

Secondary reconnection between interlinked flux tubes driven by magnetic reconnection with a short x-line¹

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Abstract

Magnetic reconnection is a fundamental energy conversion process in plasmas, and exists in varieties of space environments. Recent observations find magnetic reconnection occurring in the current sheet between two elbow like flux tubes interlinked with each other. The observational features of such a kind of event are very similar to that of a flux rope, which is a helical magnetic field structure. However, the formation condition for interlinked flux tubes and magnetic reconnection between them is not well understood, the relation between interlinked flux tubes and flux ropes is also not very clear.

We use three-dimensional particle-in-cell simulation to study secondary reconnection between two interlinked flux tubes produced by neighboring guide field reconnection x-lines. The reconnecting magnetic fields of this secondary reconnection is enhanced toward the diffusion region, agree well with that in observations. The magnetic field pileup is attributed to the upstream magnetic tension force, that smashes the flux tubes into each other. We propose that the primary reconnection x-line length is a key parameter to determine the formation of interlinked flux tubes and secondary reconnection therein. Interlinked flux tubes will form only if the x-line is short; when the x-line is long enough, the regular flux ropes are formed instead. The critical x-line length to form interlinked flux tubes is determined by the distance between two neighbor x-lines and the magnetic shear angle of the primary reconnection. The results provide a novel scenario of secondary reconnection generation during three-dimensional reconnection.

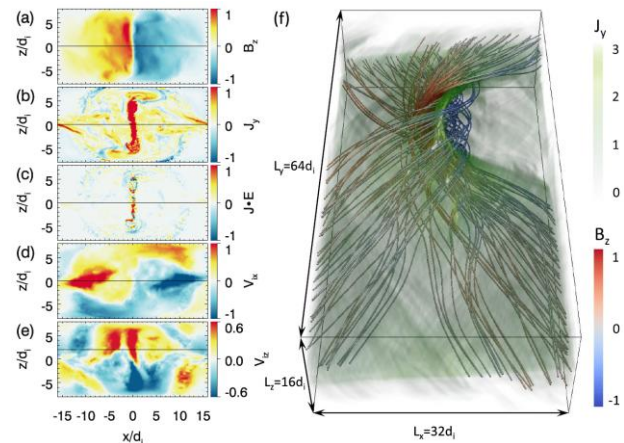


Figure 1. Panel (f) shows the three-dimensional magnetic field lines of interlinked flux tubes and the current sheet formed between them. Panels (a-e) show the characteristics of secondary reconnection inside this current sheet.

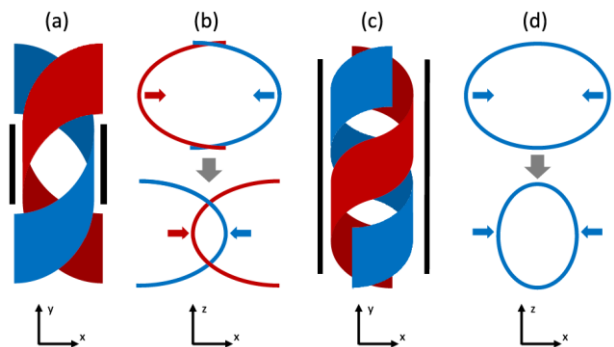


Figure 2. A sketch of the formation of interlinked flux tubes (panels (a) and (b)) and a flux rope (panels (c) and (d)). Interlinked flux tubes and secondary reconnection between them can form when the x-line (black solid lines) is short.

References

- [1] Huang, K., Lu, Q., Liu, Y. - H., Lu, S., Li, X., Tang, H., & Peng, E. (2024). Secondary reconnection between interlinked flux tubes driven by magnetic reconnection with a short x-line. *Geophysical Research Letters*, 51, e2024GL111812. <https://doi.org/10.1029/2024GL111812>