Abrupt excitation of a subcritical instability in magnetically confined plasmas in the LHD

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Abstract

New phenomenon of an abrupt excitation of intense instability has been discovered in magnetically confined plasmas produced in the Large Helical Device (LHD) [1]. This instability is abruptly excited when the up-chirping frequency of an energetic-particle driven geodesic acoustic mode (EGAM), which is a kind of zonal flows with a finite frequency in torus plasmas, approaches twice the ordinary GAM frequency. Measurement of the electric potential fluctuation, density fluctuation, and magnetic field fluctuation indicates that the frequency and the spatial structures of the abrupt instability agree with the dispersion relation of the GAM. Therefore, the abrupt instability is also identified as a GAM.

The abruptly exited GAM has larger amplitude than the initially excited EGAM. The estimated growth rate of the abrupt GAM indicates that the GAM is excited through nonlinear processes. In addition, the observed specific phase relation between the GAM and the EGAM indicates the coupling between the GAM and the EGAM. The abrupt and intense excitation cannot be explained by well-known driving mechanisms such as nonlinear coupling of turbulence [2] and inverse Landau damping of energetic particles[3]. Thus, the observed phenomenon indicate the existence of a new excitation mechanism of the GAM.

A candidate mechanism of the abrupt excitation of the GAM is proposed in Refs. 4,5 and 6, in which it is shown that a subcritical instability of the GAM is driven by a cooperative collaboration of fluid parametric coupling and kinetic nonlinearity. The model can reproduce the observed phase relation, amplitude, and time scale of the abrupt excitation, quantitatively. Thus, this experiment would be the first demonstration of the existence of subcritical instability driven by a kinetic process in magnetically confined plasmas. Since a subcritical instability is one of working hypotheses of the onset of abrupt phenomena such as the sawtooth oscillation in laboratory plasmas and the solar flare in space plasmas, this study may suggest an experimental path to explore the abrupt phenomena.

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