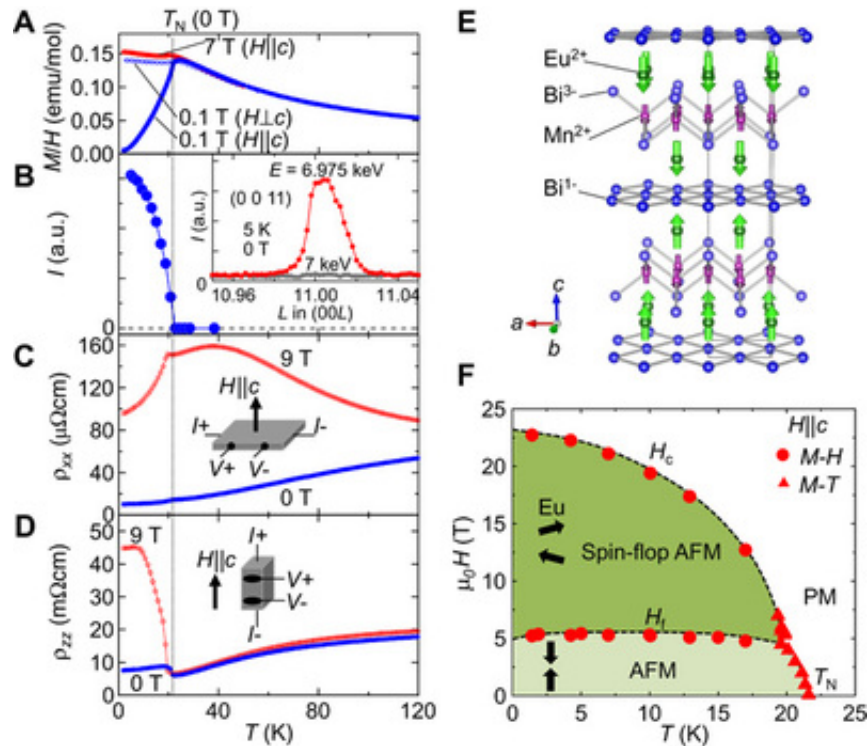


Discovery of a magnet capable of controlling Dirac fermions with zero mass

March 31 2016



(A to D) Temperature dependence of magnetic and transport properties near the AFM transition temperature (T_N) for EuMnBi₂. (A) Magnetic susceptibility M/H for the field parallel to the c axis (H||c) at 0.1 T (blue) and 7 T (red). Open symbols are the data for the field perpendicular to the c axis (H⊥c) at 0.1 T. (B) Intensity of resonant magnetic reflection (0 0 11) at 6.975 keV at 0 T. The inset shows the profile of the (0 0 11) reflection along [001] at 6.975 keV (resonant) and 7.00 keV (nonresonant). In-plane resistivity ρ_{xx} (C) and interlayer resistivity ρ_{zz} (D) at 0 and 9 T (H||c). Schematic sample configuration for the resistivity measurement is shown in each panel. emu/mol, electromagnetic unit per mole; a.u., arbitrary unit. (E) Schematic illustration of the plausible magnetic structure for EuMnBi₂ at zero field, together with the formal valence of each ion. The

arrangement of the Mn sublattice is assumed to be the same as in SrMnBi₂ (45). (F) Magnetic phase diagram for the Eu sublattice as functions of field (H||c) and temperature. PM and AFM denote the paramagnetic and antiferromagnetic states, respectively. H_f and H_c correspond to the transition fields to the spin-flop AFM and PM (forced ferromagnetic) phases, respectively. Black arrows are schematic illustration of the Eu moments sandwiching the Bi- layer. Note the Mn sublattice orders at ~315 K (>T_N).

A group of researchers from Osaka University and The University of Tokyo succeeded in synthesizing two-dimensional layers of bismuth (Bi) with Dirac electrons and magnetic multilayer blocks of europium.

Using flux growth in a high vacuum, this group succeeded in the synthesis of EuMnBi₂, a layered substance of high-quality single crystal thought to have both properties of Dirac fermions and magnets. This substance features hybrid architecture consisting of two-dimensional layers of Bi with Dirac electrons and europium with magnetic properties.

In order to verify the strong correlation between Dirac fermions and the magnetic state, this group measured electric resistance in a strong magnetic field (some 30 to 60 tesla) at The Institute for Solid State Physics of The University of Tokyo and the High Field Laboratory for Superconducting Materials of Tohoku University.

In order to elucidate the [magnetic state](#), the group conducted magnetic scattering experiments of radiated x-rays at the Photon Factory of the Institute of Materials Structure Science, High Energy Accelerator Research Organization.

As a result, they found that electric resistance significantly changed according to the magnetic order of europium. They also found that when a magnetic field was applied perpendicularly to the surface and the

direction of magnetic moment was rotated by 90 degrees, the conductivity perpendicular to the surface was suppressed by 10 percent and Dirac fermions were confined within the surface.

Furthermore, by confining Dirac electrons in the two-dimensional layer of Bi, or the superconducting layer, through the use of this effect, this joint group achieved a bulk half-integer quantum Hall effect, in which the value of the Hall resistance becomes discrete, in a bulk magnet of Dirac fermions for the first time.

This group's achievement will develop a new field of study, strong correlated quantum conductance of Dirac electrons, and contribute to realizing super high-speed spintronics, the foundation of high-speed and energy-saving electronics.

More information: H. Masuda et al. Quantum Hall effect in a bulk antiferromagnet EuMnBi₂ with magnetically confined two-dimensional Dirac fermions, *Science Advances* (2016). [DOI: 10.1126/sciadv.1501117](https://doi.org/10.1126/sciadv.1501117)

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