Flux tube dependant propagation of Alfvén Waves in the Solar Corona

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INTRODUCTION

We present first results of our study to characterize the dynamics of Alfvén waves in the solar corona. Using MHD **simulations**, we study the propagation of **monochromatic Alfvén waves injected** at the base of the corona and quantify their characteristics higher up in the corona.

In particular, we investigate how **different flux tube geometries** affect the properties of the waves.

MHD MODEL

We solve the MHD equations along a single flux tube with a varying cross-sectional area a

$$\frac{\partial}{\partial t}\rho + \frac{1}{a}\frac{\partial}{\partial r}(a\rho v_r) = 0$$

$$\frac{\partial}{\partial t}(\rho v_r) + \frac{1}{a}\frac{\partial}{\partial r}[a(\rho v_r^2 + p + \frac{\mathbf{B}_\perp^2}{2\mu_0})] = (p + \frac{\rho \mathbf{v}_\perp^2}{2})\frac{1}{a}\frac{\partial}{\partial r}a - \rho g$$

$$\frac{\partial}{\partial t}(\rho \mathbf{v}_\perp) + \frac{1}{a}\frac{\partial}{\partial r}[a(\rho v_r \mathbf{v}_\perp - \frac{B_r \mathbf{B}_\perp}{\mu_0})] = -\frac{1}{2a}(\rho v_r \mathbf{v}_\perp - \frac{B_r \mathbf{B}_\perp}{\mu_0})$$

$$\frac{\partial}{\partial t}\mathbf{B}_\perp + \frac{1}{a}\frac{\partial}{\partial r}[a(\mathbf{B}_\perp v_r - B_r \mathbf{v}_\perp)] = \frac{1}{2a}(\mathbf{B}_\perp v_r - B_r \mathbf{v}_\perp)$$

$$\frac{1}{a}\frac{\partial}{\partial r}(aB_r) = 0$$

$$\frac{\partial}{\partial t}e + \frac{1}{a}\frac{\partial}{\partial r}[a(v_r\{e + p - \frac{B_r^2}{\mu_0}\} - B_r\frac{\mathbf{B}_\perp \cdot \mathbf{v}_\perp}{\mu_0})] = -\rho g v_r + S$$

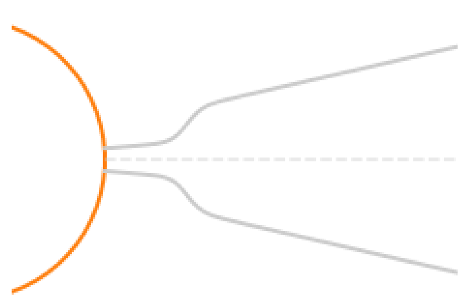
$$\text{where} \quad e = \frac{p}{\gamma - 1} + \frac{\rho \mathbf{v}^2}{2} + \frac{\mathbf{B}^2}{2\mu_0} \quad \text{and,} \quad S = S_0 \exp(-\frac{r}{L})$$

FLUX TUBE GEOMETRY

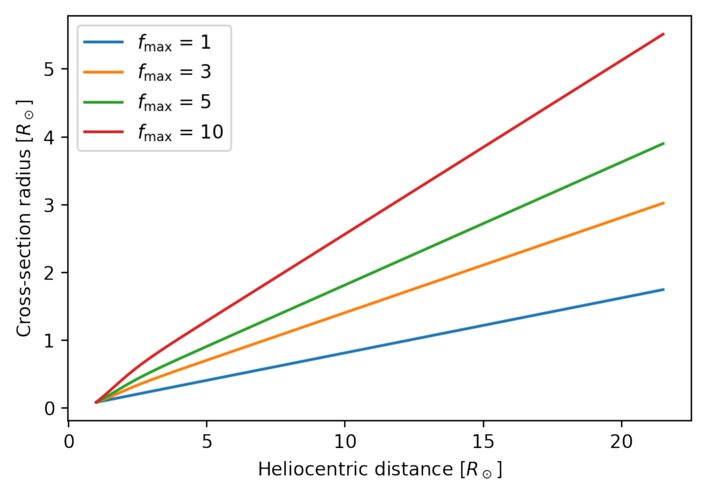
The flux tube geometries are parameterised following Kopp & Holzer:

$$f = \frac{f_{\max}\exp((r - R_1)/\sigma_1) + f_1}{\exp((r - R_1)/\sigma_1) + 1} \qquad \text{Cross-sectional area} \quad a \propto r^2 f$$

The **expansion factor** $f \to f_{\max}$ when $r \to \infty$



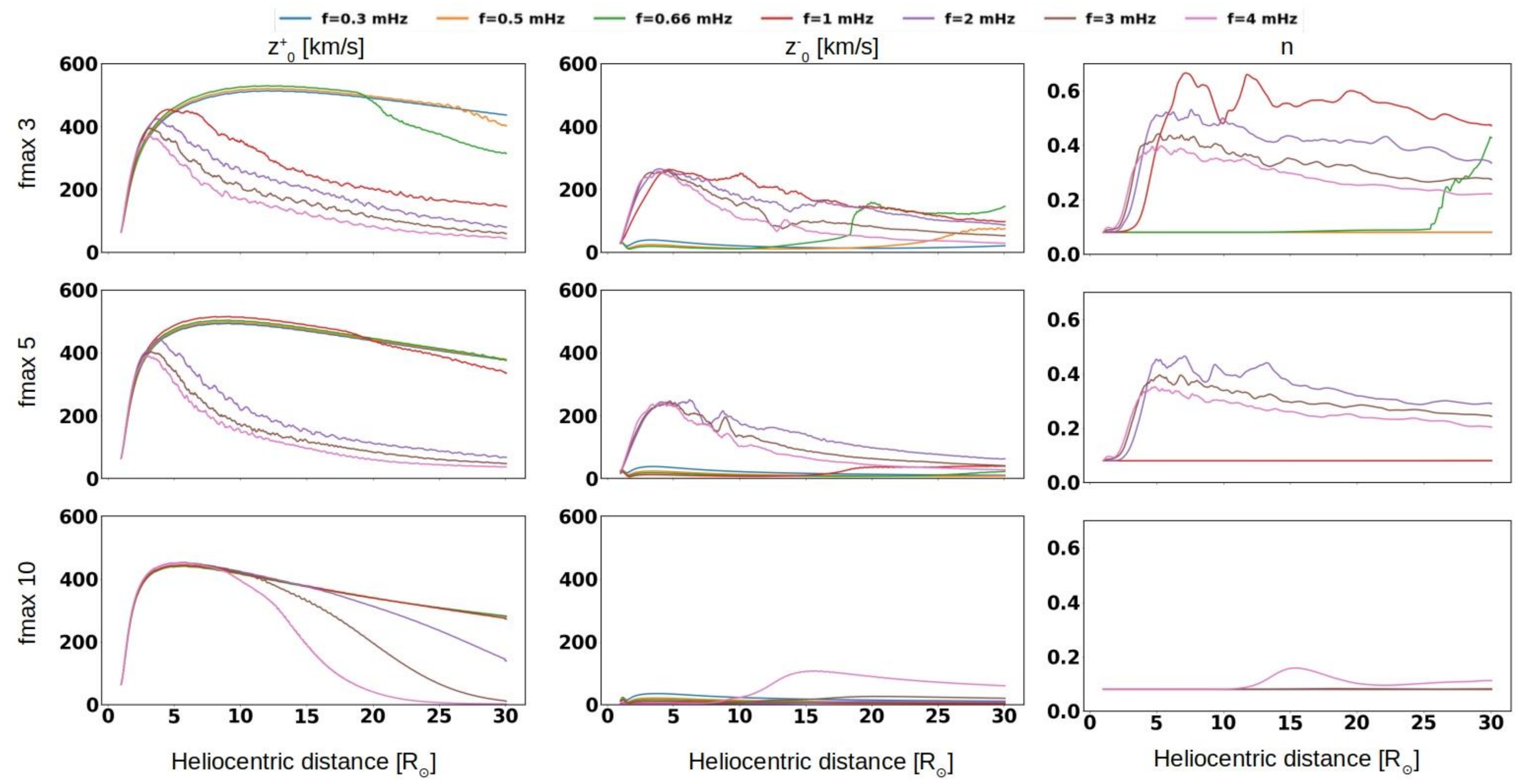
Cartoon of the flux tube geometry



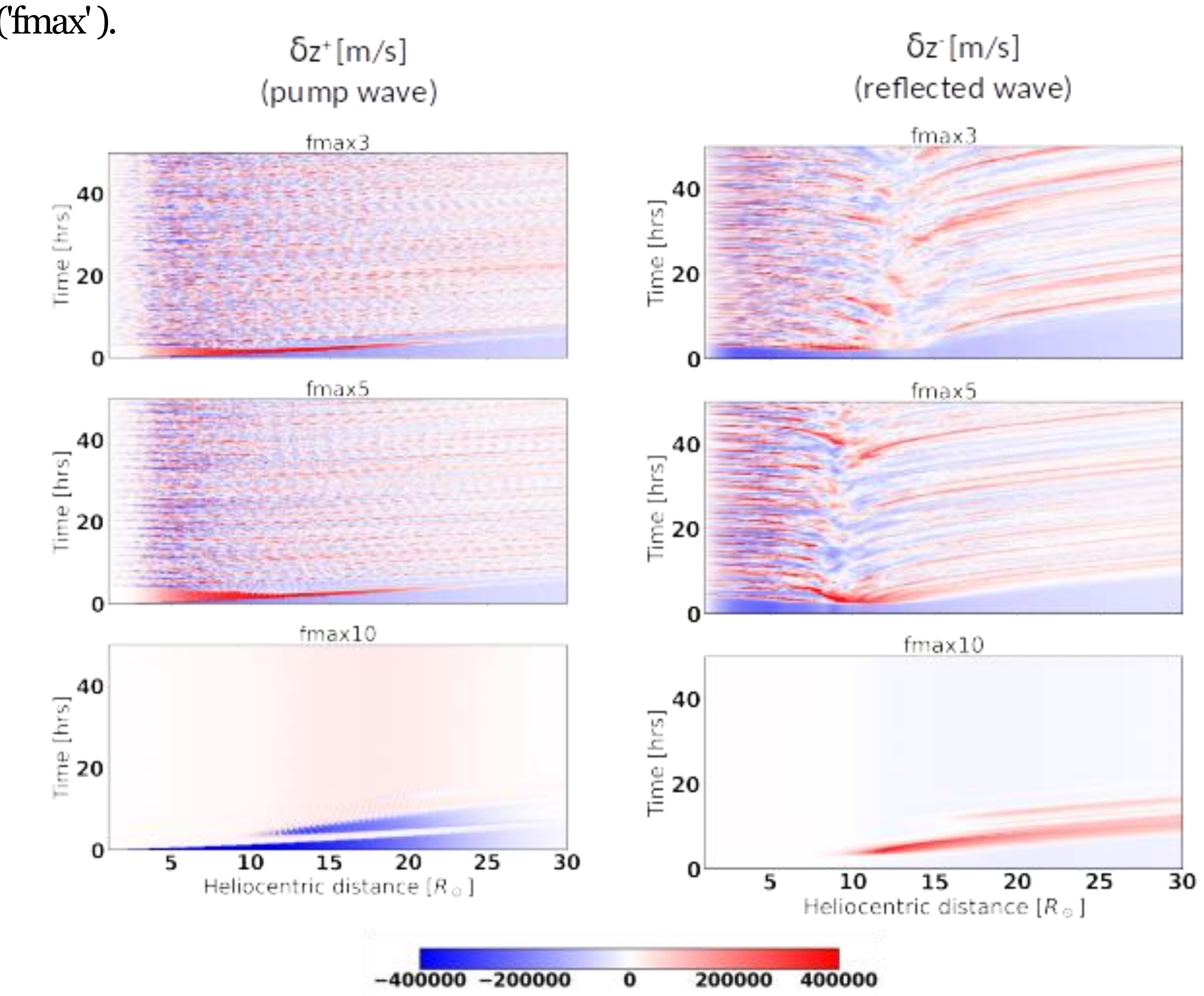
REFLECTED ALFVÉN WAVES IN THE SOLAR WIND

We perform a parameter study by injecting single frequency Alfvén waves between 0.3 mHz to 4 mHz in a quasi-steady state solar wind with different flux tube expansion profiles, which are constructed by the varying the 'fmax' variable.

- Here we present the time-averaged values of the injected (z^+) & reflected (z^-) Alfvén waves, and the fractional density fluctuations (n) in the simulated solar wind. The injection of a single mode of AWs causes density perturbations and generation of an inward propagating AW, indicating the presence of a parametric decay instability (PDI).



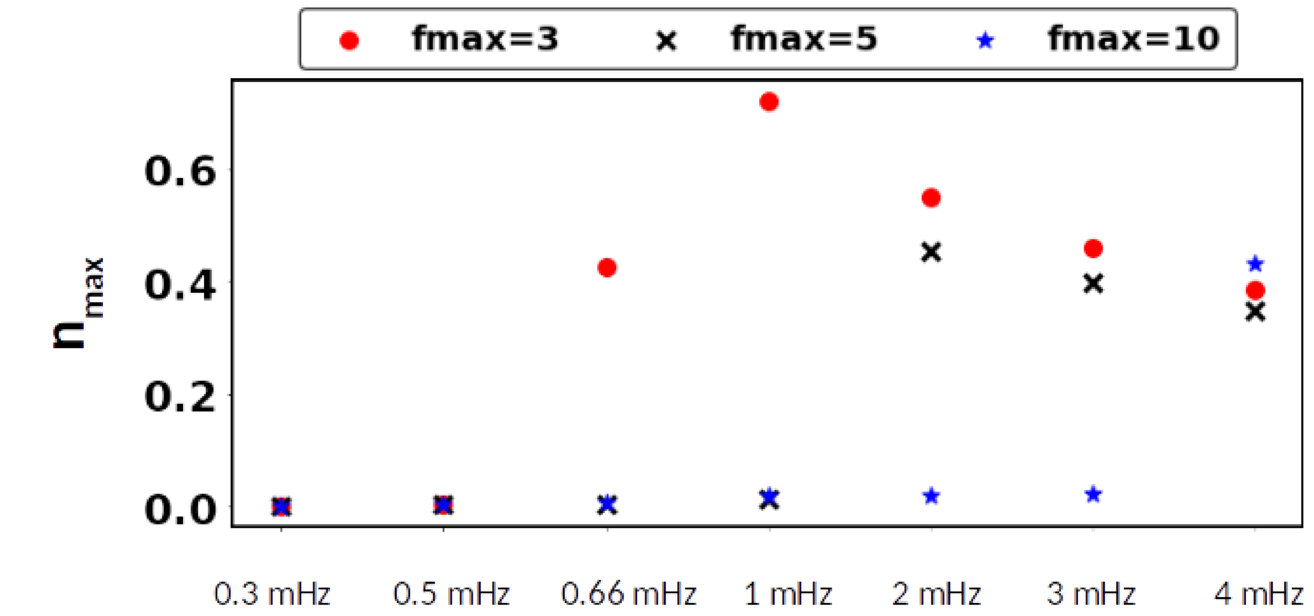
- The evolution of perturbations associated with the injected (z+) and reflected (z-) Alfvén waves for an injected frequency of 3 mHz are presented. The response of the solar wind and the generation of the reflected wave is highly dependant on the flux tube geometry ('fmax').

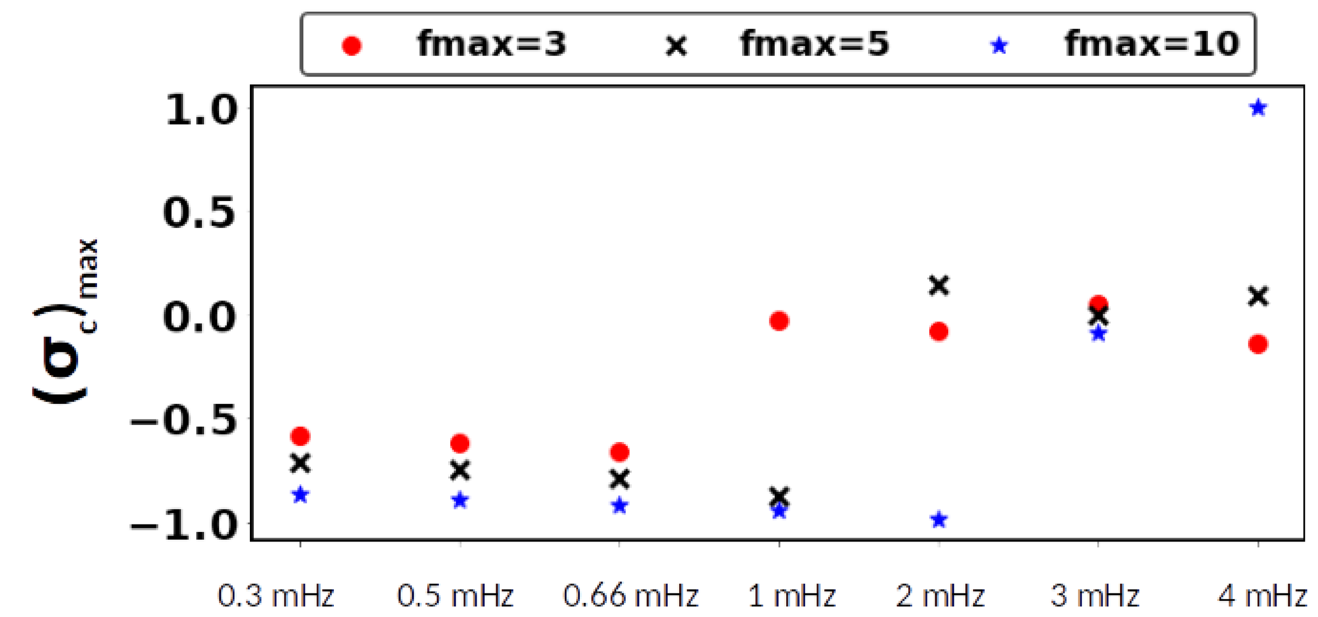


PARAMETRIC DECAY INSTABILITY (PDI)

This instability is characterised by the decay of a forward propgating pump Alfvén wave into a reflected Alfvén wave and a MHD sound wave. The PDI has emerged as an important mechanism for the generation of counter-propagating Alfvén waves in the solar corona.

- In order to discuss the onset threshold of PDI for the different flux-tube expansion factors we calculate parameters n_{max} = max(n) and $\sigma_{c,max}$ = max(σ_c). Here the parameter 'σ' is defined as the cross-helicity and captures the relative extent of the reflected Alfvén wave as compared to the injected pump wave.
- Here we study the dependancy of the flux tube geometry on the onset of PDI. The presence of sound waves are observed using the 'n' parameter while reflected Alfvén waves cause a deviation from −1 in the cross helicity.





FUTURE WORK

- Introduce multiple AW modes and study turbulent heating due to counter propagating AWs in our simulation.
- Extend the model into 3D and inject broadband frequency Alfvén waves.
- Discuss the effect of heat conduction and radiation on the propagation of AWs in the corona for varying flux tube geometries.

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