Geophysical Research Abstracts
Vol. 19, EGU2017-18196, 2017
EGU General Assembly 2017

Quasi-Static Evolution, Catastrophe, and "Failed" Eruption of Solar Flux Ropes

James Chen

Naval Research Laboratory, Plasma Physics Division, United States (james.chen@nrl.navy.mil)

This paper presents the first unified theoretical model of solar flux rope dynamics—a single set of flux-rope equations in ideal MHD—to describe as one integrated process the quasi-static evolution, catastrophic transition to eruption, cessation ("failure") of eruption, and the post-eruption quasi-equilibria. The model is defined by the major radial *and* minor radial equations of motion including pressure. The initial equilibrium is a flux rope in a background plasma with pressure $p_c(Z)$ and an overlying magnetic field $B_c(Z)$. The flux rope may be initially force-free, but the evolution is not required to be force-free. As the poloidal flux is slowly increased, the flux rope rises through a sequence of quasi-static equilibria. As the apex of the flux rope expands past a critical height Z_{crt}, it erupts on a dynamical (Alfvénic) timescale. Mathematically, the onset of eruption is shown to be *explosive*, not exponential. The acceleration is rapidly quenched due to the geometrical effects of the stationary footpoints, and a new equilibrium is established at height $Z_1 > Z_{crt}$. The calculated velocity profile resembles the observed velocity profiles in "failed" eruptions including a damped oscillation. In the post-eruption equilibria, the outward hoop force is balanced by the tension of the toroidal self magnetic field and pressure gradient force. Thus, the flux rope does not evolve in a force-free manner. The flux rope may also expand without reaching a new equilibrium, provided a sufficient amount of poloidal flux is injected on the timescale of eruption. This scenario results in a full CME eruption. It is shown that the minor radial expansion critically couples the evolution of the toroidal self-field and pressure gradient force. No parameter regime is found in which the commonly used simplifications—near-equilibrium minor radial expansion, force-free expansion, and constant aspect ratio R/a (e.g., the torus instability equation)—are valid.

Work supported by the Naval Research Laboratory Base Research Program