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PIC Simulation Study of Relaxation Phenomena in Counter-helicity Merging

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In this research, the relaxation of spheromak-like plasmoids formed by counter-helicity merging to an FRC-like plasmoid has been investigated by means of 2D particle-in-cell (PIC) simulation in Cartesian coordinates and our PIC simulation results agree with the experimental results in TS-3 and TS-4 merging device. The counter-helicity merging is one of the methods of creating an FRC by colliding spheromaks with opposite helicities. It was observed that the merging spheromaks relaxed into either an FRC or spheromak depending on whether the initial total magnetic helicity was smaller or larger than a threshold value [1]. This result of relaxation to FRC does not agree with the Taylor relaxation or MHD simulations [2].

In this study, spheromak-like plasmoids merging and relaxation process are investigated by 2D Cartesian coordinates PIC simulations. Initial conditions are given by coupling GS equilibrium with out-of-plane magnetic field B_z of different strengths and signs.

The simulations revealed that after merging, B_z decays when initial B_z ratio is small while it remains when initial B_z ratio is large, as shown in Figure 1 (a). These results are consistent with the experimental results that relaxation into either an FRC or a spheromak is determined depending on whether the initial B_z ratio was smaller or larger than a threshold value. Previous studies showed that heavier ion species have a large threshold value, and the simulation results agree with it [3].

The hypothesis that poloidal flux decays when the size of ion gyroradius exceeds the size of unreconnected flux has been proposed in previous studies. The experimental and simulation results support it. Additionally, test particles analysis has shown that electrons take non-magnetized orbits when B_z decays after merging. This result suggests that electron's kinetic effects play an important role in the relaxation process.

References

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[3] E. Kawamori et al 2005 Phys. Rev. Lett. 95, 085003

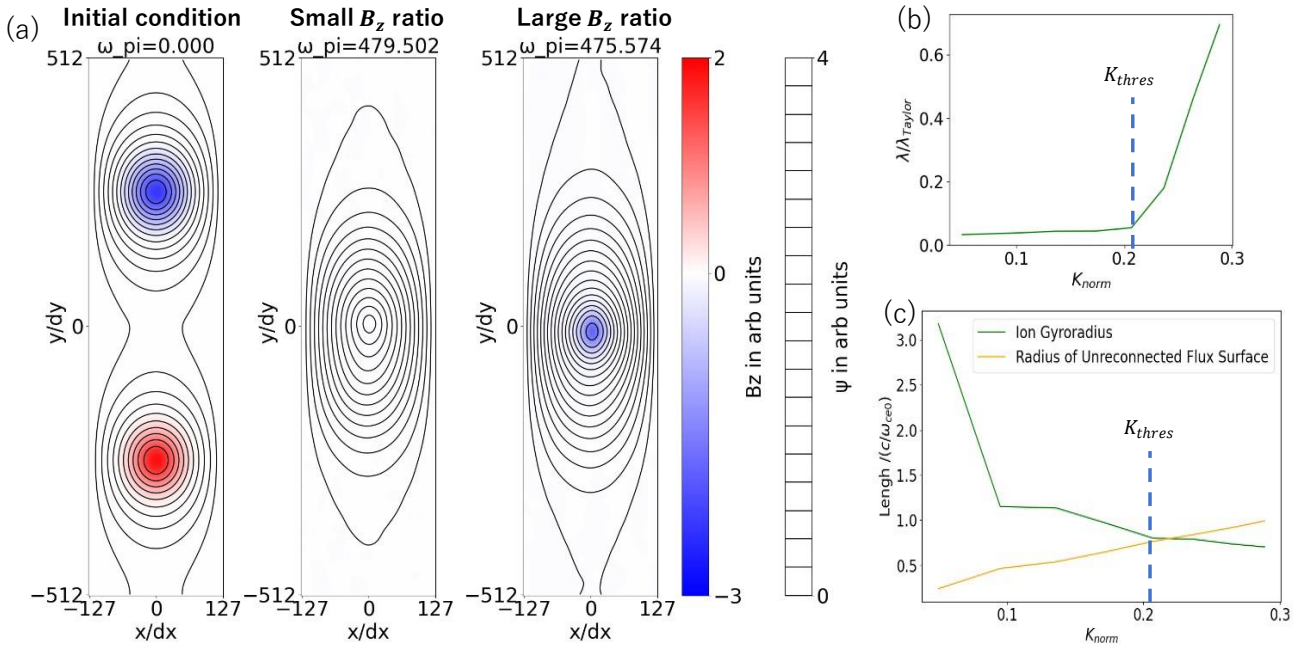

Figure 1: (a)PIC simulation results in the case of relaxation into an FRC (small B_z ratio) or an spheromak (large B_z ratio) after counter-helicity merging. (b)Normalized initial helicity dependence of normalized eigen value λ/λ_{Taylor}. (c)Normalized initial helicity dependence of ion gyroradius and radius of radius of unreconnected flux surface.