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Nonlinear wave-particle interaction in magnetized high temperature plasmas confined in Large Helical Device

Takeshi Ido[1], Akihiro Shimizu[1], Masaki Osakabe[1,2], Kimitaka Itoh[1,3,4], Maxime Lesur[5], Kunihiro Ogawa[1,2], Hao Wang[1], Makoto Sasaki[3], Yusuke Kosuga[3], Shigeru Inagaki[3], Sanae.–I. Itoh[3], and the LHD Experiment Group[1]

[1] National Institute for Fusion Science, Japan,
[2] SOKENDAI(Grad. Univ. for Advanced Study), Japan,
[3]Research Institute for Applied Mechanics, Kyushu Univ.,
[4]Institute of Science and Technology Research, Chubu University, Kasugai, Aichi, 487-8501 Japan,
[5]Institut Jean Lamour, Université de Lorraine, France

e-mail (speaker):ido.takeshi@nifs.ac.jp

Wave-particle interactions are ubiquitous in plasmas, and cause interesting phenomena. In this presentation, observation of an abrupt phenomenon driven by nonlinear wave-particle interaction in magnetized plasmas will be shown.

In magnetically confined high-temperature plasmas in the Large Helical Device (LHD), an energetic-particle driven instability named geodesic acoustic mode(GAM) is excited through the inverse Landau damping. The frequency of this instability usually increases with the time scale of a few milliseconds, and the temporal evolution of the frequency reflects the evolution of the velocity distribution which is a result of wave-particle interaction.

When the frequency of the GAM reaches twice the ordinary GAM frequency and the amplitude of the GAM exceeds a threshold, another GAM is abruptly excited with the shorter time scale of 1 ms or less[1, 2]. The phase relation between the originally-existing GAM, hereinafter referred to as the primary mode, and the abruptly excited GAM, hereinafter referred to as the secondary mode, is locked. Thus, the secondary mode couples with the primary mode. In addition, the evolution of the growth rate of the secondary mode behaves nonlinearly.

This abrupt phenomenon can be interpreted as the excitation of the subcritical instability of the secondary mode[3-5]. The primary mode is considered to be the trigger which is necessary for the excitation of the subcritical instability. The threshold in the magnitude of the primary mode for the abrupt secondary mode excitation has been observed in the LHD experiment, and this observation supports the above interpretation. In addition, a numerical simulation using MEGA code[6], in which MHD fluid plasma and kinetic energetic particles are solved in the three dimensional magnetic configuration, indicates that the secondary mode which has a half frequency of the primary mode can couple to the primary mode through the modification of the velocity space distribution function by the primary mode[7].

Abrupt excitation phenomena have been wildly observed in laboratory plasmas (e.g. sawtooth oscillation and disruption) and astro-plasmas(e.g. onset of solar flares), and subcritical instabilities are one of the working hypotheses of the onset of abrupt phenomena. The finding of the abrupt excitation of the GAM and the understanding of the phenomena as the subcritical instability demonstrate an example of a path to the understanding of the physical mechanism of the onset of the abrupt phenomena.

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