Japanese researchers find new classes of electron orbits

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Phenomena like solar flares and auroras are consequences of magnetic reconnection in the near-Earth space. These "magnetic reconnection" events are akin to magnetic explosions that accelerate particles as they rapidly change the topology of the magnetic field lines. Researchers in Japan have used a new Particle-In-Cell (PIC) simulator to understand how magnetic reconnection works for the tenuous plasma surrounding our Earth and have identified new classes of electron orbits that help scientists understand the characteristics of the fast jets of electrons that stream from the reconnection region. The researchers explain their results this week in *Physics of Plasmas*.

The ionized gas in space, called "plasma," is so tenuous that the charged particles (ions and electrons) rarely collide with each other, but move in very complex ways due to the electric and magnetic fields. This process is highly nonlinear because as the electrons move, they carry the electric current which in turn changes the electromagnetic field. The self-consistent nonlinear motion of the particles and of the electromagnetic field is a complex system that is hard to predict.

"We investigate basic mechanisms of magnetic reconnection in tenuous space plasma, by using a computer simulation that allows us to solve both the electromagnetic fields and the motions of virtual plasma particles," said Seiji Zenitani, a scientist at the National Astronomical Observatory of Japan. Although PIC simulations are widely used and can solve the motion of virtual particles, often all the particle trajectories are not checked. The reason is two-fold: on the one hand, because PIC simulation generates very large data sets; on the other, because until now, scientists had thought that all the basic orbits were already discovered in the 1980s. By comprehensively scanning the simulation data, the research team was careful not to overlook anything.

While this approach is straightforward for a small collection of particles, as a result of an extensive survey of PIC simulation with nearly two billion particles, researchers were able to identify several new classes of electron orbits.

"We were surprised to find 'noncrossing electron orbits' that do not cross the midplane, a finding contrary to conventional belief that all the particles cross the midplane (z=0) during magnetic reconnection," Zenitani said. So, while it is a standard strategy to track electron trajectories from the midplane, by definition, this does not work for the noncrossing electrons. Analysis suggests that the noncrossing electrons are the majority, at least in the number density. The particle orbits are fundamental elements for the kinetic physics of magnetic reconnection which could lead to the revision of theoretical models.

"In addition, NASA's Magnetospheric Multiscale (MMS) mission observes the electron properties in and around near-Earth reconnection sites now," Zenitani said. "Our results provide hints that will help to better interpret MMS data."

More information: Seiji Zenitani et al. Particle dynamics in the electron current layer in collisionless magnetic reconnection, *Physics of Plasmas* (2016). DOI: 10.1063/1.4963008

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