Physicists create nanoscale spinning magnetic droplets

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Researchers have successfully created a magnetic soliton – a nano-sized, spinning droplet that was first theorized 35 years ago. These solitons have implications for the creation of magnetic, spin-based computers.

Solitons are waves, localized in space, that preserve their size and momentum. They were first observed in water. Solitons composed of light have proved useful for long distance, high speed information transmission. But droplet solitons had never been observed in a magnetic environment, although scientists believed they could exist there.

North Carolina State University mathematician Mark Hoefer had created a mathematical model of what such a soliton might look like. When physicist Johan Åkerman and graduate student Majid Mohseni from Sweden's Royal Institute of Technology (KTH) and the University of Gothenburg got experimental data back that seemed to correspond with Hoefer's model, they decided to try and confirm the existence of a magnetic droplet soliton.

The physicists used a nanoscale wire to deliver a small amount of DC current to a magnet. All electrons possess angular momentum in the form of spin. Picture a spinning top. Angular momentum is what keeps that top upright, or pointed in a particular direction. Each electron within the magnet is like a spinning top, and in magnets, all of the electrons' spins are aligned in roughly the same way. Putting DC current into that group of electrons injects energy into the magnetic system, changing the spin of the local electrons in that immediate area. The spins of the electrons then precess, or "lean" like a top does when it is no longer upright, which causes a tiny spinning magnetic droplet, or soliton, to form.

The scientists were able to detect the soliton's presence by measuring the frequency of the precession. They observed the soliton's unique signature – a pronounced drop in frequency coupled with a large jump in power output – and knew they had been successful.

"These solitons are called 'dissipative,' because magnets want to dissipate energy from precession," Hoefer says. "They maintain their stability by balancing the amount of energy coming into the system via the DC current with the amount going out, and by balancing the nonlinearity, or amplitude, with dispersion, or a tendency to spread out."

In addition to demonstrating the existence of these solitons, the researchers also noted some other interesting properties of the solitons, including oscillatory motion and a periodic deformation they referred to as "breathing."

The researchers' findings appear in *Science*.

"Solitons are excellent transmitters of information, so finding them in a magnetic system could have all sorts of implications for spin-based computing, from new ways to process information to higher density hard drives," Hoefer says.

More information: "Spin Torque–Generated Magnetic Droplet Solitons" March 15, 2013 in *Science*.

Abstract
Dissipative solitons have been reported in a wide range of nonlinear systems, but the observation of their magnetic analog has been

experimentally challenging. Using spin transfer torque underneath a nanocontact on a magnetic thin film with perpendicular magnetic anisotropy (PMA), we have observed the generation of dissipative magnetic droplet solitons and report on their rich dynamical properties. Micromagnetic simulations identify a wide range of automodulation frequencies, including droplet oscillatory motion, droplet "spinning," and droplet "breather" states. The droplet can be controlled by using both current and magnetic fields and is expected to have applications in spintronics, magnonics, and PMA-based domain-wall devices.

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