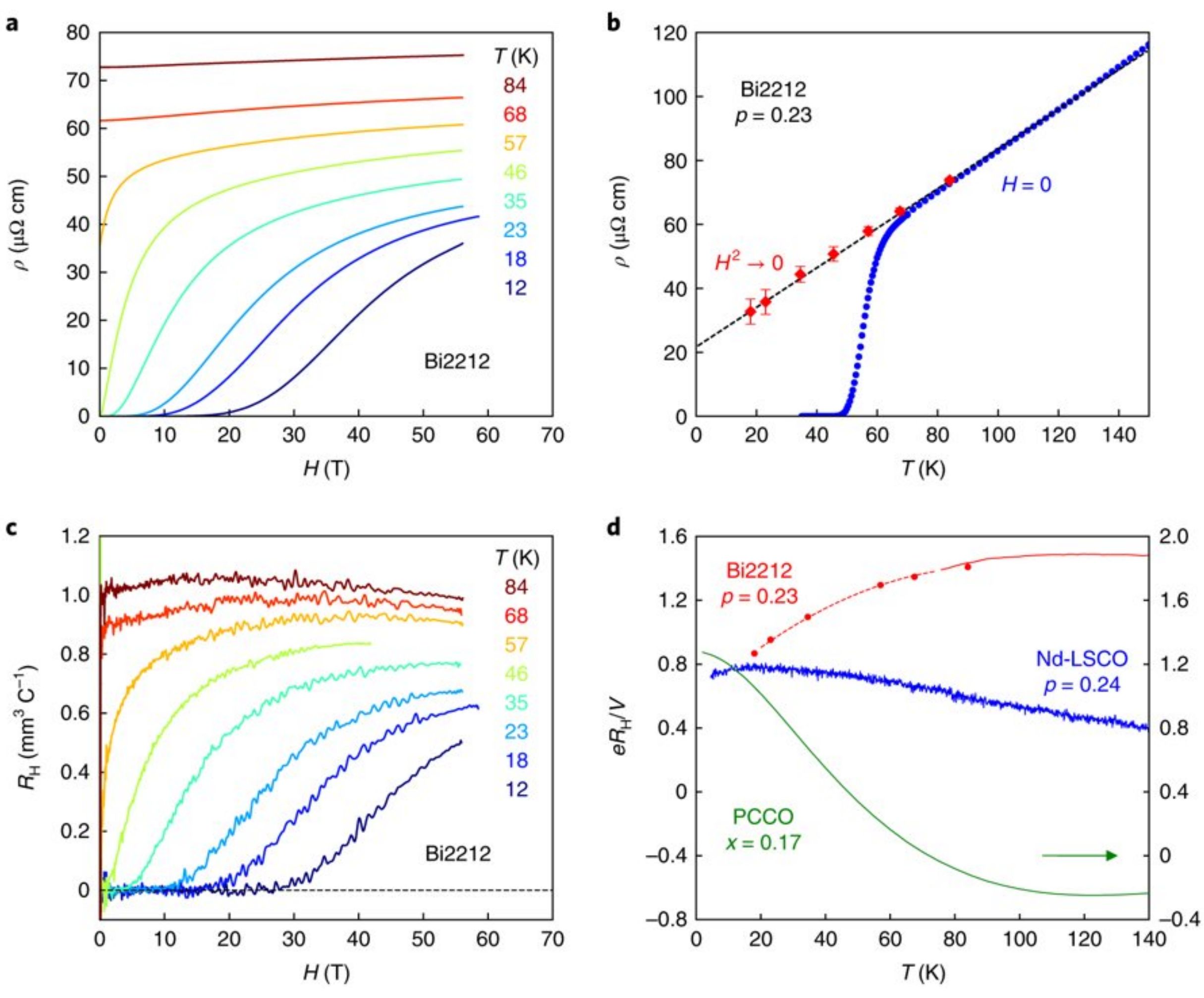
Electrons inside of some ceramic crystals appear to dissipate in a familiar way

November 20 2018, by Bob Yirka



a, Resistivity of our Bi2212 film with p = 0.23 as a function of magnetic field, at the indicated temperatures. The value of ρ at H = 55 T is plotted versus T in Supplementary Fig. 3b of Supplementary section 3. b, Resistivity as a function of temperature, at H = 0 (blue). The red diamonds are high-field data extrapolated to zero field by fitting ρ(H) to a + bH2. The error bars are estimated by the difference [ρ(H = 55 T) − ρ(H2 → 0)]/2. The dashed line is a linear fit to the red diamonds. c, Hall coefficient of our Bi2212 film as a function of magnetic field, at the indicated temperatures. The value of RH at H = 55 T is plotted versus T in d. d, Hall coefficient as a function of temperature for three cuprates, plotted as eRH/V, where e is the electron charge and V is the volume per Cu atom: Bi2212 at p = 0.23 (red curve, H = 9 T; red dots, H = 55 T, c); Nd-LSCO at p = 0.24 (blue, H = 16 T; from ref. 11); PCCO at x = 0.17 (green, H = 15 T, right axis; from ref. 41). The red dashed line is a guide to the eye. Credit: *Nature Physics* (2018). DOI: 10.1038/s41567-018-0334-2

A team of researchers from Canada, France and Poland has found that electrons inside of some ceramic crystals appear to dissipate in a surprising, yet familiar way—possibly a clue to the reason for the odd behavior of "strange metals." In their paper published in the journal *Nature Physics*, the researchers describe their experiments to better understand why strange metals behave the way they do.

The strange metals referred to in the study are also known as cuprates—materials that at room temperature are poor conductors of electricity, but at very cold temperatures are superconductors. Their strangeness comes about as they are cooling, just prior to becoming superconductive—they enter a state in which electrons inside of them appear to dissipate energy as fast as theory suggests is possible. And no one has been able to explain how or why this happens. Equally strange, the strangeness of the materials appears to be associated with the Planck constant.

To learn more about the behavior of strange metals when they enter their strange state, the researchers subjected samples of the cuprate $Bi_2Sr_2CaCu_2O_{8+\delta}$ to both high and low temperatures while measuring its resistance and other characteristics. They report evidence that bolsters theories suggesting that electrons in such materials organize themselves into a quantum state where the properties of each are dependent on the properties of all the others—a so called "maximally scrambled" state. Put another way, they found evidence that all of the electrons in the strange metal become entangled with all of the others. The researchers suggest such a state would surely explain how electrons in the material are able to scatter as fast as theory allows—and why their resistance would be dependent on Planck's constant.

The results add credence to work by other theorists who applied the theory of holographic duality to look at the behavior of cuprates—the theory that allows for connecting scrambled quantum particles mathematically. It is currently used by theorists to explain the nature of black holes that exist in a higher dimension.

More information: A. Legros et al. Universal T-linear resistivity and Planckian dissipation in overdoped cuprates, *Nature Physics* (2018). DOI: 10.1038/s41567-018-0334-2