Torus instability of a line-tied flux rope

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Abstract

In this study we presupposed the existence of a line-tied flux rope in the corona and impose that 1. its footpoints remain fixed to the solar surface, and 2. that the vertical magnetic field at the photosphere remain constant during an eruption. We adopt the magnetic configuration of Titov & Démoulin 1999 to model the flux rope. To satisfy the line-tying condition, an image current loop is specified that mirrors the evolution of the flux rope, as was done by Isenberg & Forbes 2007. Three forces are identified in this configuration: 1. the repulsive current force attributed to the image current loop, 2. the outward Lorentz self-force due to the curvature, and 3. the restoring external Lorentz force of the ambient magnetic fields. In this work, for the first time, all three forces are analyzed together. We use an ellipse current loop to model the flux rope plus image loop system. This model has the property that it can smoothly reproduce the force of the infinite straight current channel model and the circular loop model. Our analysis finds that stability is most dependent on how the ambient fields decay, in agreement with the torus instability. Finally, our study reveals that the imposed line-tying condition gives stability to shallow flux ropes, which are stable for all decay index values. These results are in contradiction to the conclusions of Démoulin & Aulanier 2010 and not in agreement with the law of instability of low lying loops.

Keywords: flux rope, initiation, instability

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