Observation and simulation of TAEs in KSTAR plasmas

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Toroidicity induced Alfven eigenmodes (TAE) [1-3] can be driven unstable by fast particles from neutral beam heating or fusion reactions and have been observed in different tokamaks [4-5]. We report the observation of TAEs in KSTAR plasmas during the 2013-2015 campaigns by the fast particles produced the neutral beam injection and global gyrokinetic simulations of them by using the GTC and GENE codes. Mode analysis indicates that the TAEs in KSTAR have low n numbers, mainly n=1, differently from the cases of other tokamaks which showed rather high n toroidal mode numbers. This seems to indicate that the finite Larmor radius (FLR) stabilizing effects are playing in KSTAR. To understand the TAE mode characteristics and finite orbit Lamor radius stabilization effects, we carried out linear simulations by using the GTC and GENE codes, which give results in agreement. The mode frequency, growth rate, poloidal and radial mode structures analyzed by using these two codes are presented.

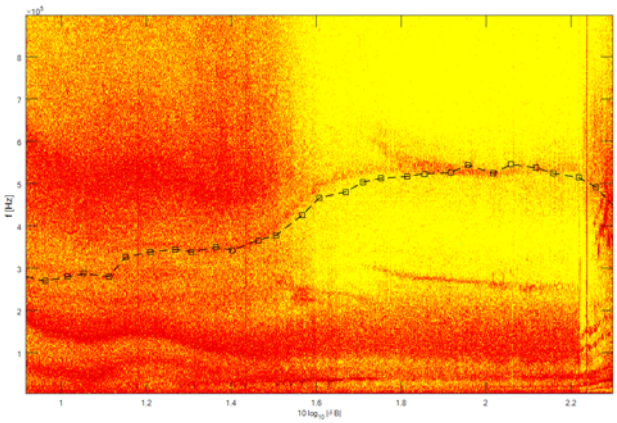

Fig. 1. Frequency spectrum of MC signals for n=1 TAE observed during the NBI heating. The mode is traced by the TAE frequency given by $f = v_A/(4\pi qR)$, confirming that these modes are TAEs

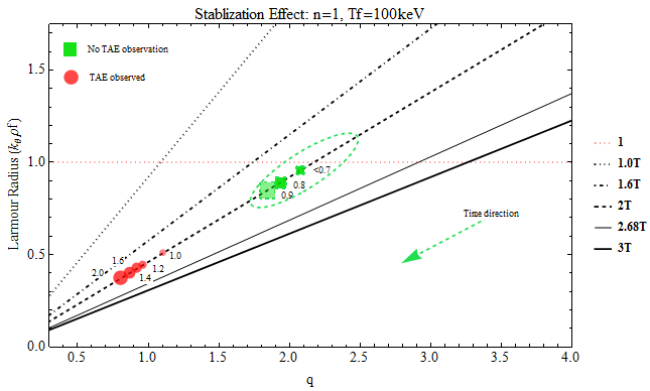

Fig.2. Finite Lamor radius stabilization of n=1 TAEs. Red circles represent the unstable TAEs observed, and the green squares represent stabilization of expected TAEs for B=2T.

Fig. 1 shows the observation of n=1 TAE activity in KSTAR frequency varying from 280KHz to 520KHz and activity lasts up to the beginning of the H-mode. We have overplotted the theoretical estimation with square. We have seen TAE n=1 activities in plasma discharges for magnetic fields B=1.6, 1.8, 2 and 2.9 Tesla, and found that in all the experiment, the observed TAE is in good agreement with the

theoretical estimation. In Fig. 2 we have plotted the $k_\theta \rho_f$ vs. q. This figure shows the TAE FLR stabilization. As q(t) decreases with time plasma moves from stable region to TAE unstable region. Green arrow head indicates time evolution of the plasma discharge and red circles correspond to the TAE destabilization, whereas the green square corresponds to no observation of TAE.

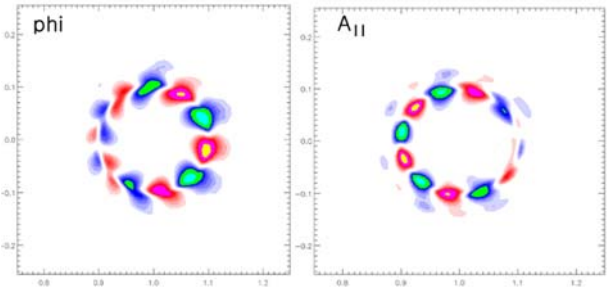

Fig. 3 Poloidal mode structures of a TAE obtained by GTC simulation for, (left) electrostatic potential and (right) parallel electromagnetic potential.

For detailed analysis, we carried out the Gyrokinetic simulation, and the simulation results shows the excitation of fast particle driven TAEs, for instance, due to the coupling of m=5 and 6. Figure 3 shows the poloidal mode structure for electrostatic and parallel vector potential. Figure 4 shows the radial mode structure of poloidal harmonics and frequency spectrum as a function of radial coordinate plotted together with the Alfven continuums. We have also performed the simulation study of the stabilization of the TAE using GENE code and results shows that FLR has a stabilizing effect on TAEs in agreement with the GTC results.

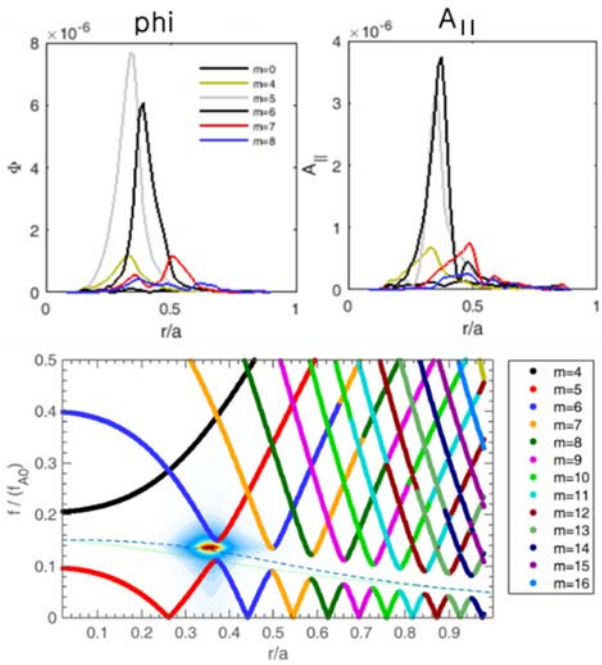

Fig. 4 Simulation results for the radial mode structures of different poloidal components for electrostatic (upper-left) and vector potentials (upper-right), and the TAE frequency of the mode in the gap of Alfven continuum (lower).

References:-

[1] Zonca F. et al 206 Plasma Phys. Control. Fusion 48, B15
[2] Heidbrink W.W. 2008 Phys. Plasmas 15, 055501
[3] Sharapov S.E. et al 2013 Nucl. Fusion 53, 104022
[4] Lauber Ph. 2012 Nucl. Fusion 52, 094007 (2012).
[5] Grac, S.da et al 2012 Plasma Phys. Control. Fusion 54, 095014