#### Torsional Alfvén Pulses in Zero-beta Flux Tubes & Potential Connection to Solar Spicules





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#### Motivation

- **Spicules** are capable of transferring significant mass and energy.
- Magnetic bright points (MBPs) are intense magnetic regions observed in the lower solar atmosphere.
- Torsional Alfvén waves have been observed in association with both spicules and MBPs.
- We aim to analytically model the effect of a magnetic perturbation on plasma in a flux tube.
- Want to account for the fact that only a small amount of material from spicules reaches the outer solar atmosphere.





• An analytical flux tube model was developed using the regular perturbation method.

$$f(r, z, t) = f_0 + \sum_{i=1}^{\infty} \varepsilon^i f_i(r, z, t)$$

• The torsional Alfvén waves are introduced via a shear perturbation.

$$\frac{\partial^2 B_{\theta 1}}{\partial t^2} = \frac{B_0^2}{\mu_0 \rho_0} \frac{\partial^2 B_{\theta 1}}{\partial z^2}$$

• This approach allows us to study **non-linear** effects.

$$\mathbf{F}_{\mathbf{z}} = (\mathbf{j} \times \mathbf{B})_z = -\varepsilon^2 \frac{1}{\mu_0} \frac{\partial B_{\theta 1}}{\partial z} B_{\theta 1}$$

- Simplified using the zero plasma-beta approximation.
- Density discontinuity results in partial wave reflection.







# Example / Results

- Example solution in the form of a propagating wave pulse.
- Vertical mass flux due to the Lorentz force.
- Pulse propagates at the Alfvén speed, typically around 10–20 km/s in this context.
- Maximum vertical extent of up to 3Mm within 150 seconds.







# Reflection / Transmission

• Transmitted mass flux depends on density discontinuity.

$$\frac{M_t}{M_i} = \frac{4v_{A1}^3}{v_{A2}(v_{A2} + v_{A1})^2}$$

- Significant 1% transmission threshold reached at  $v_{A2}/v_{A1} \approx 6.7$ (or  $\rho_1 \approx 45 \rho_2$ ).
- Interaction between transmitted and reflected pulse may contribute to vertical mass flux.
- Distinction between **spicule types** could be attributed to localised density differences between the chromosphere / transition region.







# Discussion / Future

- We analytically studied the effects of torsional Alfvén waves in the context of spicules and MBPs.
- A torsional perturbation in a magnetic flux tube may result in vertical mass flux.
- **Reflection** from a density discontinuity may affect the evolution of spicules.
- **Observational** data is being collected for verification of our results.
- Working to include atmospheric stratification and gravity.







Propagation of Torsional Alfvén Pulses in Zero-beta Flux Tubes Joseph Scalisi, William Oxley, Michael S. Ruderman, and Robertus Erdélyi 2021 *ApJ* **911** 39 <u>https://iopscience.iop.org/article/10.3847/1538-4357/abe8db</u>



Formation of Chromospheric Spicules in Magnetic Bright Points: An Analytical Approach Using Cartesian Slab Geometry William Oxley, Joseph Scalisi, Michael S. Ruderman, and Robertus Erdélyi 2020 *ApJ* **905** 168 https://iopscience.iop.org/article/10.3847/1538-4357/abcafe





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