldman[2], H. Ding[1], H. Ji[3], R. J. **Cava**[1], S. L. Sondhi[1], S. A. Parameswaran[4] and A. **Yazdani**[1]; Nature **566**, 363-367 (2019).
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