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The Origin and Dynamic Evolution of Solar Eruptions

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The Sun's atmosphere is frequently disrupted by coronal mass ejections (CMEs), coupled with solar flares and energetic particles. In the standard model, the coupling is explained by magnetic reconnection at a vertical current sheet connecting the flare loops and the CME, with the latter embedding a helical magnetic structure known as magnetic flux rope. As it jumps upward due to loss of equilibrium or instability, the flux rope stretches the overlying coronal loops so that oppositely directed field is brought together underneath, creating the current sheet. Magnetic reconnection that occurs in the current sheet both provides for the impulsive and vast energy release used for plasma heating and particle acceleration in flares, and facilitates the CME acceleration by reducing the tension of the overlying arcade and supplying additional poloidal magnetic flux. However, neither the origin of flux ropes nor their evolutionary paths toward eruption have been clarified by observations, and the coupling between flares and CMEs are less understood during different stages of solar eruptions.

Here we present observational studies of the formation of solar magnetic flux rope and the dynamic evolution of the subsequent CME in the solar corona. We observe the complete evolution of how a stellar-sized CME bubble continuously evolves from plasmoids, mini flux ropes that are barely resolved, within half an hour[1]. The eruption initiates when plasmoids springing from a vertical current sheet merge into the leading plasmoid at the upper tip of the current sheet. Rising at increasing speeds to stretch the overlying loops, this hot plasmoid expands impulsively into the CME bubble, in tandem with hard X-ray (HXR) bursts. While the peak acceleration of the CME occurs during the early stage of the eruption, the flare energy release revealed by HXR emission is much stronger afterwards[2,3], which shows a different scenario from the synchronization between the flare nonthermal emission and CME acceleration as supposed in the standard model.

The observation illuminates a complete CME evolutionary path by revealing the origin of magnetic flux rope and its dynamic evolution in the corona. Our results substantiate the connection between macro-scale activities and micro-scale dynamics in current sheets and also provide some new insights on the flare-CME relationship.

References

[1] Gou, T., Liu, R., Kliem, B., Wang, Y., & Veronig, A. M. (2019). The birth of a coronal mass ejection. Science advances, 5(3), eaau7004.
[2] Gou, T., Veronig, A. M., Dickson, E. C., Hernandez-Perez, A., & Liu, R. (2017). Direct observation of two-step magnetic reconnection in a solar flare. The Astrophysical Journal Letters, 845(1), L1.
[3] Gou, T., Veronig, A. M., Liu, R., Zhuang, B., Dumbović, M., Podladchikova, T., ... & Wang, Y. (2020). Solar Flare–CME Coupling throughout Two Acceleration Phases of a Fast CME. The Astrophysical Journal Letters, 897(2), L36.