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Acceleration and Phase-space Structure Formation of Cold Ions in Collisionless Reconnection

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Acceleration is a major mechanism of particle energization, and thus widely studied in many areas such as astrophysical phenomena, catastrophe space weather events, as well as radio-frequency and neutral beam injection heating in fusion plasma, with various research focuses. Moreover, particle acceleration is a crucial course in magnetic reconnection for its decisive role in energy transfer. In reconnection processes, a substantial amount of magnetic energy is rapidly released and transferred to kinetic energy to heat and accelerate charged particles in plasmas, causing various fast events on space, fusion, and astrophysical plasmas.[1] Besides, a significant feature of magnetic reconnection is magnetic topology variation, which can be a dominant factor to affect the particle acceleration and phase-space structure formation. [2]

The cold ions effect on magnetic reconnection is also a latest research focus in space and plasma physics. A characteristic feature of the cold ions is their gyroradius being smaller than that of background warm ions.[3] Thus, certain memories of trajectory correlation in the MHD region are kept as they entering the reconnection region of a spatial scale majorly characterized by the warm ion gyroradius. Such a property then contributes to their acceleration and formation of characteristic phase-space structures in the reconnection region.

In this work, we analyze typical processes for collisionless reconnection with cold ions in an initial two-dimensional Harris sheet equilibrium, by numerical simulation. It is found that the formation of phase-space structure of the cold ions is closely related to the topological property of magnetic configurations. For those entering the diffusion region around the X-point (Fig.1(a, c)), cold ions are accelerated mainly by the reconnection electrical field, and a clump-like structure in the phase-space is formed near the outflow region. On the other hand, for those entering the diffusion region across the separatrix away from the X-point (Fig.1(b, d)), cold ions are accelerated mainly by the Hall electrical field, and a crescent-shaped distribution in the velocity-space is formed in the magnetic island due to the gyro-phase effect during demagnetization. Acceleration processes and formation mechanisms of phase-space structures are analyzed by the particle tracing method.

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References

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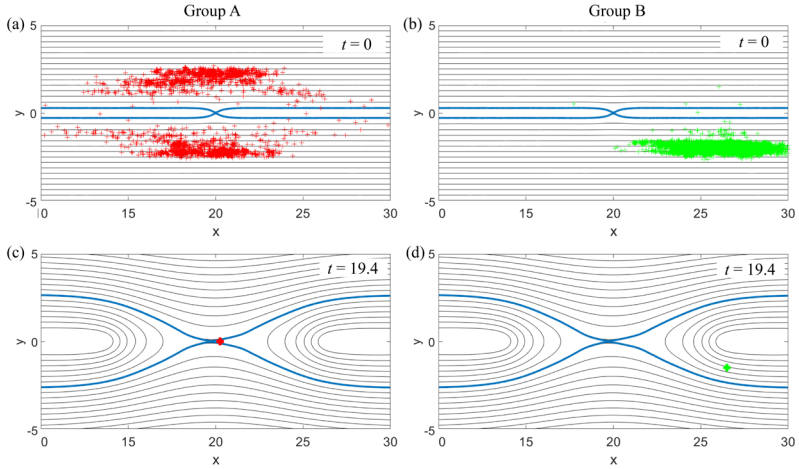

Figure 1. (a, b) Initial and (c, d) quasi-steady state (at t = 19.4) spatial distributions of Groups A and B (marked by red and green respectively) cold ions.