Shock Driven Evaporation near Post-CME Arcade Structures

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Abstract

Models of patchy reconnection allow for heating and acceleration of plasma along reconnected field lines but do not offer a mechanism for transport of energy and momentum across field lines. There is, however, a substantial body of evidence that field lines in flaring regions experience "pre-heating" and "pre-densification" prior to their reconnection. Here we present a model in which a localized region of reconnected flux creates a flow constriction in the surrounding layer of unreconnected field. The moving constriction acts as a de Laval nozzle and ultimately leads to shocks that can extend out to several times the diameter of the intruding flux-tube, altering the plasma properties in the affected region. The shocks travel down to the transition region where they upset the hydrostatic equilibrium and drive evaporation, which leads to increases in density and temperature in the unreconnected field. These findings have direct implications for observations in the solar corona, particularly in regard to such phenomena as wakes seen behind supra-arcade downflows and high temperatures in post-CME current sheets.

1. Supra-Arcade Features

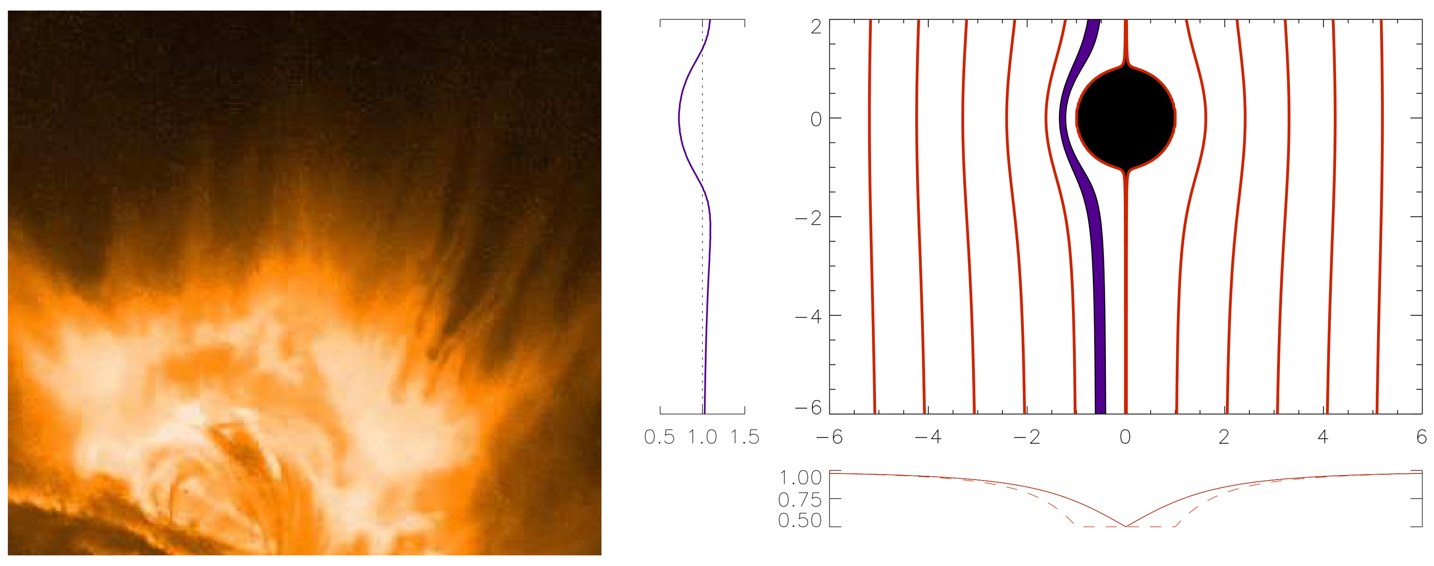

Figure 1: EUV and X-Ray images reveal enhanced emission with high-contrast voids above post-CME arcade structures. The generally high emission suggests that plasma has been evaporated from higher density transition region while the voids bear striking resemblance to wakes. These observations have been interpreted in terms of an intruding element of reconnected flux, which deforms the surrounding field as it retracts toward the arcade.

The Model

1. Magnetic Intrusion

- Results from localized patchy reconnection.
- Creates descending deformation in surrounding field.

2. Peristaltic Flow

(a) Deformed magnetic field acts as a de Laval nozzle.
(b) Plasma exhibits steady flow, shocks and rarefaction waves.
(c) Leading shock descends toward the limb at $\sim$ Mach 1.

3. Shock Driven Evaporation

(a) Leading shock drives thermal conduction front.
(b) Temperature spike upsets hydrostatic equilibrium in transition region.
(c) Antisunward plasma flow increases density in the corona.

Remarks

The model that we present suggests an explanation for the enhanced emission measures and high contrast voids that are observed above post-CME flare arcades. The shocks that are formed by descending elements of reconnected flux create columns of material with depleted tails of low density plasma, which we interpret as Supra-Arcade Downflows. As the leading shock ultimately makes its way to the transition region it drives a thermal conduction front that upsets the hydrostatic equilibrium and creates a pressure gradient, driving material up into the corona. The unreconnected coronal magnetic field adjacent to the current sheet is ultimately filled with higher density plasma, which explains the enhanced emission measure in these regions.

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2. Peristaltic Shocks

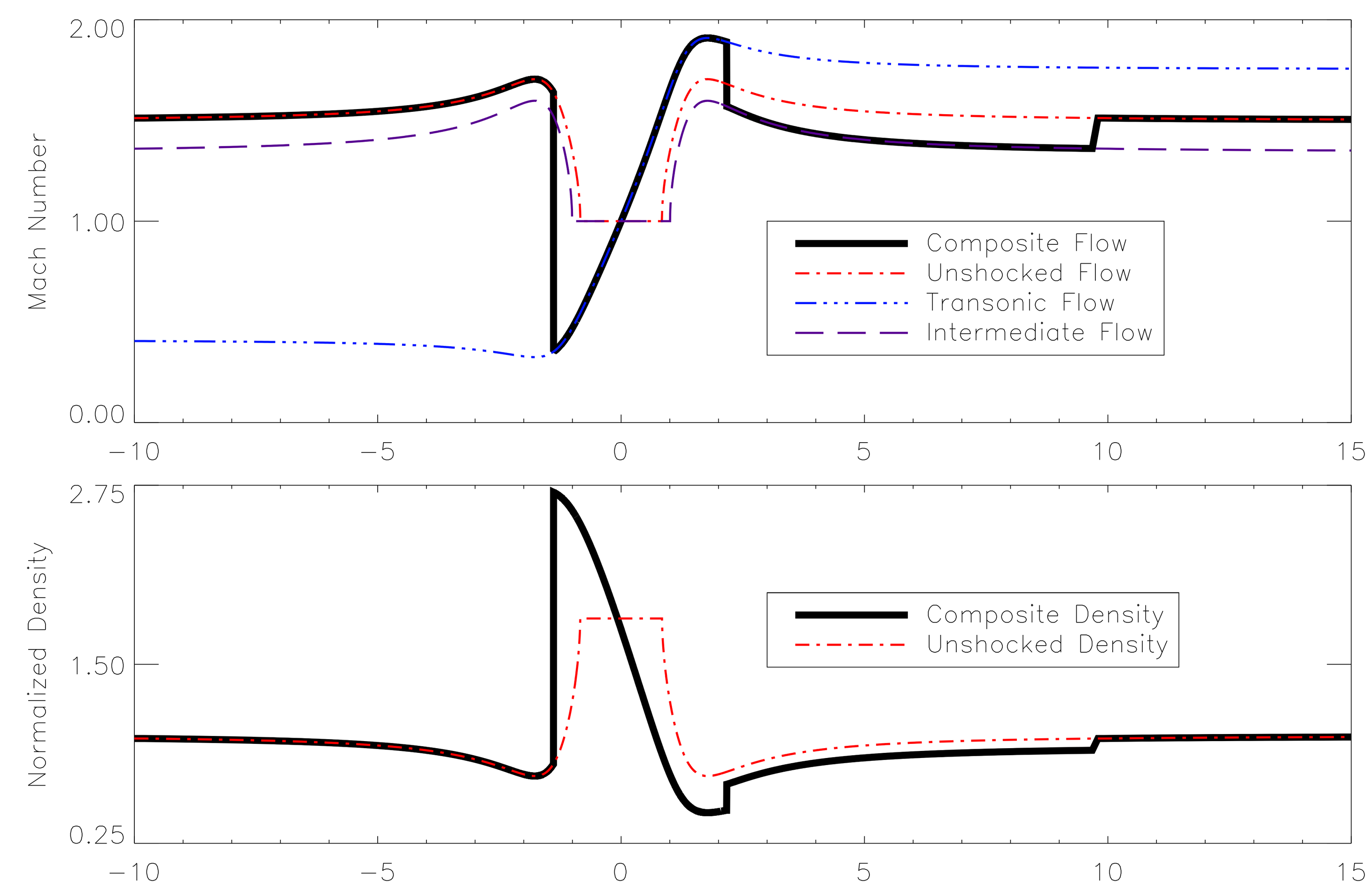

Figure 2: Plasma flow is depicted along a highly constricted field line in a frame that is comoving with an intruding element of reconnected flux. The descending intrusion creates a constriction in the surrounding unreconnected field, which moves supersonically toward the limb. The constriction acts as a nozzle, which dictates the field aligned plasma flow. Shocks form as a result of strong viscous forces for highly constricted field lines. A leading shock travels toward the limb and eventually makes its way down to the transition region.

3. Chromospheric Evaporation

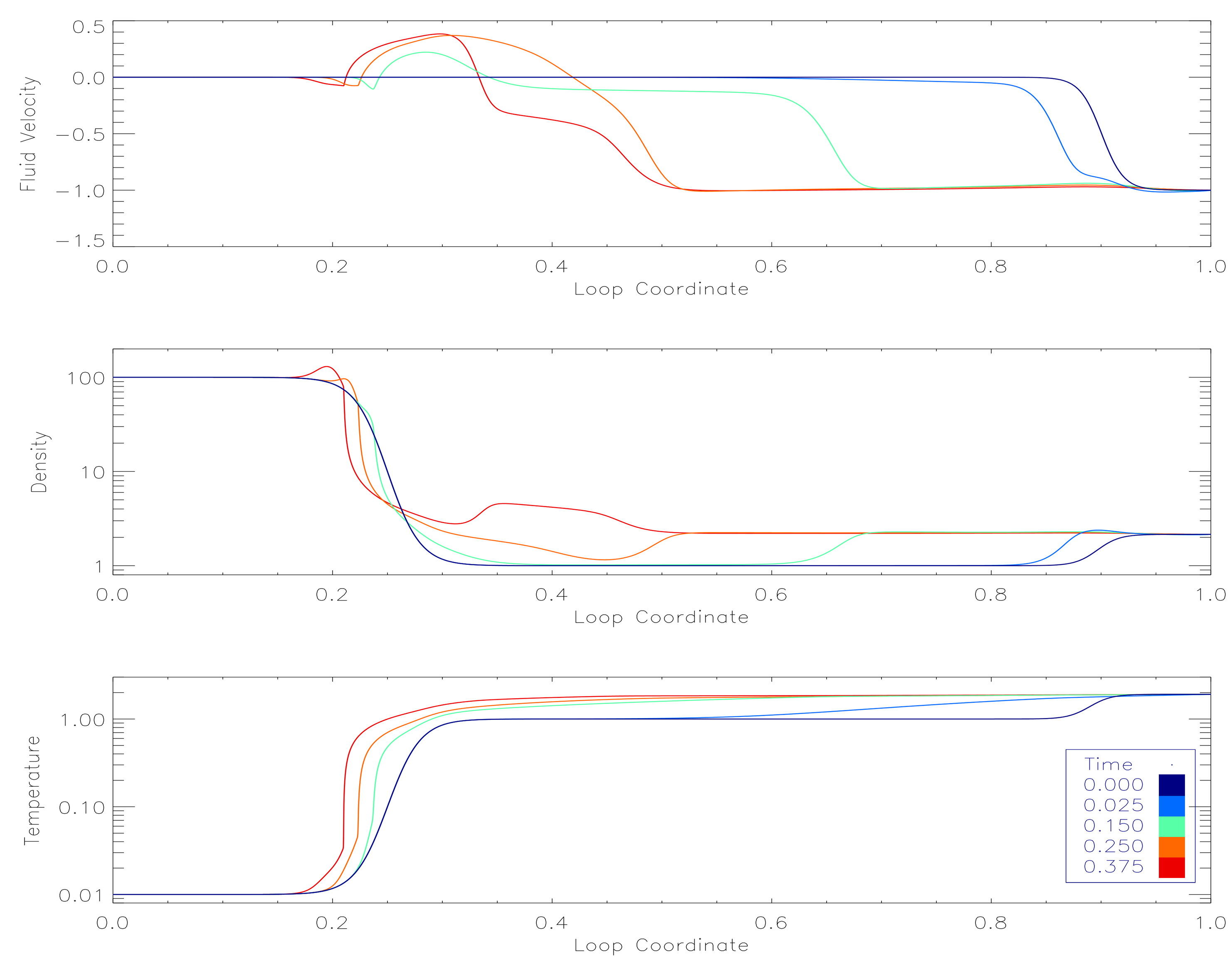

Figure 3: The downward propagating shock drives a thermal conduction front that rapidly makes its way down to the transition region, which is modeled by a sharp drop in temperature and corresponding rise in density. Thermal conduction causes an abrupt increase in temperature, which upsets the initially hydrostatic equilibrium and creates evaporative upflows. High density plasma and thermal energy are driven back up into the coronal magnetic field, resulting in an increase in emission measure adjacent to the current sheet above the arcade.

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