# Observation of Global Alfvén Eigenmode Avalanche-like events on the National Spherical Torus Experiment


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A super-Alfvénic fast-ion population, such as the fusion $\alpha$'s on ITER, can excite instabilities extending from low frequency Energetic Particle Modes (EPMs) at 10's of kHz, through Toroidal Alfvén Eigenmodes [TAE] with frequency in the range of $V_{Alfvén}/(4\pi qR)$ to Global and Compressional Alfvén Eigenmodes [GAE and CAE] in the frequency range from roughly $0.1\omega_{ci}$ to $0.7\omega_{ci}$. This paper presents the first observations of GAE mode avalanching, and the evidence of fast ion redistribution resulting in the triggering of lower frequency TAE instabilities. Instabilities excited by fast ions can exhibit complex non-linear behavior, including strong growth which onsets above an amplitude threshold when resonance regions in phase space start to overlap, resulting in strong fast ion transport [2]. The GAE and CAE are excited through a Doppler-shifted ion cyclotron resonance in neutral beam heated NSTX plasmas and may also be present in ITER, excited by the fusion $\alpha$'s.

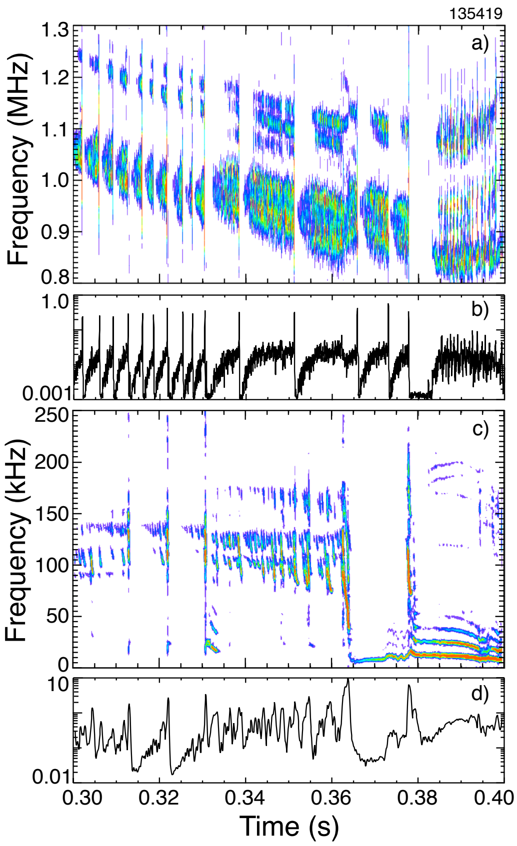


Fig. 1. a) spectrogram showing GAE modes, b) rms magnetic fluctuations 0.8MHz<freq<1.3MHz, c) spectrogram showing TAE and low frequency kink activity, d) rms magnetic fluctuations from 30kHz<freq< 200 kHz.

Figure 1 shows examples of both GAE and TAE avalanching. Figures 1a and 1b show a spectrogram of the GAE activity near 1 MHz and the rms fluctuation level, respectively. The modes are seen to grow slowly for several ms, then very quickly for a brief period (the spikes seen in Fig. 1b, or Fig. 2) and then a quiescent period, after which the cycle starts again. Figures 1c and 1d show similar, concurrent spectrograms depicting TAE avalanches and the rms mode evolution, as described in previous reports [3].

Single modes create one or more resonant fast-particle phase space 'islands', the region where fast ions have become trapped in the wave field. As the mode amplitude increases, the size of the resonant 'island' increases. With multiple resonances, islands close together can overlap, creating a larger, stochastic region which greatly enhances fast-ion redistribution, that is, avalanches. The strong, periodic bursts of GAE activity shown in Fig. 1 have all of the characteristics of avalanching behavior. Neutron rate drops are not seen with the GAE avalanches, however, the GAE-quiescent period following each strong burst is consistent with a fast-ion redistribution which reduces the free-energy available to drive the modes. Additional, indirect or qualitative evidence of fast ion redistribution is shown in Fig. 2, where the rms fluctuation level for GAE (red) and TAE (blue) are shown. The three TAE avalanche events in this time range are seen as spikes in the blue curve. Each of the three TAE avalanches has a GAE avalanche several hundred microseconds earlier, although not every GAE avalanche triggers a corresponding TAE avalanche. The timing suggests that the redistribution of fast ions from the GAE avalanche provided some of the impetus to trigger the TAE avalanche.

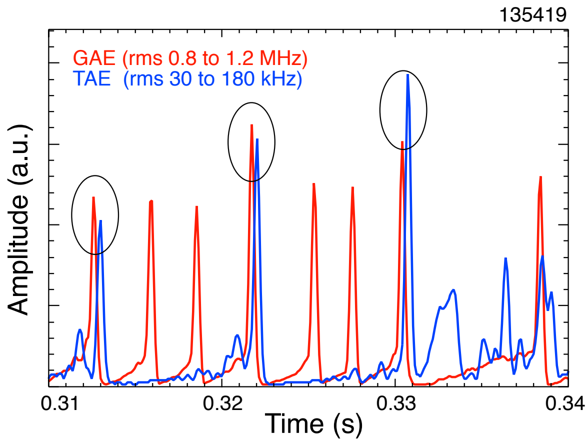


Fig. 2. RMS fluctuation levels in GAE frequency band (red) and TAE frequency band (blue). Relative fluctuation amplitudes between red/blue curves is arbitrary; shown for timing only.

These are believed to be the first reported observations of avalanching behavior in modes excited through a Doppler-shifted ion cyclotron resonance. Of further importance is the suggestion from the time behavior of the TAE and GAE that the GAE are redistributing fast ions at a level which destabilizes the TAE, apparently triggering TAE avalanches. This observation has repercussions regarding the development of a self-consistent predictive capability for TAE induced fast ion transport in future fusion devices, like ITER, with super-Alfvénic fast ion populations.

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