Parametric Decay of Alfven Waves

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Abstract

Understanding how magnetohydrodynamic (MHD) waves propagate and interact nonlinearly within a plasma is an essential step to modeling the solar wind, which remains a topic of great interest in space plasma physics. This poster describes preliminary work on numerically modeling the parametric instability in the solar wind using an MHD code. In this instability, an outward-propagating Alfven wave decays into an outward-propagating sound wave (slow-wave) and an inward-propagating Alfven wave (Figure 3). To model this instability in the solar wind, we have taken an existing code for compressible MHD and modified it to account for collisionless damping of slow waves.

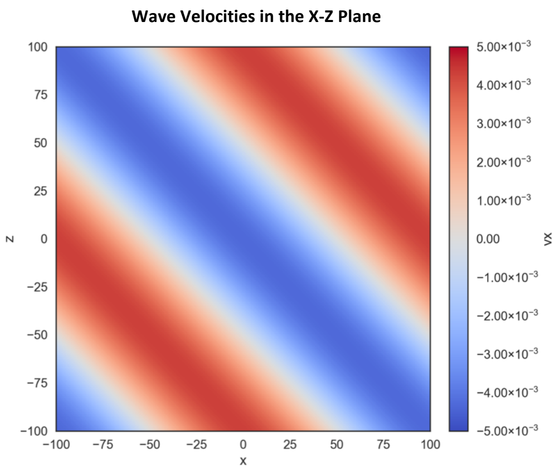

Figure 1: MHD Code Output – XZ Plane Velocity Plot

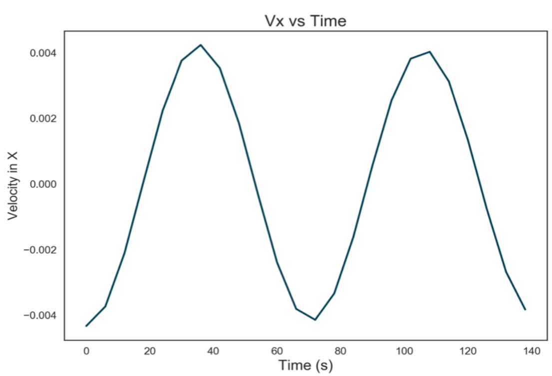

Figure 2: Wave Velocity at a single point over time.

Code Verification

Output from the MHD code produces time stepped wave velocity plots at specified intervals. Stepping through these plots shows the propagation of the wave velocities in the x-z plane (in normalized units), with **B** in the z direction. The code outputs wavelength values (λ), which were verified through measurements of the output plots. Wavelength was used to determine the wavenumber (k):

$$k = \frac{2\pi}{\lambda}$$

The Vx vs Time graph (Figure 2) was then used to determine the period (T) of the waves and to verify the accuracy of the code period output. Phase velocity was found by:

$$V_p = \frac{\lambda}{T}$$

and angular frequency (ω) was found by:

$$\omega = V_p \cdot k$$

Individual MHD wave frequencies were found using the methods of Maron and Howes (2001), Appendix C.

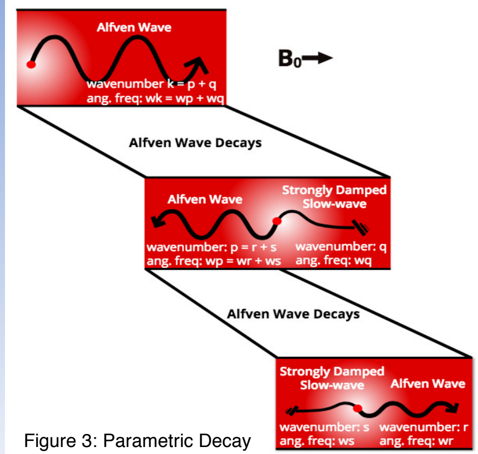

Figure 3: Parametric Decay

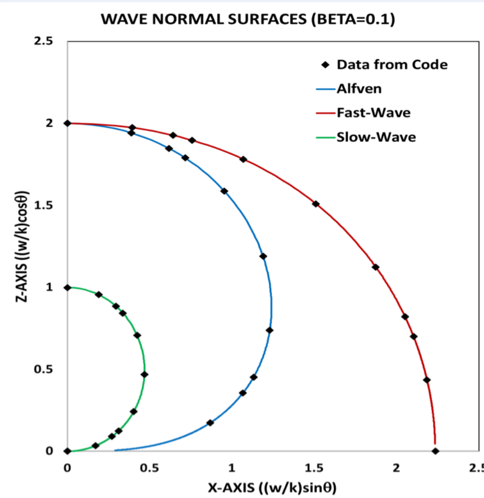

Figure 4: Wave Normal Surfaces. Values of ω for the different waves were determined by the methods used in Maron and Howes (2001), Appendix C.

Using the values found in the previous steps, wave normal surface plots were created to determine the accuracy of the code when modeling the different MHD waves at varying angles. These are polar plots of ω/k vs θ, where θ is the angle from the z-axis.

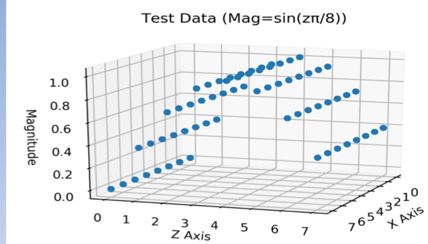

Figure 5: FFT Test Data

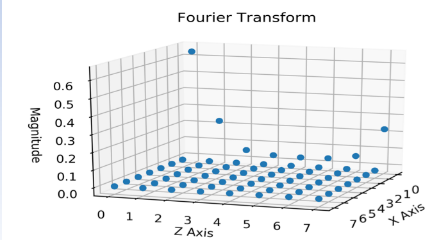

Figure 6: FFT Transform Data

The sample Fast Fourier Transform was completed using the open source FFTW. The above samples were run using the 3D code with the Y dimension set to a depth of one, thereby functioning like a 2D code.

Work to be Completed

Having successfully created sample FFT code that functions in three dimensions, next is to incorporate the FFT into the MHD code. The subsequent step is to implement the LAPACKE (C based linear algebra library) eigenvector and eigenvalue operations into the sample code before combining it into the MHD code as well. After that will consist of modifying damping processes to include Landau damping.

References

Maron, J.L., Howes, G. G. (2001, July 24). Gradient particle magnetohydrodynamics. arXiv:astro-ph/0107454v1. doi:10.1086/377296

"A Fast Fourier Transform Compiler," by Matteo Frigo, in the Proceedings of the 1999 ACM SIGPLAN Conference on Programming Language Design and Implementation (PLDI '99), Atlanta, Georgia, May 1999