SP43B-01

Modeling Coronal Jets with FLUX

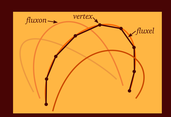
Laurel Rachmeler, E. Pariat, S.K. Antiochos, C.E. Deforest
laurel.rachmeler@colorado.edu

Abstract

We report on a comparative study of coronal jet formation with and without reconnection using two different simulation strategies. Coronal jets are features on the solar surface that appear to have some properties in common with coronal mass ejections, but are less energetic, massive, and broad. Magnetic free energy is built up over time and then suddenly released, which accelerates plasma outward in the form of a coronal jet. We compare results from the ARMS adaptive mesh and FLUX reconnection-less codes to study the role of reconnection in this system. This is the first direct comparison between FLUX and a numerical model with a 3D spatial grid.

FLUX

FLUX is a computational code that finds non-linear force free equilibrium solutions for magnetic fields with a prescribed initial topology and line-tied boundary conditions. It computes equilibrium by balancing the magnetic tension and pressure forces, which is an approximation that is valid for low-β plasmas like the low solar corona. Because it computes equilibrium solutions, FLUX does not model dynamic evolution, but produces quasi-static evolution from evolving boundary conditions. FLUX represents a magnetic system as a collection of fluxons, which are analogous to field lines except that they contain a finite amount of magnetic flux. More information about FLUX is available in DeForest & Kankelborg (2006). **With a fluxon description, topology is locked because there is no reconnection that is not explicitly allowed.**

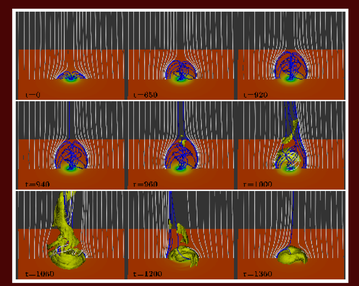


Background and Motivation

Coronal jets were first discovered after the launch of the Yohkoh satellite with SXT, the Soft X-ray Telescope (Shibata et al. 1992; Strong et al. 1992). **Found in coronal holes, coronal jets are short lived (10s of minutes) upward bursts of hot plasma that are collimated into thin streams by the surrounding open field.** They often have an inverted **Y** structure, similar to a small helmet streamer, with a unipolar or a bipolar footprint. Because they are usually found in polar coronal holes and can be quite small, it is hard to determine the exact nature of the footprint. One commonly used model is of a uniform background field with a small unipolar spot superimposed – the so-called anemone-type active region (Shibata et al. 1994).

These jets can develop on timescales less than an minute, release a significant amount of energy ($10^{25\text{-}28}$ ergs solely in kinetic energy), and are associated with X-ray brightenings. They are thus often thought to be driven by a reconnection process. **An outstanding question is how to accumulate that much energy and release it all instantaneously.** One way is to create an axisymmetric null-point topology and inject energy with an axisymmetric twist so that reconnection is held off until symmetry is broken through a kink-like instability. This system is illustrated below using the ARMS adaptive mesh code, and was studied by Pariat et al. (2008). Magnetic free energy was effectively built up through twist, and released through reconnection after the axisymmetry was broken at ~1.5 turns.

Our research focuses on directly recreating the system of Pariat et al. (2008) with FLUX, and studying the evolution without reconnection. What would happen to the system without reconnection? Would the free energy continue to increase, or would it be able to escape without a reconnective event?



Conclusions

- The background field behavior with height affects the stability of the system; it is more stable against symmetry breaking if the field drops off with height.
- The evolution FLUX system was almost identical to the ARMS system until reconnection set in, showing that FLUX can be directly compared to grid codes.
- After kinking, more of the energy goes into the deformation of the background field.
- There is a 'corner' in the energy plot just after kinking sets in that appears to be an artifact of the pause in the twisting motion; this may indicate that the system is not fully relaxed between steps.
- The energy released by the kinking motion appears to be minimal, meaning that **this mechanism for coronal jet initiation does require reconnection.**

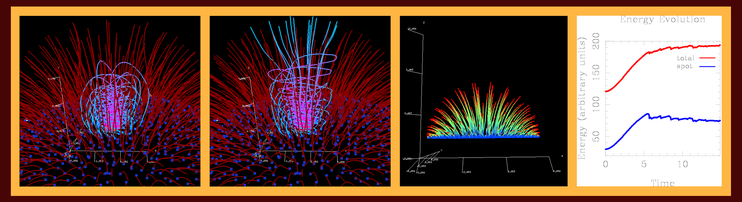
References:
Cirtain, J.W. et al. 2007, *Science*, 318, 1580
Shibata, K. et al. 1994, *ApJ*, 431, L51
Shibata, K. et al. 1992, PASJ, 44, L173
Strong, K. et al. 1992, PASJ, 44, L161
Pariat, E., Antiochos, S.K., DeVore, C.R., 2008, submitted

FLUX software is available for download:
www.flux.boulder.swri.edu/wiki

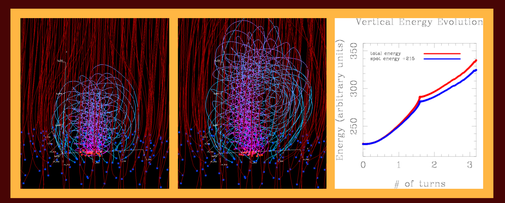
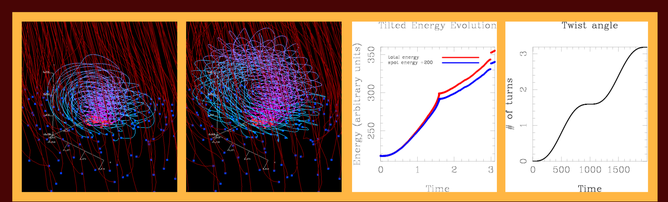
Simulation Results

Simulations were carried out with a **hemispherical or cylindrical (straight and tilted) open upper boundary** with a uniform background field and a vertical bipole under the photospheric line-tied surface. The magnetic flux in the bipole was incrementally rotated.

The hemispherical system remained very symmetric throughout the simulation. No kink-like behavior was recorded. The spot swelled in height until it hit the open boundary. The background field was not uniform and dropped off with height, which probably contributed to the lack of symmetry breaking.



The vertical cylindrical system swelled initially and then showed kink-like behavior, albeit later than expected. The background field in this system was uniform. Kinking began after ~1.5 turns, the same critical twist that Pariat et al. found, the height of the null point at that time was also approximately the same height. The energy is deposited mostly in the spot, with some going to the deformation of the background field, more so after kinking.



The tilted cylindrical system began earlier than the vertical system. By ~1.5 turns, a tilt in the axis of the twisted axis, separate from the 15º background field tilt was evident. Energy deposition is similar to the vertical case. We believe that this is an artifact because it occurs at the time that the twist levels off and because it happens at the exact same amount of twist for the vertical and the tilted case. Other than this bend, there is no discernible drop in the energy corresponding to the kink onset.