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Multi-dimensional parametric decay instability of Alfven waves driven by finite amplitude density fluctuations

Yasuhiro NARIYUKI
Faculty of Education, Academic Assembly, University of Toyama
e-mail (speaker): nariyuki@edu.u-toyama.ac.jp

Low-frequency Alfvenic fluctuations are frequently observed in the solar wind plasma[1]. Although the Alfvenic nature of the solar wind magnetohydrodynamic (MHD) fluctuations gradually disappears with increasing heliocentric distance[1], the detailed processes of the disappearance through wave-wave interactions have not been clarified yet.

Since wave-particle interactions do not cause the sufficient damping of low-frequency Alfven waves, parametric instabilities[2] play essential roles in collisionless damping of the Alfven waves. It is important that the finite amplitude Alfven wave is an exact solution of the ideal MHD system with the Bernoulli law[3]. When the thermal pressure can be regarded as constant, the Bernoulli condition corresponds to the condition of the constant magnetic field intensity, which has been known as a characteristics of the solar wind Alfvenic fluctuation[4].

Due to its simplicity, parametric instabilities of circularly polarized, monochromatic Alfven waves have been discussed in theoretical works[2]. Parametric instabilities of non-monochromatic and/or non-circularly polarized waves have also been discussed by using direct numerical simulations[5]. Note that exact non-circularly polarized waves have finite wave numbers perpendicular to the ambient magnetic field. An analytical approach of non-monochromatic parallel propagating waves is given by Malara and Velli[6].

On the other hand, even circularly polarized (parallel propagating) Alfven waves can excite the obliquely propagating daughter waves[7]. In this talk, we discuss the parametric decay instabilities of Alfven waves including obliquely propagating waves. It is known that while the Alfven waves are unstable to the obliquely propagating waves, the instabilities among parallel propagating waves usually have the maximum linear growth rates[7]. However, if finite amplitude obliquely propagating waves unstable to the parent Alfven waves are initially given as a “seed”, the oblique waves can preferentially be enhanced, resulting in the suppression of the growth of the modes with the maximum linear growth rate. Recently, the author showed that through the multi-step wave-wave interactions, the initial oblique waves wave number spectra can also amplify the growth of the mode with the maximum linear growth rate[8]. For instance, if three initial waves with same parallel wave numbers and different perpendicular wave numbers are given, the perpendicularly propagating waves can be excited through wave-wave interactions among initial waves. Then, the secondary excitation of parallel propagating waves can occur. If the parallel propagating wave has the wave number of the maximum linear growth rate, the amplification of the growth of the mode with the maximum linear growth rate can be observed[8].

In general, the growth of the wave number mode, which we select as a target system, is affected by the nonlinear wave-wave interaction among the other modes. Wave-particle interactions can also affect the growth of the parametric decay instability of the Alfven wave through the growth/damping of the daughter (seed) waves. In this talk, we also discuss such influences of other wave-wave and wave-particle interactions on the parametric decay instability from the point of view of the stochastic modeling. The case of the exact non-circularly polarized wave is also shown.

The computer simulation was partially performed on the A-KDK computer system at Research Institute for Sustainable Humanosphere, Kyoto University.

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