Alcator C-Mod

Mini-Proposal

MP No. 494a

Subject: Fast Electron Driven Alfvén Eigenmodes

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Group: MHD

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Approved by: **Date Approved:**

1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

Use lower hybrid current drive very early in the plasma startup to excite fast electron driven instabilities and determine if their frequencies scale as expected for Alfvén eigenmodes. Fast particle driven modes have often been observed during ICRH in the current rise excited by fast ions, called Alfvén Cascades or Reversed Shear Alfvén Eigenmodes (RSAEs). These modes have been used to calculate the time evolution of the q profile through their frequency evolution. This proposal seeks to clarify the frequency dependence of recent observations of high frequency modes early in the current rise that were excited by LHCD.

2. Background

Discuss Physics Basis of the proposed research. Prior results at Alcator or elsewhere, and any related work being carried out separately.

The lower hybrid heating was accidentally turned on from 0.02 – 0.1 s in the discharges 1070427001, 1070523001, and 1070523002. In each of these discharges, both high frequency (200 kHz < f < 700 kHz) modes and very low frequency (f < 10 kHz) were observed that are not seen without the lower hybrid heating. The low frequency modes appear to be double tearing modes given two phase inversions across the radial ECE temperature profile. This indicates that the LHCD is modifying the q profile early in the current rise. The high frequency modes increase in frequency from about 200 kHz to about 700 kHz with three simultaneous sweeps (Fig. 1) that appear to increase in frequency with increasing toroidal mode number. Such frequency ramping is reminiscent of Alfvén Cascades. The earlier shot had lower density that the later two shots and had somewhat higher frequency, suggesting that the frequency of the modes may scale as 1/sqrt(n_e) as expected for Alfvén eigenmodes. This proposal aims to test whether or not the frequency of these high frequency modes scales as B/sqrt(n_e) as expected for Alfvén eigenmodes. Fast electron driven modes have been observed on DIII-D [1] and on Compass-D [2] with ECH and LHCD as expected theoretically [3,4].

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The toroidal field and density will be systematically varied from shot to shot while injecting LHCD very early in the current rise phase to excite the high frequency modes that were previously observed. Such systematic scans will enable us to determine if the frequency of the modes scales as expected for Alfvén eigenmodes, as $f_{AE} \sim B_T/\text{sqrt}(n_e)$ if the modes begin at the same q surface or if we can determine the q. Since density is less likely to change q, we will begin by varying the density through changes in wall conditions. A factor of three variation in density from nl04 = 0.045 – 0.15 × 10^{20} m^{-2} has been achieved for various shots at 0.03 s. Achieving this much variation in one run day may be difficult, but if we can piggy-back on several runs with varying wall conditions, we may be able to achieve this much density variation. In addition, the toroidal field at breakdown will be varied first around the standard 5.4 T from say 5 T to 6 T to see if the frequency increases linearly with B_T. Through small variations in B_T, it may be possible to maintain the same rational q surface that excites the modes. Attempts will also be made to determine both m and n to see if it is possible to determine the rational q surface of the excited modes. Then, if dedicated run time is obtained, we will first increase B_T up to 7 T and then down to 4 T in several steps to see if the mode frequency continues to scale linearly with B_T or if the rational q surface changes.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 4 – 7 T
Plasma Current: 0.8 MA
Working Gas Species: Deuterium
Density: 4 x 10^{18} m^{-3} – 1.5 x 10^{19} m^{-3} in the current rise
Equilibrium configuration (if possible, refer to database equilibria): 1070523001

4.2 Auxiliary Systems

RF Power, pulse length, phasing: LH up to 500 kW, 60, 90, and 120° phasing
Pellet Injection (species): None
Impurity blow-off injection: None
Diagnostic Neutral Beam: No
Special gas puffing: No special puffing
Non-axisymmetric Coils (Connections, Current); None
Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Fast magnetic pick-up coils are required with sampling of 2.5 MHz. PCI could also be valuable if the signal level is sufficient at these low densities, but is not required. Hard x ray camera for fast electron distribution function.

5. Experimental Plan

Both sections must be filled in.

5.1 Run sequence Plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period – 10 hours maximum – etc.

One run is probably not sufficient to achieve all of the wall conditions necessary to vary the early density substantially, but these conditions could be achieved in piggy-back over a series of different runs since we will only add some LHCD in the very early phase of the current rise and the rest of the discharge could be used for other purposes. To obtain significant toroidal field variation in the current rise, a dedicated run would probably be needed. The lower field data may be more difficult to get as breakdown conditions will be affected as well as LH accessibility. The high field data should not be a problem if we can run high field in the current rise phase.

5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

The density could be varied in piggy-back on other runs mainly through changes in wall conditions over perhaps a factor of three from $0.04 – 0.15 \times 10^{20}$ m^{-2}. A toroidal field scan would be more difficult to obtain in piggy-back mode because it is unlikely that other runs will ask for high or low field in the startup. Lower field could be problematic as it would change the startup conditions and may make it difficult to get sustained current rises. Lower hybrid accessibility is also affected at low field. So, we would start with standard 5.4 T and then change gradually up and then down in field and look for changes in the mode frequency. A systematic scan could be done in 5 – 10 shots. Previous results indicate that 300 – 400 kW are sufficient to excite these modes, but we may inject 500 kW if the LH is working well at that power level. In addition to the scans of toroidal field and density, we would also like to scan LH phasing from 60 to 90 to 120˚ to look for changes in the excited modes, since changes in the current drive profile could also affect Alfvén eigenmodes. This would take an additional 3 shots or perhaps 6 shots to ensure some reproducibility.

6. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

Previous discharges indicate that these modes will be readily excited. The frequency dependence on toroidal field, density, and LH phasing is unknown, but if these modes are indeed Alfvén eigenmodes, the frequency should scale as expected if the excited q surface is the same or can be determined. If the frequency does not scale as expected for a given rational q surface, this will indicate that the modes are not Alfvénic. This will provide food for thought and may lead to new theory through collaborations and publications of the results.

7. References

Include references both to external and internal literature or communications which bear on this proposal. See Section 2.

[1] K L Wong, et al, *Phys. Rev. Lett* **85** (2000) 996.
[2] M Valovic, et al, *Nucl. Fusion* **40** (2000) 1569.
[3] H Furth, *Phys. Fluids* **8** (1965) 2020.
[4] F Zonca, et al, IAEA (2006) Chengdu, TH/3-2.

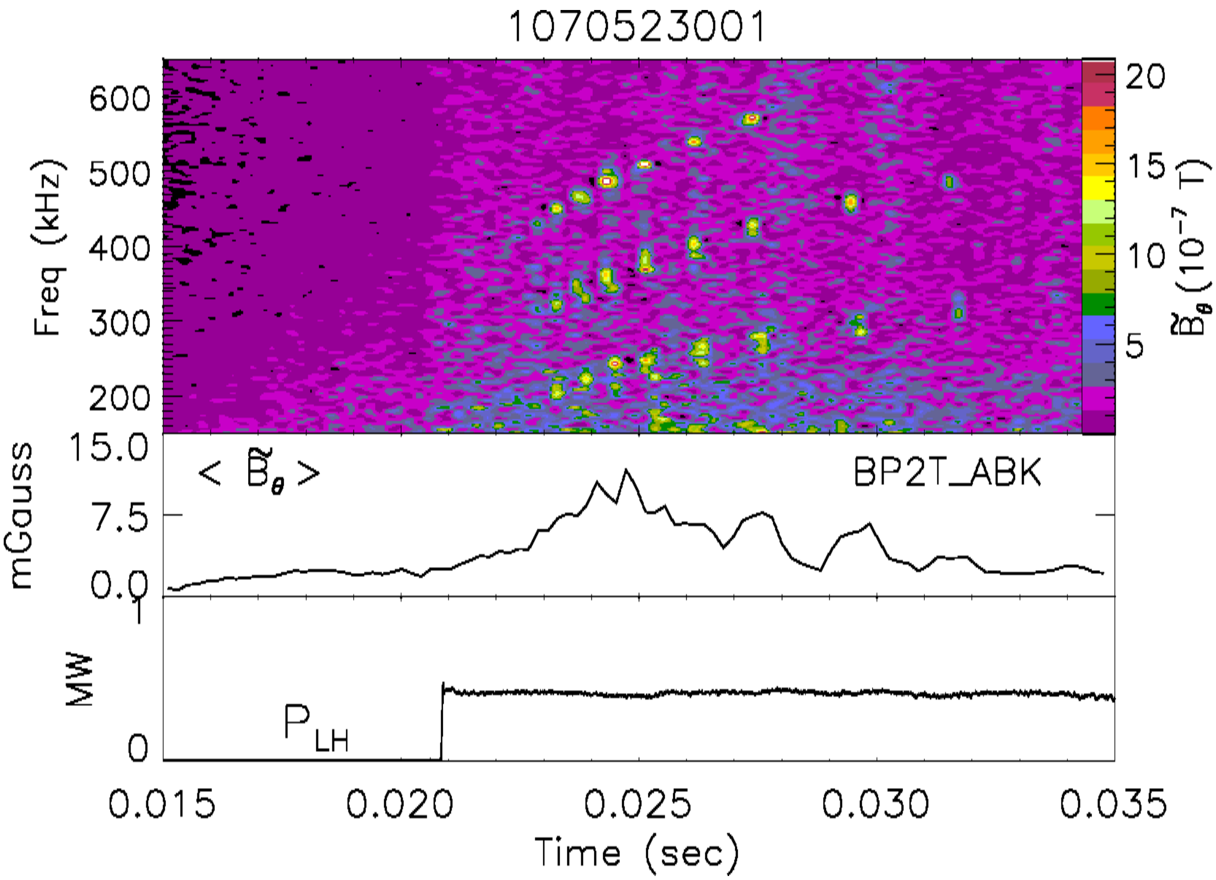

Fig. 1. High frequency sweeping bursts of magnetic fluctuations in the current rise with LHCD in the frequency range of Alfvén cascades.