

Dynamics of Post-Reconnection Magnetic Flux Tubes

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Introduction

- ▶ Building off of previous work done by Dr. Longcope and others ([2] [3] [4]).
- ▶ Original model [3] followed the dynamics of a Λ -shaped post-reconnection flux tube, with downward flows.
- ▶ My project was to evaluate different sets of initial conditions with upward flows.
- ▶ One potential application was to see how this matched Type-II spicules [1].

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Background: Flux Tubes

- ▶ Flux tubes describe when magnetic field lines occur in field-free environments (like the sun's corona).
- ▶ Plasma conforms to these tubes and travels along them as a propagating wave.
- ▶ When the waves are much longer than the width of the tube, we get a nice simplification of their dynamics called the "thin flux tube" model. This allows us to use the equations of MHD to approximate their motion.

Reconnection

- ▶ Flux tubes in the upper regions of the sun's atmosphere can become crossed.
- ▶ When this occurs, they can reconnect:

- ▶ These then retract at the Alfvén speed.
- ▶ My project was to see what happens next.

Numerical Model

Initial Conditions:

- ▶ One pre-reconnection tube is a large, low-density, high-temperature coronal flux tube approximate by a vertical line.
- ▶ The other is a low-lying, high-density, lower-temperature tube.
- ▶ We ignore gravitational forces and assume a low β ($\ll 1$).

This gives the following equation of motion[4] which we solve using a Lagrangian numerical method (PREFT):

$$\rho \frac{d\vec{v}}{dt} = -\hat{\mathbf{b}} \frac{\partial p}{\partial l} + \frac{B^2}{4\pi} \frac{\partial \hat{\mathbf{b}}}{\partial l} - \frac{1}{4\pi} \nabla_{\perp} B^2 + B \frac{\partial}{\partial l} \left(\frac{\mu}{B} \hat{\mathbf{b}} \hat{\mathbf{b}} \cdot \frac{\partial \vec{v}}{\partial l} \right)$$

Analytic Solution

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Derivation:

- ▶ Assume we can divide the tube into five regions:
 - ▶ The two endpoints
 - ▶ The center
 - ▶ A point between each end and the center where there is a shock.
- ▶ Ignore thermal conduction.
- ▶ Numerical model is computationally intensive. This gives us a closed-form solution.

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Results: Parameter Studies

- ▶ Interested in what causes the maximum upflow velocities.
- ▶ Conducted runs with angles ranging from 10 to 135 degrees and density ratios from 0.1 to 100
- ▶ Also evaluated temperature, pressure, and some other parameters.

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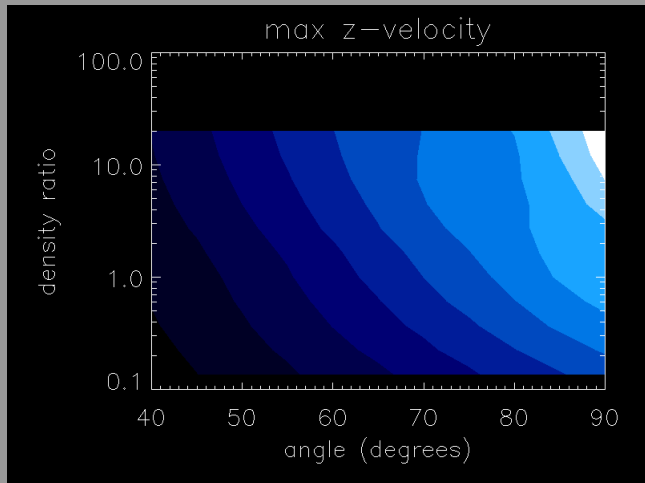
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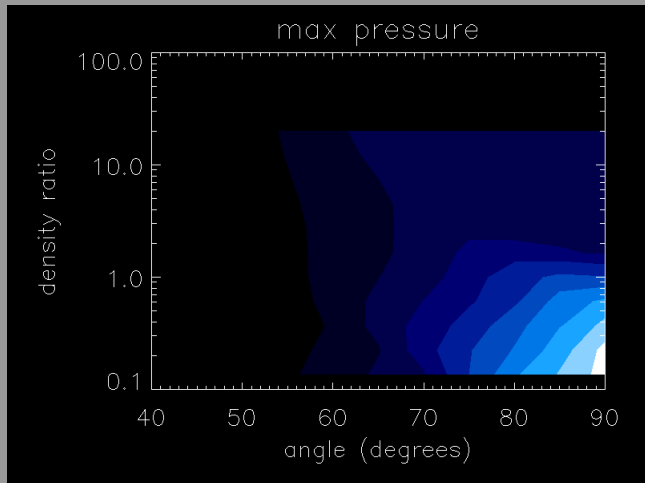
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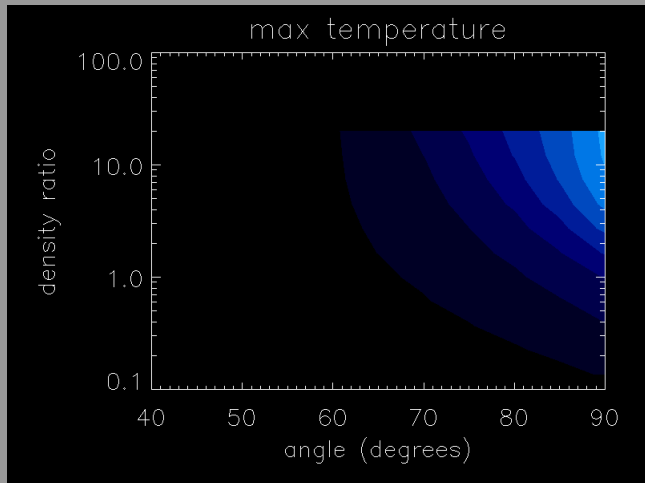
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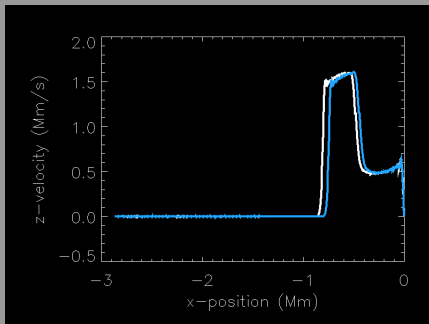
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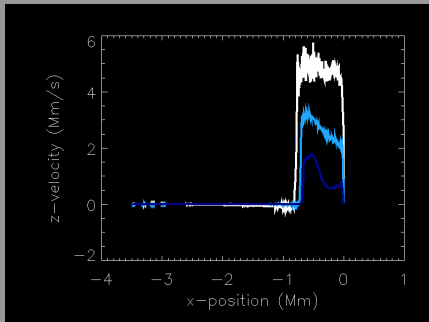


Constant Pressure or Temperature?

- ▶ Original code fixed the temperature ratio between the two connecting tubes.
- ▶ Modified to hold pressure constant and allow temperature to vary.
- ▶ Not much changed.



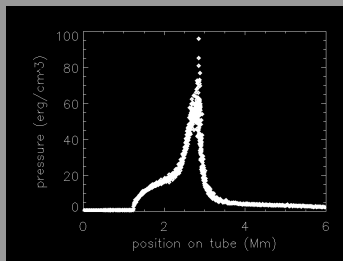
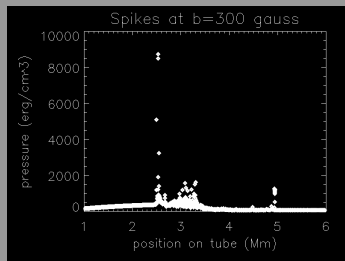
Magnetic Field



- ▶ Images shows $B=100, 200,$ and 300 .
- ▶ Alfvén speed changes when B does. Graph compensates for that.
- ▶ Magnitude of different quantities tend to be proportional to changes in magnetic field.
- ▶ Stronger fields also cause jagged lines...

Spikes

- ▶ Runs were cutting out, returning `-NaN` for all variables after some amount of time.
- ▶ Stronger fields caused it to happen sooner.
- ▶ Looks like a mathematical error—information outrunning the grid.
- ▶ Smoothing out the code didn't solve it.



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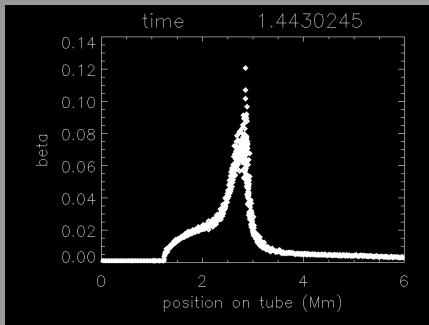
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Magnetic β

- ▶ $\beta = \frac{P}{B^2/4\pi}$
- ▶ Tells us the relative importance of tension versus pressure forces.
- ▶ $\beta > 2$ means pressure dominates.
- ▶ code assumes $\beta \ll 1$.
- ▶ Here's the issue:

Not a numerics problem, actually a physical issue! The assumptions behind our equations quickly become invalid at extreme angles and densities.



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What did we learn?

- ▶ We now understand the dependence of this model upon various parameters much better.
- ▶ We found some physical limits on when the code is useful.

Does this tell us anything about spicules?

- ▶ I have no idea.
- ▶ It does give a method of launching heating material into the corona.
- ▶ Further work should be done here.

References

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