New Electron Orbits in Collisionless Magnetic Reconnection

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Magnetic reconnection, an explosive energy-release process in space plasmas, is mediated by complex particle motion of plasmas. The electron motion is one of the smallest elements in reconnection systems, and has long been studied by using particle-in-cell (PIC) simulations. However, as PIC data have become larger and larger in size, it has become more and more difficult to diagnose particle orbits in simulations. The theories on particle orbits in the reconnection system were established in 1980's.

In this work, we extensively analyzed electron dynamics in magnetic reconnection by using a 2D PIC simulation. We surveyed twenty million trajectories, so as not to overlook any interesting trajectories. As a result, we discovered various electron orbits that have never been discussed before. Figure 1 show example electron orbits. One can see that the red and blue orbits do not cross the midplane (the horizontal dotted line), while the traditional theories assume that all orbits cross the midplane. We examined and classified various electron orbits, as schematically illustrated in Figure 2. The new orbits are indicated by the double frames. Surprisingly, it was found that a majority of electrons follow the new orbits. These results raise a serious question to previous discussions for the kinetic physics of magnetic reconnection. Since the particle orbits are fundamental elements, our findings could lead to the revision of theoretical models.

Our results were published in the *Physics of Plasmas* journal [1]. Owning to fundamental results in this research field, our paper was highlighted by American Institute of Physics (AIP) [2] and by Physics of Plasmas.

We note that NASA's Magnetospheric Multiscale (MMS) spacecraft will start detail observation in the nightside reconnection regions in the Earth magnetosphere in May, 2017. Our findings will provide a clue to interpret MMS data and to understand the fundamental physics of magnetic reconnection.

References

[1] Zenitani, S., Nagai, T.: 2016, *Phys. Plasmas*, **23**, 102102.
[2] https://publishing.aip.org/publishing/journal-highlights/japanese-researchers-find-new-classes-electron-orbits

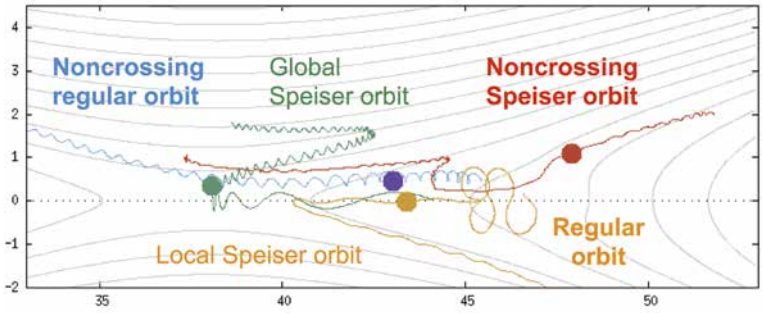

Figure 1: Typical electron orbits in our PIC simulation. Magnetic field lines are overplotted.

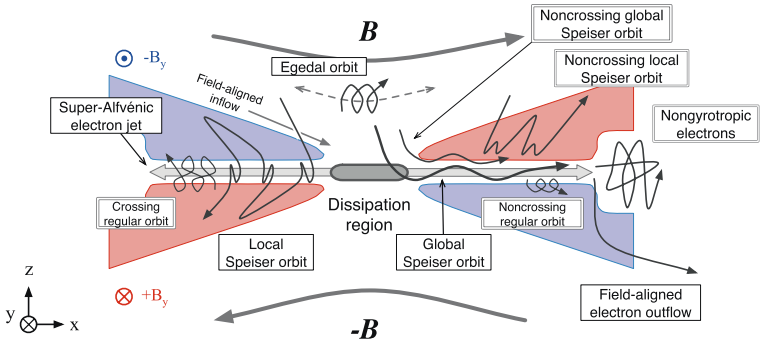

Figure 2: Summary of electron orbits in magnetic reconnection (Ref. [1]). The new orbits are indicated by the double frames.