Coronal flux-rope formation through flux cancellation of a sheared arcade in a 3D convectively-driven MHD simulation

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Résumé

Coronal flux ropes are generally believed to be one of the prime candidates for the magnetic configuration of solar prominences and of coronal mass ejection (CME) progenitors. Observations suggest that flux-rope formation should be ensured by series of flux cancellations that typically occur at the the Sun's surface, along the polarity inversion-line, below pre-existing sheared coronal loops. This has been the origin of the so-called flux-cancellation model. This model has first been proposed in the late eighties, and since then it has been implemented in many independent line-tied coronal MHD simulations of flux-rope formation and CME initiation, ours included. One major issue, however, is that the real Sun has no line-tied boundary. The fact that real-life flux cancellation does not work like in these simulations have raised questions about the validity of this scenario in particular, and even about the very existence of pre-eruptive flux-ropes in general. Given the CME onset-threshold which is now widely accepted for pre-eruptive flux ropes in the framework of the torus instability, this controversy becomes sensitive in terms of space-weather research. In order to address this issue, we used the BIFROST code to model the 3D coupling between the upper convection-zone and the above corona to model this scenario from first-principles. Through a careful setup, we find that the self-consistent stochastic plasma flows of the convection zone drive multiple small-scale flux cancellations and photospheric magnetic reconnection. And for the first time, we show and we interpret how these reconnections convert an initially linear force-free sheared coronal-arcade into a finite-size non-linear force-free flux rope. On one hand, we reveal that the flux-rope formation process is more complex than in the idealized simulations. Indeed, reconnection can happen at various altitudes, sometimes in the 3D slipping mode. Also there are some instances where cancellations are unrelated to reconnection. On the other hand, however, we confirm that the flux cancellation model works: it does form a flux rope.

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