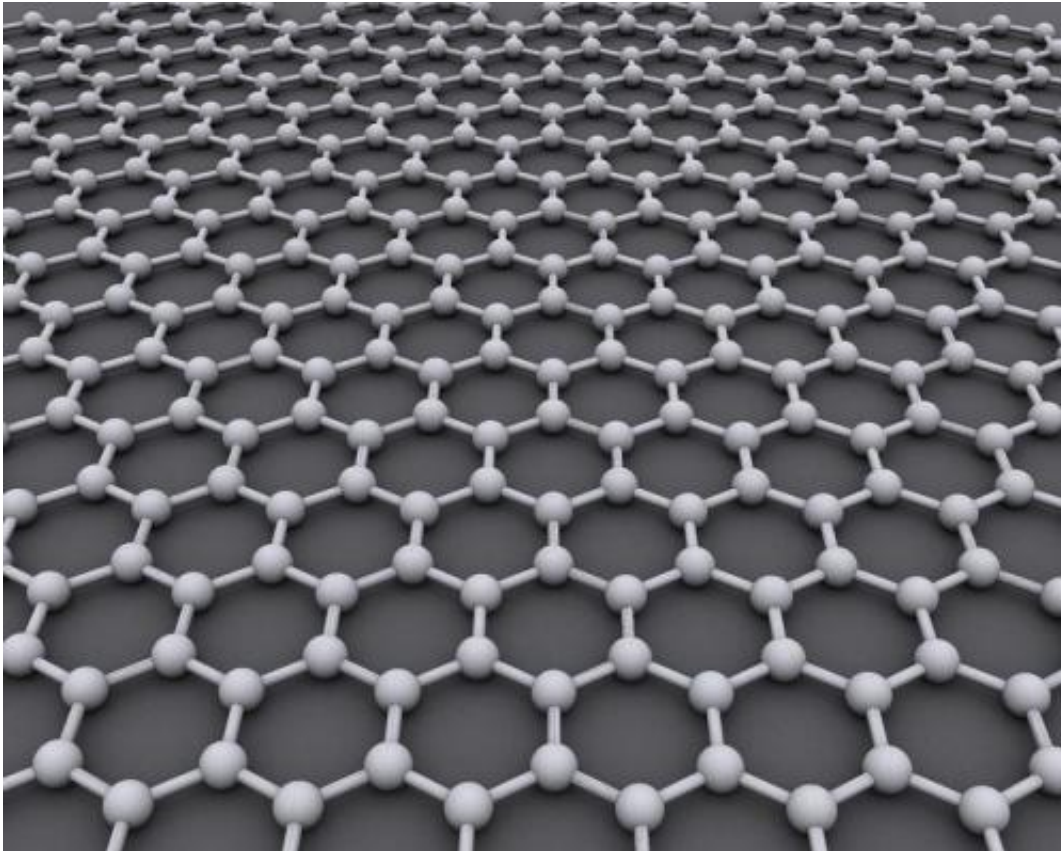


# Hall effect becomes viscous in graphene

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Researchers at The University of Manchester in the UK have discovered that the Hall effect—a phenomenon well known for more than a century—is no longer as universal as it was thought to be.

In the research paper published in *Science* this week, the group led by

Prof Sir Andre Geim and Dr. Denis Bandurin, found that the Hall effect can even be significantly weaker, if [electrons](#) strongly interact with each other giving rise to a viscous flow. The new phenomenon is important at [room temperature](#)—something that can have important implications for when making electronic or [optoelectronic devices](#).

Just like molecules in gases and liquids, electrons in solids frequently collide with each other and can thus behave like viscous fluids too. Such electron fluids are ideal to find new behaviours of materials in which [electron-electron interactions](#) are particularly strong. The problem is that most materials are rarely pure enough to allow electrons to enter the viscous regime. This is because they contain many impurities off which electrons can scatter before they have time to interact with each other and organise a viscous flow.

Graphene can come in very useful here: the carbon sheet is a highly clean material that contains only a few defects, impurities and phonons (vibrations of the crystal lattice induced by temperature) so that electron-electron interactions become the main source of scattering, which leads to a viscous electron flow.

"In previous work, our group found that electron flow in graphene can have a viscosity as high as  $0.1 \text{ m}^2\text{s}^{-1}$ , which is 100 times higher than that of honey," said Dr. Bandurin "In this first demonstration of electron hydrodynamics, we discovered very unusual phenomena like negative resistance, electron whirlpools and superballistic flow."

Even more unusual effects occur when a magnetic field is applied to graphene's electrons when they are in the viscous regime. Theorists have already extensively studied electro-magnetohydrodynamics because of its relevance for plasmas in nuclear reactors and in neutron stars, as well as for fluid mechanics in general. But, no practical experimental system in which to test those predictions (such as large negative

magnetoresistance and anomalous Hall resistivity) was readily available until now.

In their latest experiments, the Manchester researchers made graphene devices with many voltage probes placed at different distances from the electrical current path. Some of them were less than one micron from each other. Geim and colleagues showed that while the Hall effect is completely normal if measured at large distances from the current path, its magnitude rapidly diminishes if probed locally, using contacts close to the current injector.

"The behaviour is radically different from the standard textbook physics" says Alexey Berdyugin, a Ph.D. student who conducted the experimental work. "We observe that if the voltage contacts are far from the current contacts, we measure the old, boring Hall effect, instead of this new 'viscous Hall effect'. But, if we place the voltage probes near the current injection points—the area in which viscosity shows up most dramatically as whirlpools in electron flow—then we find that the Hall effect diminishes.

"Qualitative changes in the electron flow caused by viscosity persist even at room temperature if graphene devices are smaller than one micron in size, says Berdyugin. "Since this size has become routine these days as far as [electronic devices](#) are concerned, the viscous effects are important when making or studying graphene devices."

**More information:** "Measuring Hall viscosity of graphene's electron fluid" *Science* (2019). [science.sciencemag.org/lookup/...1126/science.aau0685](https://www.science.org/lookup/1126/science.aau0685)

Provided by University of Manchester

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