Observations of Alfvénic-character oscillations in ohmic plasmas on the COMPASS tokamak

T. Markovič[1,2], A. Melnikov[3,4], J. Seidl[1], L. Eliseev[3],
J. Havlicek[1], A. Havránek[1,5], M. Hron[1], M. Imríšek[1,2], K. Kovařík[1,2], S. Medvedev[6],
K. Mitošinková[1,2], J. Mlynar[1], D. Naydenkova[1], R. Pánek[1], J. Stockel[1], J. Varju[1], V. Weinzettl[1]
[1] *Institute of Plasma Physics of the CAS, Prague, Czech Republic*
[2] *Faculty of Mathematics and Physics, Charles Uni. in Prague, Prague, Czech Republic*
[3] *National Research Centre 'Kurchatov Institute', Moscow, Russian Federation*
[4] *National Research Nuclear University MEPhi, Moscow, Russian Federation*
[5] *Faculty of Electrical Engineering, Czech Tech. Uni. in Prague, Prague, Czech Republic*
[6] *Keldysh Institute of Applied Mathematics, RAS, Moscow, Russian Federation*

In plasma magnetic confinement devices, a significant presence of superthermal Energetic Particles (EP) (e.g. from auxiliary plasma heating systems) can drive instabilities via resonance of particle velocity with plasma Alfvén velocity, which can in turn negatively affect the EP confinement [1]. However, there have been reports of plasma Alfvén eigenmode oscillations in purely ohmically-heated plasmas (i.e. without external sources of fast ions) on several experimental devices, including TFTR [2], ASDEX-U [3] and MAST [4]. In this paper we report observation of similar Alfvén eigenmode oscillations in ohmically heated plasmas on the COMPASS tokamak [5] and classify them with respect to the reports from other devices from the perspective of mode frequency scaling, localization and possible excitation mechanisms.

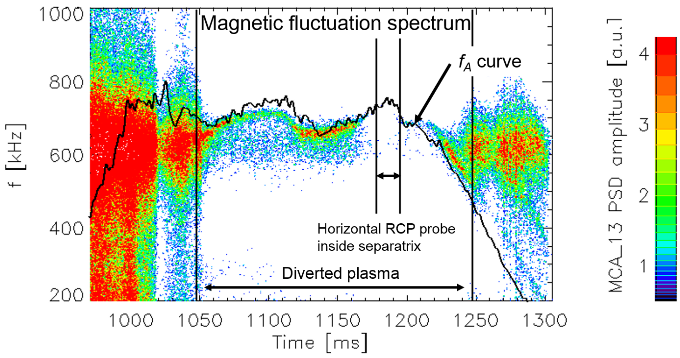

Figure 1: *Spectrogram of local B_θ sensor signal located on HFS, discharge #11153. f_A curve represents parametric dependency from eq. (2).*

Long-lived Alfven oscillations

The most of the COMPASS tokamak discharges contain high-frequency ($f \approx 200$ kHz –1000 kHz) oscillations of local poloidal magnetic field B_θ on High Field Side (HFS) and on divertor electric probes – a typical example of the magnetic spectrum is shown in fig. 1. The frequency of the oscillations evolves over the discharge duration and it has been found that it follows plasma parameter scaling of shear Alfvén wave propagating along helical fieldline [1]:

$$f_A = \frac{1}{2\pi R q(r)} \frac{B_0}{\sqrt{\mu_0 \rho(r)}}, \qquad (1)$$

where R is major radius, q safety factor, B_0 toroidal magnetic field, μ_0 vacuum permeability and ρ plasma ion mass density. Assuming constant plasma composition, stiff plasma profiles and taking experimental arrangement into consideration, the above relation can be approximated by simple relation:

$$f_A \sim \frac{I_p}{\sqrt{n_e}}, \qquad (2)$$

where I_p stands for total plasma current and n_e represents line averaged electron density. Fig. 2 shows very high correlation between the observed frequencies of the oscillations and eq. (1) for multitude of discharges of different parameters, but same plasma composition. This leads to the conclusion that observed oscillations are of Alfvénic character. Furthermore, preliminary simulations by KINX MHD code [6] show that frequencies of the observed oscillations are in agreement with position of Bragg gaps in Alfvén continuum, implying that these oscillations are Alfvén Eigenmode oscillations.

Similar oscillations in ohmic plasmas have been first reported on TFTR tokamak [2] and referred to as Alfven Frequency Modes (AFM). These modes have been localized in edge plasma, which seems to be also valid for COMPASS oscillations, taking into consideration the supression of the mode amplitude over the period when horizontal reciprocation probe perturbs the edge plasma regions (see fig. 1). AFM have further been reported to be unaffected by NBI, correlated with edge MHD events (ELMs), but not core events (e.g. sawteeth) and having amplitude suppressed upon H-L transition, all of which has been observed also for COMPASS oscillations. The AFM amplitude scales as:

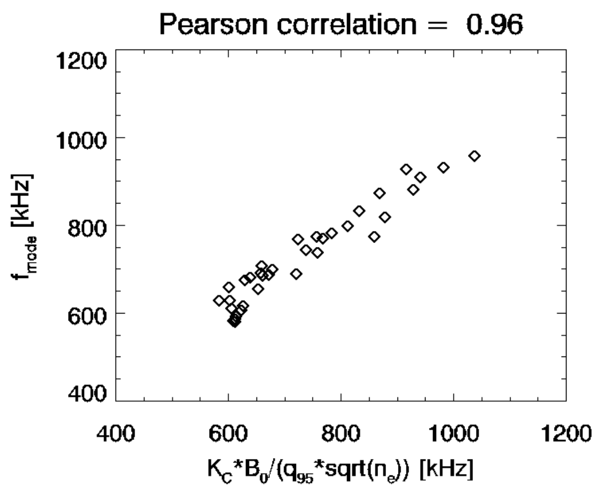

Figure 2: *Multi-discharge correlation between observed oscillation frequency and eq. (1). K_c represents parameter dependent on plasma ion mass composition (which was the same for the plotted discharges).*

$$A \sim q^3 n_e^{1.5}, \qquad (3)$$

which is also valid for the COMPASS oscillations, with linear correlation coefficient of 0.83. However, AFM toroidal structure of $n = 0$ points towards them being Global Alfven Eigenmode oscillations [7], while COMPASS modes in this manner are closer to the $n = 1$ electron diamagnetic drift direction rotating ohmic TAE, observed on ASDEX-U [3]. Taking the similarities into account, as well as the fact that amplitude of the modes drops upon H-L transition, it is possible that the driving mechanism of COMPASS oscillations is the same as that of ASDEX-U ohmic TAEs. That is, coupling of the drift wave turbulence to the ordinary Alfvén wave spectrum at cold plasma edge [3, 8].

High frequency chirping oscillations

Second type of the ohmic Alfvén character modes observed on COMPASS are 800-2500 kHz oscillations, associated with low density discharges (with typically prominent runaway electron population). These are poloidally localized on Low Field Side (LFS) of the tokamak, and have more distinct mode number structure ($m > 1$, $n = 1$) than the long-lived oscillations. They typically manifest as short-lived chirping bursts of magnetic oscillations, with the whole phenomenon typically lasting several tens of milliseconds. The overall frequency of the modes follows scaling in eq. (2), as can be also seen in fig. 3. The onset of the oscillations is associated with peaks of soft X-ray and hard X-ray radiation (see fig. 3), implying possible role of internal MHD events, hence different excitation mechanism than the one responsible for the long-lived oscillations.

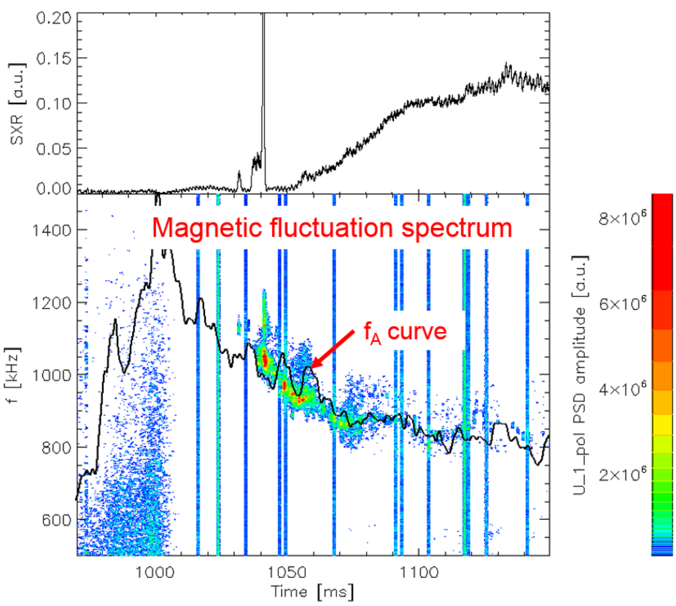

Figure 3: *Top plot – soft X-ray radiation from central plasma. Bottom plot – chirping mode time evolution on spectrogram of B_θ sensor located on LFS. f_A curve represents parametric dependency from eq. (2).*

Very similar oscillations have been recently reported on tokamak TUMAN-3M [9], whose excitation mechanism was preliminarily identified as internal reconnection MHD events taking place during sawteeth oscillations. The frequency chirps on COMPASS are also seen to be correlated with sawteeth activity. However, the modes can be present even in the absence of the sawteeth, implying possibly more general excitation mechanism, hence are also possibly associated with runaway electron population. Ohmic Alfvén oscillations driven by internal MHD reconnection events and runaway electrons have already been reported on tokamak MAST [4].

Conclusions

We observed two different types of high frequency oscillations of Alfvén character in ohmic, L-mode plasma discharges on the COMPASS tokamak. The long-lived oscillations, present during most of the discharge duration bear many similarities to the AFMs observed on TFTR [2] as well as ohmic TAEs observed on ASDEX-U [3]. The frequencies of the oscillations show very good correlation with Alfvén eigenmode parametric scaling and are possibly driven by coupling of drift wave turbulence to Alfvén wave spectrum [3]. The other type of the oscillations manifests itself as short-duration chirping bursts of magnetic signal, also follow Alfvén eigenmode scaling of the frequency and their onset is typically correlated with peaks of X-ray radiation. The possible driving mechanisms, that will be further investigated in the near future, include internal reconnection events in core plasma and significant population of runaway electrons. These observations complement our previous observations of Alfvén eigenmodes observed in both ohmic and NBI-heated COMPASS plasmas [10], providing more complete picture of Alfvén eigenmode oscillations in COMPASS plasma.

Acknowledgements

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