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# Formation of torus-unstable flux ropes and electric currents in erupting sigmoids

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**Abstract.** We analyze the physical mechanisms that form a coronal flux rope and later cause its eruption. This is achieved by a zero-$\beta$ MHD simulation of an initially potential, asymmetric bipolar field, which evolves by means of simultaneous slow magnetic field diffusion and sub-Alfvénic, line-tied shearing motions in the photosphere. As in similar models, flux-cancellation driven photospheric reconnection in a bald-patch (BP) separatrix transforms the sheared arcades into a slowly rising and stable flux rope. A bifurcation from a BP to a quasi-separatrix layer (QSL) topology occurs later on in the evolution, while the flux rope keeps growing and slowly rising, now due to shear-driven coronal sliprunning reconnection, which is of tether-cutting type and takes place in the QSL. As the flux rope reaches the altitude at which the decay index $-\partial \ln B/\partial \ln z$ of the potential field exceeds $\sim 3/2$, it rapidly accelerates upward while the overlying arcade eventually develops an inverse tear-drop shape, as observed in CMEs. This transition to non-equilibrium is in accordance with the onset criterion of the torus instability. Thus we find that photospheric flux-cancellation and tether-cutting coronal reconnection do not trigger CMEs in bipolar magnetic fields, but are key pre-eruptive mechanisms for flux ropes to build up and to rise to the critical height above the photosphere at which the torus instability causes the eruption. In order to interpret recent Hinode/XRT observations of an erupting sigmoid, we produce simplified synthetic soft X-ray images from the distribution of the electric currents in the simulation. We find that a bright sigmoidal envelope is formed by pairs of J-shaped field lines in the pre-eruptive stage. These field lines form through the BP reconnection, and merge later on into S-shaped loops through the tether-cutting reconnection. During the eruption, the central part of the sigmoid brightens due to the formation of a vertical current layer in the wake of the erupting flux rope. Slip-running reconnection in this layer yields the formation of flare loops. A rapid decrease of currents due to field line expansion, together with the increase of narrow currents in the reconnecting QSL, yields the sigmoid hooks to thin in the early stages of the eruption. Finally, a slightly rotating erupting loop-like feature (ELLF) detaches from the center of the sigmoid. Most of this ELLF is not associated with the erupting flux rope, but with a current shell which develops within expanding field lines above the

rope. Only the short, curved end of the ELLF corresponds to a part of the flux rope.