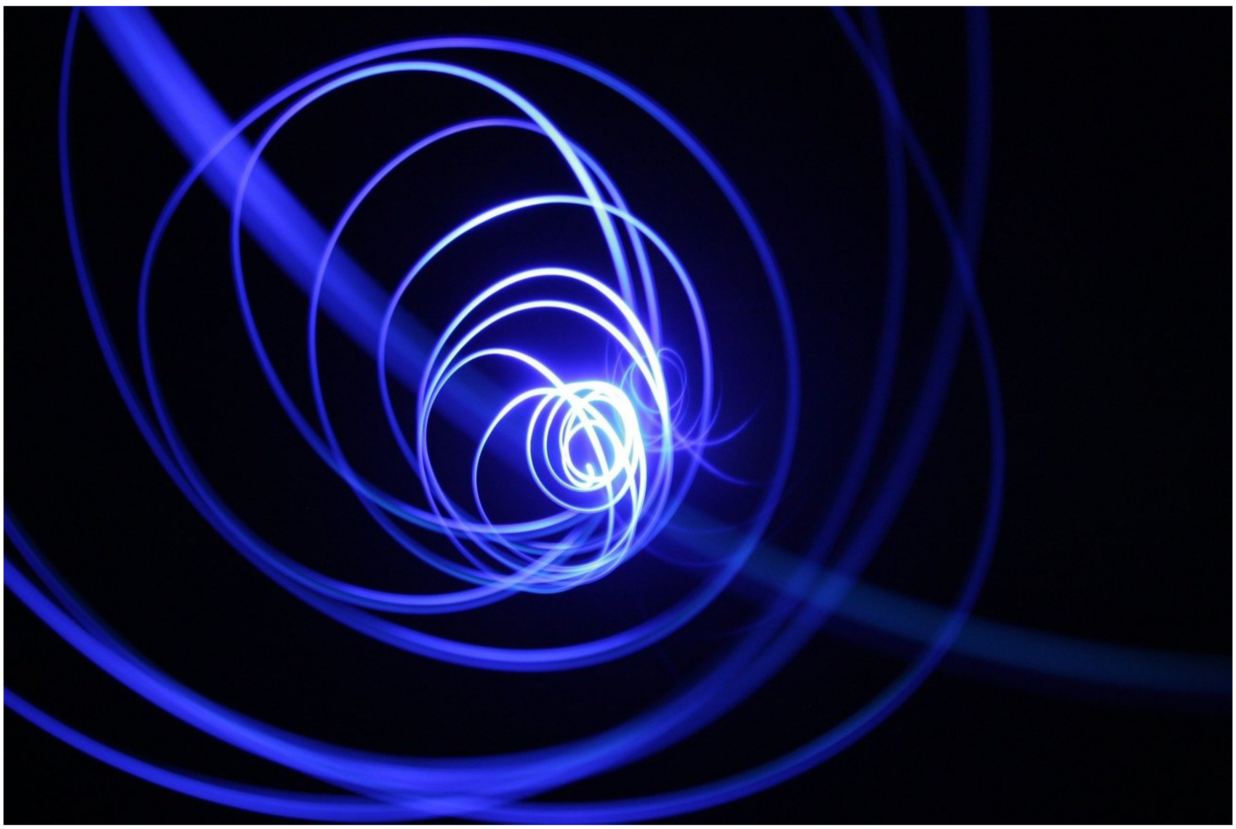
# Confirming a source of the process behind auroras and the formation of stars

February 19 2019



Credit: CC0 Public Domain

Fast magnetic reconnection, the rapid convergence, separation and explosive snapping together of magnetic field lines, gives rise to northern lights, solar flares and geomagnetic storms that can disrupt cell phone service and electric power grids. The phenomenon takes place in plasma, the state of matter composed of free electrons and atomic nuclei, or ions, that makes up 99 percent of the visible universe. But whether fast reconnection can occur in partially ionized plasma—plasma that includes atoms as well as free electrons and ions—is not well understood.

Researchers at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) have now produced the first fully kinetic model of the behavior of plasma particles and found that fast reconnection can indeed occur in partially ionized systems. Kinetic models simulate the distribution and velocity of billions of particles, compared with fluid models that treat plasma as a continuous medium rather than as a collection of individual particles.

"There is a whole class of partially ionized plasmas whose link to reconnection has not been well studied," said physicist Jonathan Jara-Almonte, lead author of a paper in *Physical Review Letters* that reports the recent findings. "We have now demonstrated that fast reconnection can occur in partially ionized systems."

For example, the research suggests that fast reconnection in the partially ionized plasma in the solar chromosphere, the region between the surface of the sun and the halo-like solar corona, could play a role in the development of jet streams. Such streams are a possible source of the solar wind that bounces hot, charged plasma off the Earth's magnetic field.

## Important implications

Fast reconnection in partially ionized plasma has important implications for the interstellar medium, the vast clouds of gas and dust that fill the cosmos between stars. The cold, dense regions of the interstellar medium where stars form are only very poorly ionized, and fast reconnection occurring within these regions can help remove magnetic fields that prevent star formation.

Understanding when and where fast reconnection occurs remains an unsolved problem, and previous analytical predictions for partially ionized plasmas relied on extrapolating from fully ionized ones. The new simulations, performed on computers at Princeton University, demonstrated that the transition to fast reconnection occurs only when the current sheet is much thinner than predicted. The results suggest that the transport of plasma and heat is different in partially ionized plasmas and can alter how and when reconnection occurs.

These findings focus on reconnection on a very small scale, unlike the process that occurs in the solar chromosphere. Nonetheless, the simulation proved compatible with reconnection in the upper chromosphere as well as in small-scale laboratory experiments.

Going forward, Jara-Almonte plans to compare findings of the kinetic simulation with those of fluid simulations that have dominated previous modeling of partially ionized plasmas. Co-authoring the recent paper were PPPL physicists Hantao Ji, professor of astrophysical sciences at Princeton University; Masaaki Yamada, principal investigator of the Magnetic Reconnection Experiment (MRX) at PPPL; and Will Fox, together with Bill Daughton of Los Alamos National Laboratory.

**More information:** J. Jara-Almonte et al, Kinetic Simulations of Magnetic Reconnection in Partially Ionized Plasmas, *Physical Review Letters* (2019). DOI: 10.1103/PhysRevLett.122.015101

Provided by Princeton Plasma Physics Laboratory