The role of parametric instabilities in solar wind plasmas

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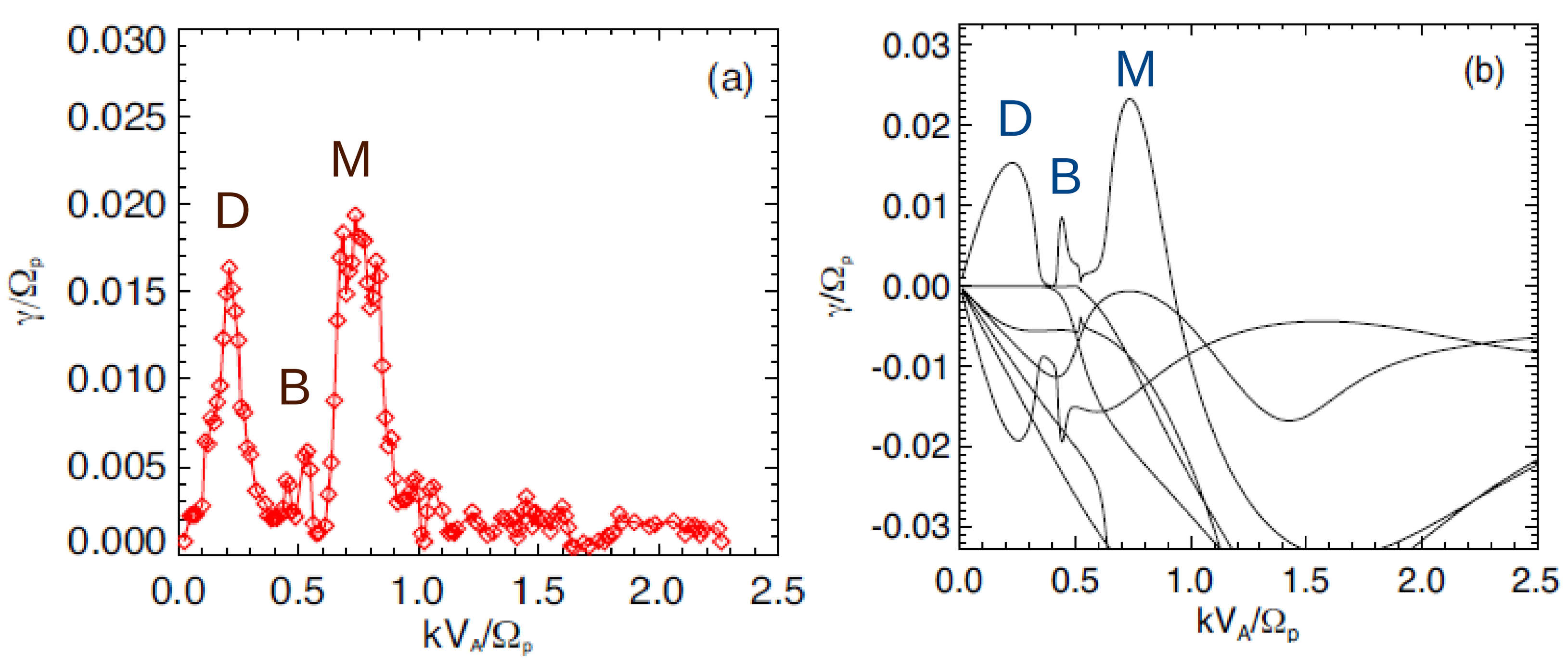
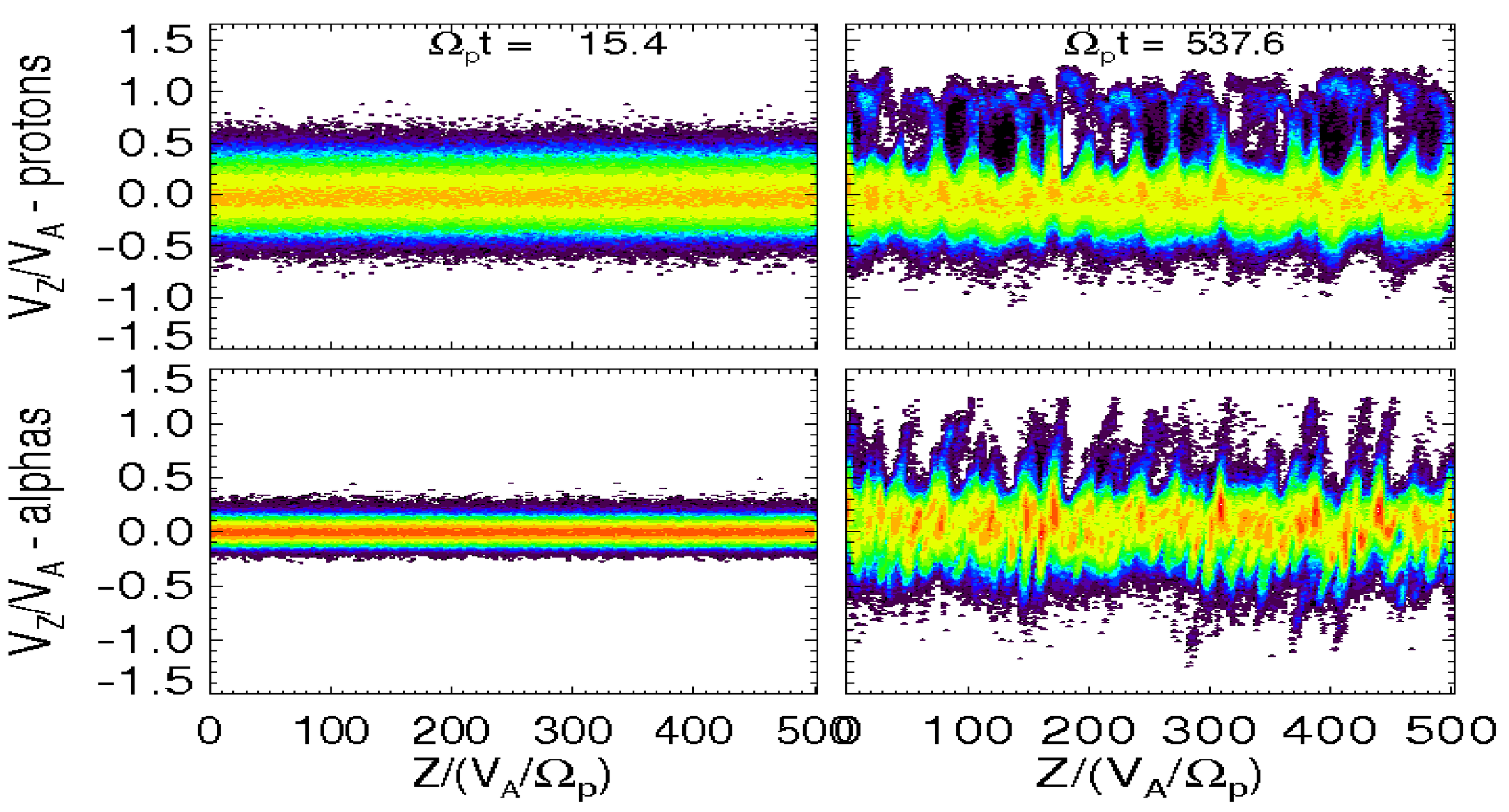
Introduction:

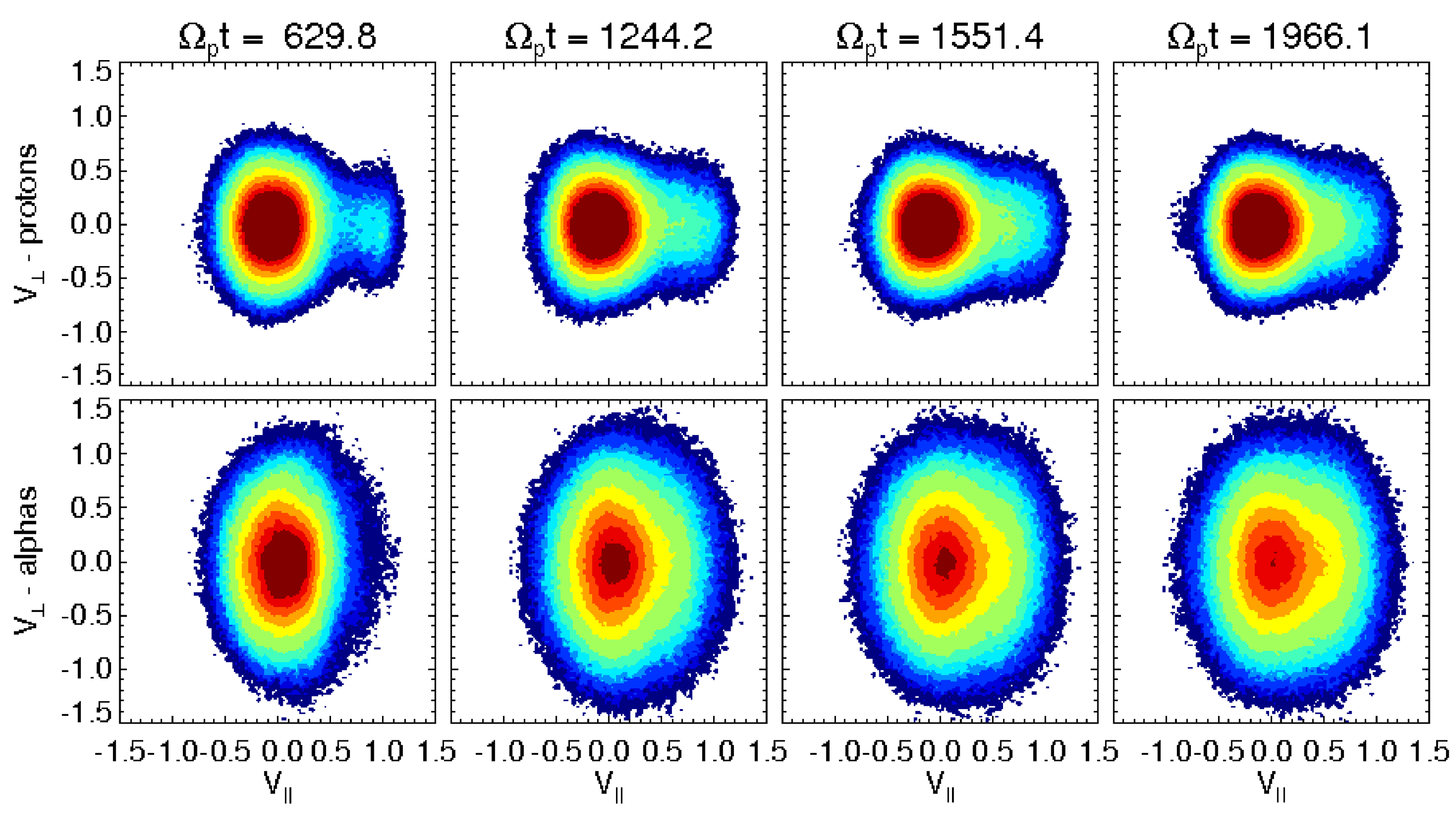
Large-amplitude Alfven waves are exact solutions of the MHD equations and have been frequently observed in the inner heliosphere. The inevitable presence of thermal fluctuations in the solar wind plasmas makes the Alfven waves prone to nonlinear wave-wave interactions, such as parametric instabilities. Parametric instabilities represent three-wave processes, which involve the coupling of the pump wave with daughter Alfven and sound waves. In the decay process energy is transmitted from the pump to the daughter Alfven waves and substantial compressible fluctuations are generated. Hereby we present the solutions of the parametric instability dispersion relation with kinetic effects in parallel direction and compare them to hybrid numerical simulations to explain the preferential heating and differential acceleration of minor ions in the solar wind. We discuss the trapping of ions in the generated ion-acoustic waves and the consequent ion beam formations.

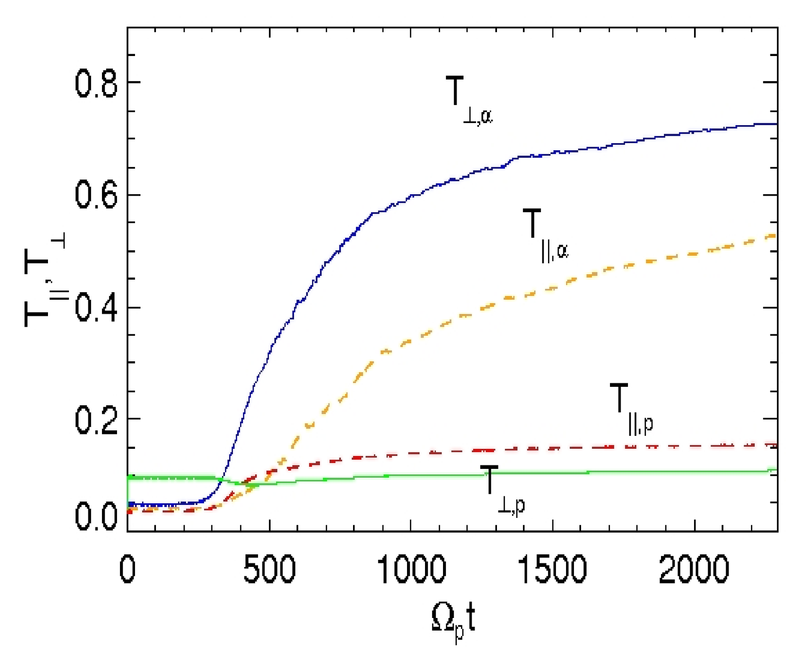
Model:

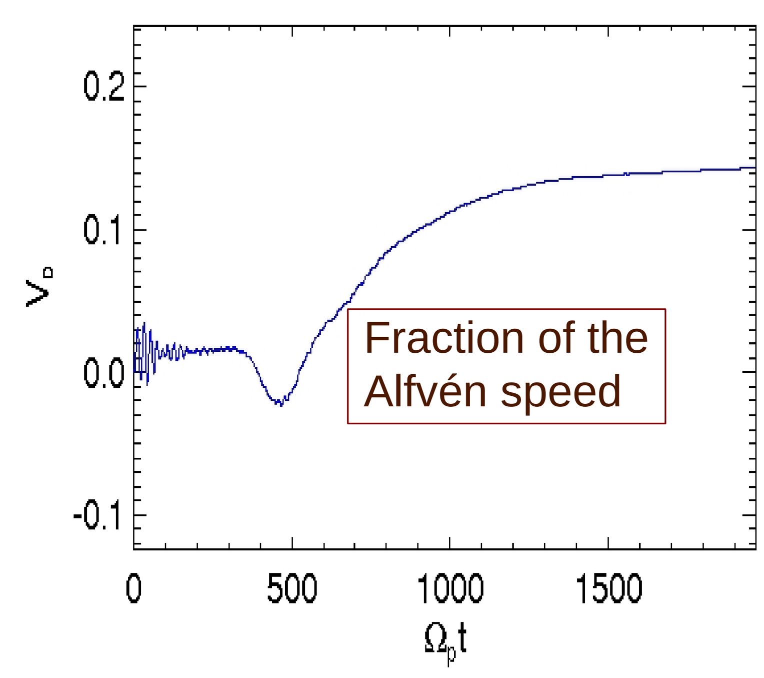
$$\frac{\partial f_i}{\partial t} + \vec{v}_i \cdot \nabla f_i + e\Big(\vec{E} + \frac{1}{c}(\vec{v} \times \vec{B})\Big) \cdot \frac{\partial f_i}{\partial \vec{p}} = 0 \quad \frac{\partial n_s}{\partial t} + \nabla \cdot (n_s \mathbf{V}_s) = 0 \quad \nabla \times \vec{E} = -\frac{1}{c}\frac{\partial \vec{B}}{\partial t} \quad \mathbf{J}_e = \frac{c}{4\pi}\nabla \times \mathbf{B} - \mathbf{J}_i, \quad n_e = n_p + Z n_i \quad n_e V_e = n_p V_p + Z n_i V_i$$





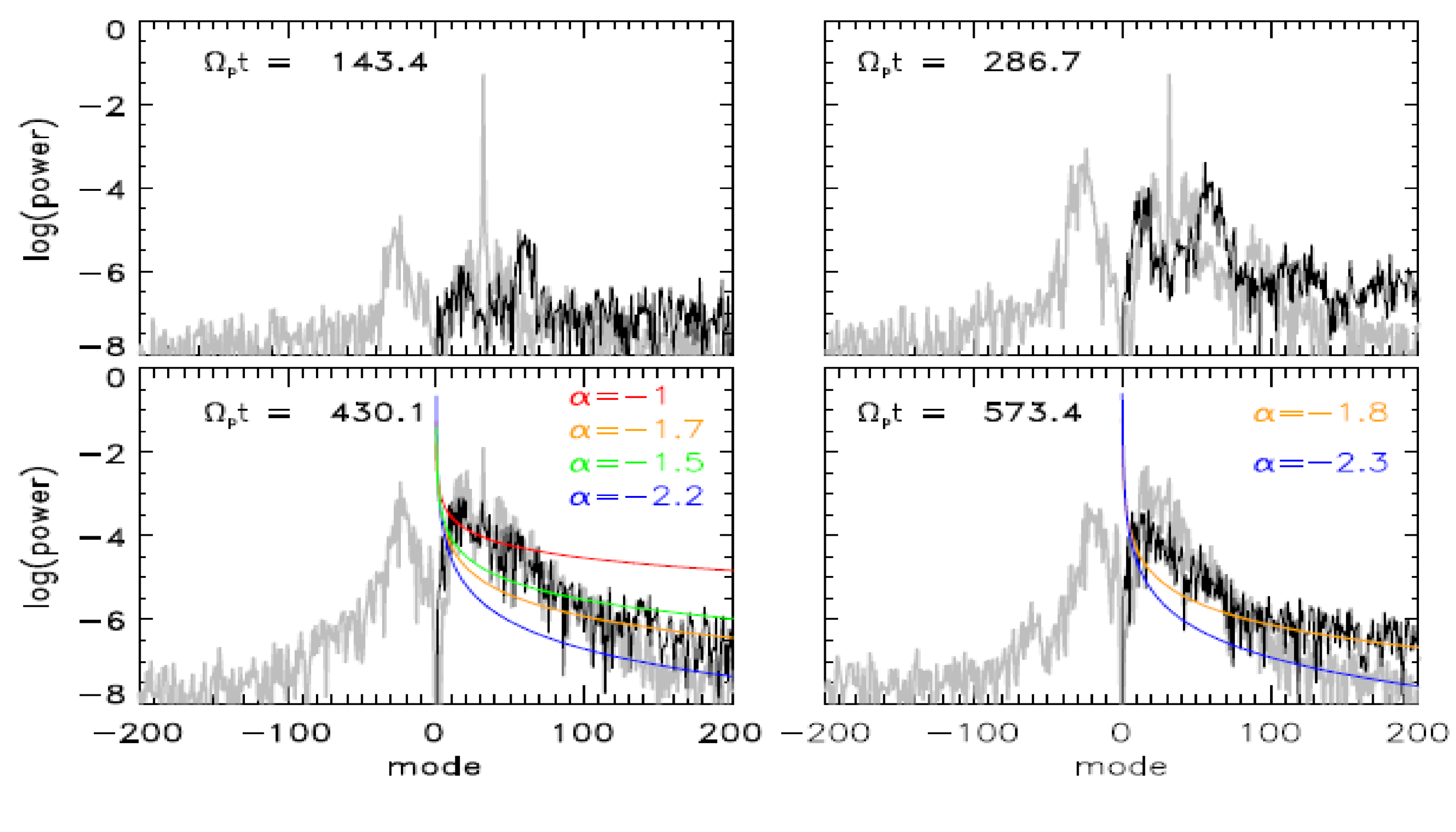






Conclusions:

This work demonstrates how nonlinear three-wave couplings operate to destabilize finite-amplitude Alfvénic fluctuations in collisionless plasmas From the quasi-linear parametric instability theory we compute the growth rate of the ion density fluctuations and compare them to the results from hybrid numerical simulations. Next, we demonstrate how the daughter ion-acoustic waves can trap protons from the tail of the velocity distribution functions and result in acceleration and proton beam formation. The resulting Ion heating and acceleratoin is shown as well. Finally we show the nonlinear evolution of the density and magnetic field fluctuations. The variable slope of the maghnetic field power spectra is in good agreement with the observed values In the solar wind.



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