1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

Energetic particle-driven Geodesic Acoustic Mode in the 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], Masaki Nishiura[5], Yusuke Kosuga[3], Makoto Sasaki[3], Katsumi Ida[1,3], 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, [5]Graduate School of Frontier Sciences, Univ. of Tokyo

Geodesic acoustic mode(GAM) is a branch of zonal flow in toroidal plasmas, and driven by not only turbulence but also energetic particles (EPs)[1]. The GAM can also affect transport of EPs, as shown in DIII-D[2], where large neutron emission drops following EP driven GAM (EGAM) bursts suggest losses of EPs. In addition, EGAMs might provide a new channel of energy transfer from energetic fusion products to the thermal plasmas [3,4], or might couple with turbulence and significantly degrade confinement of bulk plasma [5]. Therefore, investigation of the EGAM is necessary to understand transport of both thermal plasma and EPs.

In LHD, an EP driven mode with the toroidal mode number (*n*) of 0 has been observed[6]. The spatial structure of the electric potential fluctuation and the density fluctuation measured by a heavy ion beam probe (HIBP) are consistent with the spatial structures of the GAM: $m = 0$ for the electrostatic potential fluctuation and $m = 1$ for the density fluctuation, where m is the poloidal mode number. The observed frequency and its temperature dependence agrees with the EGAM frequency calculated with the observed velocity distribution function [3, 6, 7]. Because the measured spatial structures and the frequencies agree with the dispersion relation of the EGAM, the observed $n = 0$ mode is identified as an EGAM.

Recently, up-down asymmetry of the density fluctuation associated with the EGAM has been observed[8]. A possible explanation of the asymmetry is provided by a recently proposed theory[9], in which the poloidal asymmetry is caused by resonance between the EGAM and the magnetic drift of EPs. According to the theory, the observed asymmetry contributes to bulk ion heating through the ion Landau damping of the EGAM, and the mechanism may explain the observed response of the energy spectrum of the bulk ions to the EGAM[3].

Usually, the frequency of the EGAM increases with a time scale of 10 ms. When the frequency reaches twice the ordinary GAM frequency, another GAM is abruptly excited with the time scale of 1 ms or less[10]. The amplitude of the abruptly excited GAM is a few times larger than that of the EGAM. The phase relation between the GAM and the EGAM shows a common tendency in any events. In addition, large amplitude of the EGAM is necessary for the abrupt GAM excitation, and there is a threshold in the amplitude of the EGAM. These results indicate that the abrupt GAM excitation is closely related to the EGAM. On the other hand, the amplitude relation between the GAM and the EGAM does not satisfy the Manley-Rowe relation, and the result suggests that the abrupt GAM is not excited by a simple parametric coupling.

The observed features of the abrupt GAM cannot be explained by well-known driving mechanisms of the GAM, such as nonlinear coupling of turbulence and the inverse Landau damping of EPs. According to a theory[11-13], the abrupt excitation of the GAM can be interpreted as a subcritical instability of the GAM driven by the EGAM and the EPs. One of the important features of subcritical instabilities is that the instabilities are driven when the initial perturbation exceeds a threshold. The observed threshold in the amplitude of the EGAM may correspond to the threshold in the driving source which gives initial perturbation.

Since a subcritical instability is one of working hypotheses of the onset of abrupt phenomena such as the sawtooth oscillation and the disruption in torus plasmas and the solar flare, this study would show an experimental path to explore the abrupt phenomena.

References

[1] G. Fu, Phys. Rev. Lett. **101**, 185002 (2008).
[2] R. Nazikian et al., Phys. Rev. Lett. **101**, 185001 (2008)
[3] M. Osakabe et al., Proc. of the 25th IAEA Fusion Energy Conference , Ex/10 (2014)
[4] M. Sasaki, et al., Plasma Phys. Control. Fusion 53, 085017 (2011).
[5] D. Zarzoso, et al., Phys. Rev. Lett. **110**, 125002 (2013).
[6] T. Ido, et al., Nucl. Fusion **55**, 083024 (2015).
[7] H. Wang, et al., Phys. Plasma, **22**, 092507 (2015)
[8] T. Ido, et al., Proc. of the 26th IAEA Fusion Energy Conference , EX/P8-13 (2016)
[9] M. Sasaki, et al.Phys. Plasma, **23**, 102501 (2016)
[10] T. Ido, et al., Phys. Rev. Lett. **116**, 015002 (2016)
[11] M. Lesur, et al., Phys. Rev. Lett. **116**, 015003 (2016)
[12]K. Itoh, et al., Plasma Physics Reports **42** 418(2016)
[13] M. Lesur, et al., Nucl. Fusion **56,** 056009 (2016)