§17. Identification of Energetic-particle Driven Geodesic Acoustic Mode in the LHD Plasmas

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Geodesic acoustic mode(GAM) is a branch of zonal flow in toroidal plasmas, and driven by not only turbulence but also energetic particles (EPs) which will be one of major players in nuclear fusion reactors.

In the low density and NBI-heated plasmas in LHD, 0 mode with an up-chirping frequency has been n = measured by Mirnov coils, where n is the toroidal mode number, and the candidate of the mode is GAM. In this study, the electrostatic potential fluctuation ($\tilde{\phi}$) and density fluctuation (\tilde{n}_e) were measured by HIBP to identify the mode. In the last campaign, the spatial structures of $\tilde{\phi}$ and \tilde{n}_e were clarified¹⁾, and they agreed with those of the GAM. However, the temperature dependence of the frequency of the n = 0 mode show two branches as shown in Fig. 1: one branch shows the $T_e^{0.5}$ dependence, and the temperature dependence of the frequency of the other branch is week and the absolute value is much higher than the ordinary GAM. The former is concluded as the GAM, but the latter could not be identified. Thus, in this fiscal year, we investigated the effect of fast ions on the GAM to clarify the latter n = 0 mode.

In reference 2, it is indicated that the frequency of the energetic-particle driven GAM(EGAM) decreases due to the fast ions with a slowing down energy distribution function. However, the results disagree with the experimental results. In the experiments, the energy spectra of ions were measured by a neutral particle analyzer (NPA), and they were not slowing-down distribution and had the negative gradient in the energy range from 50 keV to 175 keV which corresponds to the energy of NBI³⁾. Taking into account the measured energy distribution function of the fast ions, it was clarified that several branches of the GAMs appeared as the density ratio of the fast ion increased, and that the frequencies of the high frequency branches, squares and filled triangles in Fig. 2, become the orbital frequency of the fast ions with the energy which is the upper limit of the negative gradient of the spectrum. In addition to that, the temperature dependence of the frequency was weak as shown in Fig. 2. The high frequency branches of the GAMs correspond to the observed n = 0 mode with the weak temperature dependence. Therefore, the observed n = 0modes with the chirp-up frequency are identified as the EGAM.

Influences of the EGAM on the ion energy spectra have also observed^{1,3}. The results are reported in this annual report by M. Osakabe et al.



Fig.1 Observed temperature dependence of the frequency of n = 0 mode. Filled circles and open squares indicate the n = 0 modes with up-chirping frequencies. The filled circles roughly depend on $T_e^{0.5}$, and the temperature dependence of the squares is weak.



Fig.2 Temperature dependence of the EGAM frequency. The density ratio of the fast ion is 0.03, and the observed energy distribution function is used in this calculation. The filled symbols show the modes with positive growth rate(γ). The orbital frequency of the fast ion with the energy of 175 keV is 85 kHz.

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- 3) Osakabe, M., et al.: 5th IAEA-TM on EP, Austin(2011) No.O-3