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The secrets of the ion diffusion region in collisionless magnetic reconnection

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Magnetic reconnection relies on the dissipation mechanism in a narrow region surrounding the X-line, the so-called diffusion region (DR). It is usually expected that the DR consits of an inner electron diffusion region and an outer ion diffusion region. In this work, we study kinetic aspects of the ion region in magnetic reconnection.
First, the notion of the magnetic diffusion is re-considered as relaxation to the frozen-in state, which depends on a reference velocity field. Two-dimensional particle-in-cell (PIC) simulations reveal that the magnetic fields are frozen to plasma fluids in the outer part, even though the ideal condition is violated. This provides counter-evidence for a conventional discussion, based on the ion nonidealness.
We further examine the ion velocity distribution function in the nonideal region. The distribution function is highly nongyrotropic and relevant to chaotic particle dynamics in an appropriate frame. The nongyrotropic particle motion is responsible for ion's macroscopic properties, such as the nonidealness and a sub-Alfvenic flow speed. The trapped ions are the first self-consistent demonstration of the regular orbits.