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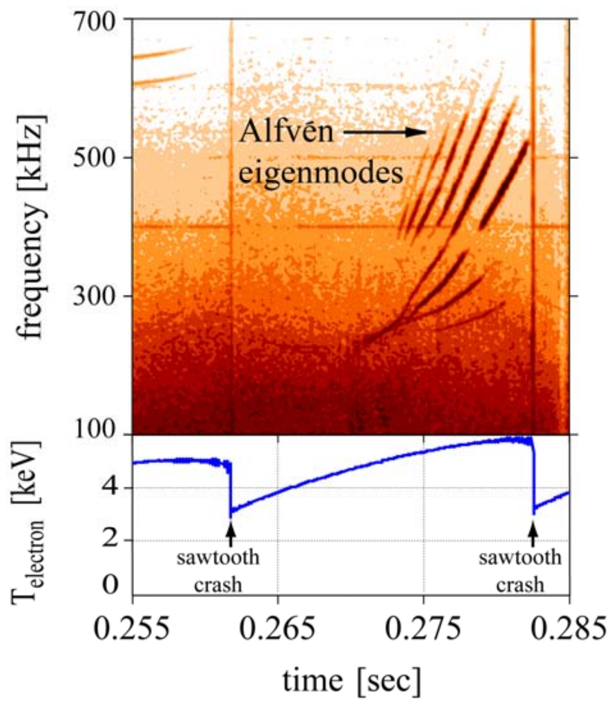
Alfvén waves provide insights into the longstanding problem of the sawtooth crash

Recent experiments on the Alcator C-Mod tokamak employ one plasma instability, the Alfven eigenmode, as a diagnostic probing into a second instability, the sawtooth oscillation, revealing new facets of the latter.

New results shed light onto an old problem. A longstanding phenomena of great practical and theoretical interest in plasma physics is the so-called "sawtooth oscillation". First reported over three decades ago [von Goeler *et al.*, Physical Review Letters **33**, 1201 (1974)], the physics of the sawtooth oscillation has remained elusive. The sawtooth is a relaxation oscillation, characterized by a periodic and abrupt "crash" in the plasma temperature, as shown in the bottom panel in the figure. Observed in most tokamaks, the instability is driven by current flowing in the plasma and can lead to the expulsion of hot plasma and current from the core, causing a reduction in plasma confinement and the excitation of other instabilities.

The study of a different type of instability, the Alfvén eigenmode, is being used to indirectly study the sawtooth oscillation. The figure presents data from a Phase Contrast Imaging (PCI) instrument, a type of laser interferometer, showing the evolution of the frequencies of Alfvén eigenmodes that arise between successive sawtooth crash events. The Alfvén modes (named after Hans Alfvén) are a type of hydro-magnetic wave which propagates along magnetic field lines, much like the vibration of a guitar sting. Alfvén waves are also common in the solar wind and other astrophysical plasmas. In the tokamak experiments the Alfven modes are excited by superthermal ions.



(Top) Data from the PCI diagnostic showing the evolution of Alfvén eigenmodes frequencies between sawtooth crash events. (Bottom) The evolution of the central electron temperature over this same time, showing the sawtooth oscillation and the crash events.

The Alfven eigenmodes have proven useful for the measurement of the current profile near the core of the plasma. The very presence of these modes implies that the current profile is inverted, meaning that there is lower current density at the center of the discharge than in surrounding regions. A theory describing the Alfven eigenmodes shows that the frequency of the modes should increase when the current in the plasma core increases. Used the other way around, we can use the evolution of the frequencies to measure how the current profile is changing in time.

The new and surprising result presented here is that the Alfvén eigenmodes are observed between the sawtooth crashes as it was not expected that the current profile would be inverted under these circumstances. Thus, the presence of these modes tests our assumptions and models of the plasma behavior during this time. These results provide a new challenge to theory and a stringent means for testing the validity of computer codes which are used to simulate the phenomena.

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Invited talk at 50th APS/DPP
Abstract: GI1.00003
"Observation of reversed shear Alfven eigenmodes during the sawtooth cycle in Alcator C-Mod"
Room Landmark A, 10:45-11:15 Tuesday 11/18/2008

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