

Limit Cycle Oscillations at the L-I-H Transition in TJ-II Plasmas: Triggering, Temporal Ordering and Radial Propagation

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Abstract

At the L-I-H transition, the turbulence-flow interaction displays Limit Cycle Oscillations (LCO) and both, radial outward and inward propagation velocities of the turbulence-flow front are observed at TJ-II. Associated to this velocity reversal, a change in the temporal ordering of the LCO is measured, however, in all cases the turbulence increase leads the process and produces an increase in the ExB flow shear. Dedicated experiments have been carried out to investigate the physical mechanisms triggering the onset and radial propagation of the LCO. Preceding the onset of the oscillations, high frequency modes are often observed accompanying a low frequency MHD mode. The results point to the interplay between the MHD mode and the ExB flow as a precursor for the LCO onset at the L-I-H transition.

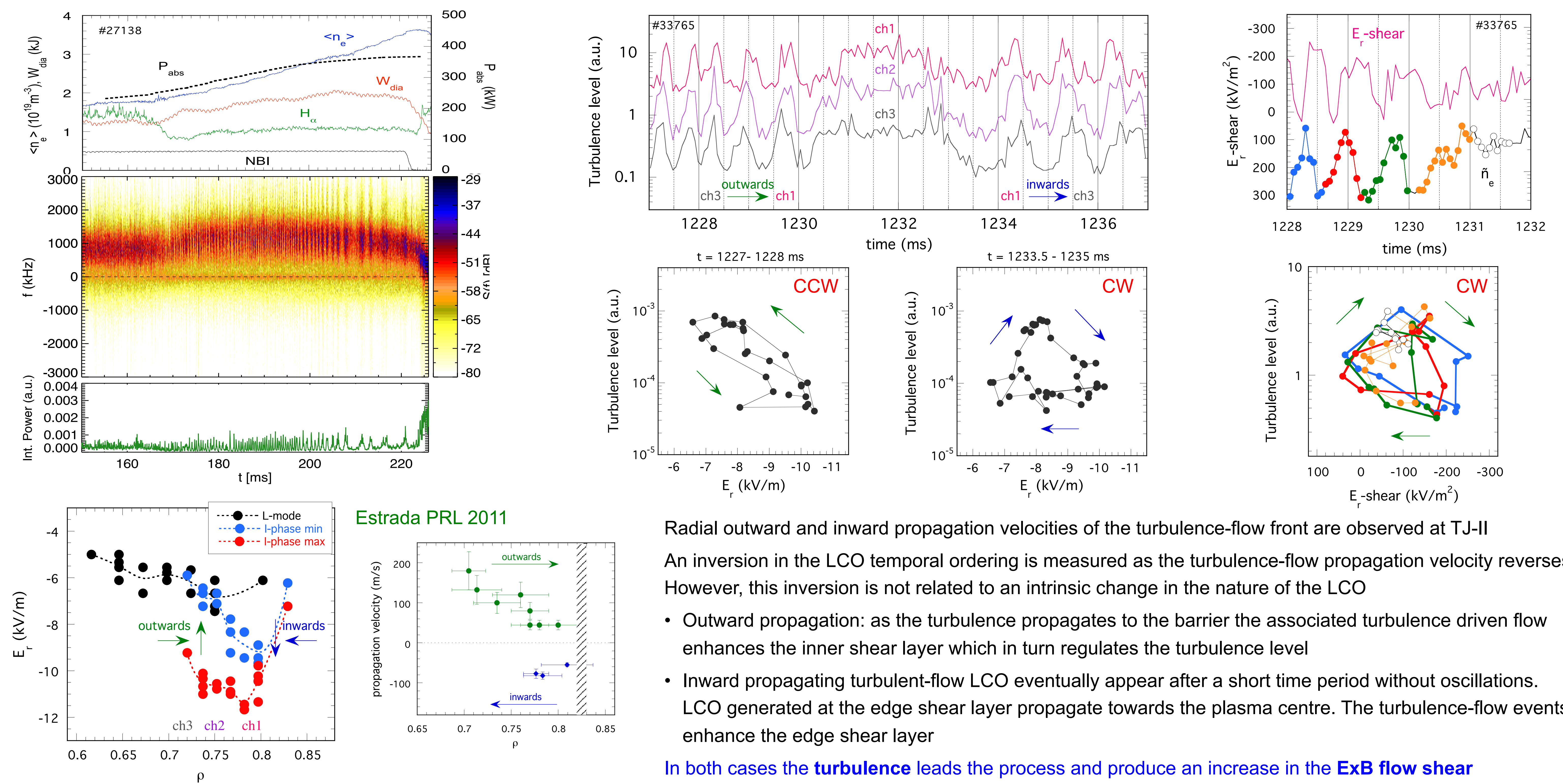
Introduction

Close to the L-H transition threshold conditions, the temporal dynamics of the interaction between turbulence and flows displays **LCO** with a characteristic **predator-prey** relationship between flows and turbulence. **This interaction is the basis for L-H transition models based on turbulence induced zonal flows [Kim and Diamond PRL 2003]**

Recently, some controversial results have been reported [Cheng et al. PRL 2013]. **Two types of LCO** have been found in the HL-2A tokamak showing **opposite temporal ordering**. In the **first type** of limit cycle, the turbulence intensity grows first followed by the increase of ExB flow, similar to previously reported observations. This is the standard predator-prey model where **the turbulence increase leads the zonal flow generation** which suppresses the former. In the **second type** of limit cycle, **the ExB flow grows first causing the reduction of the fluctuations**. This second LCO points to the pressure gradient and the corresponding radial electric field as a candidate for maintaining the oscillations and eventually inducing the transition to the H-mode, as in the bifurcation model [Itoh and Itoh PRL 1988]

At TJ-II some dedicated experiments have been carried out to investigate both the LCO temporal ordering and the physical mechanisms triggering the LCO onset

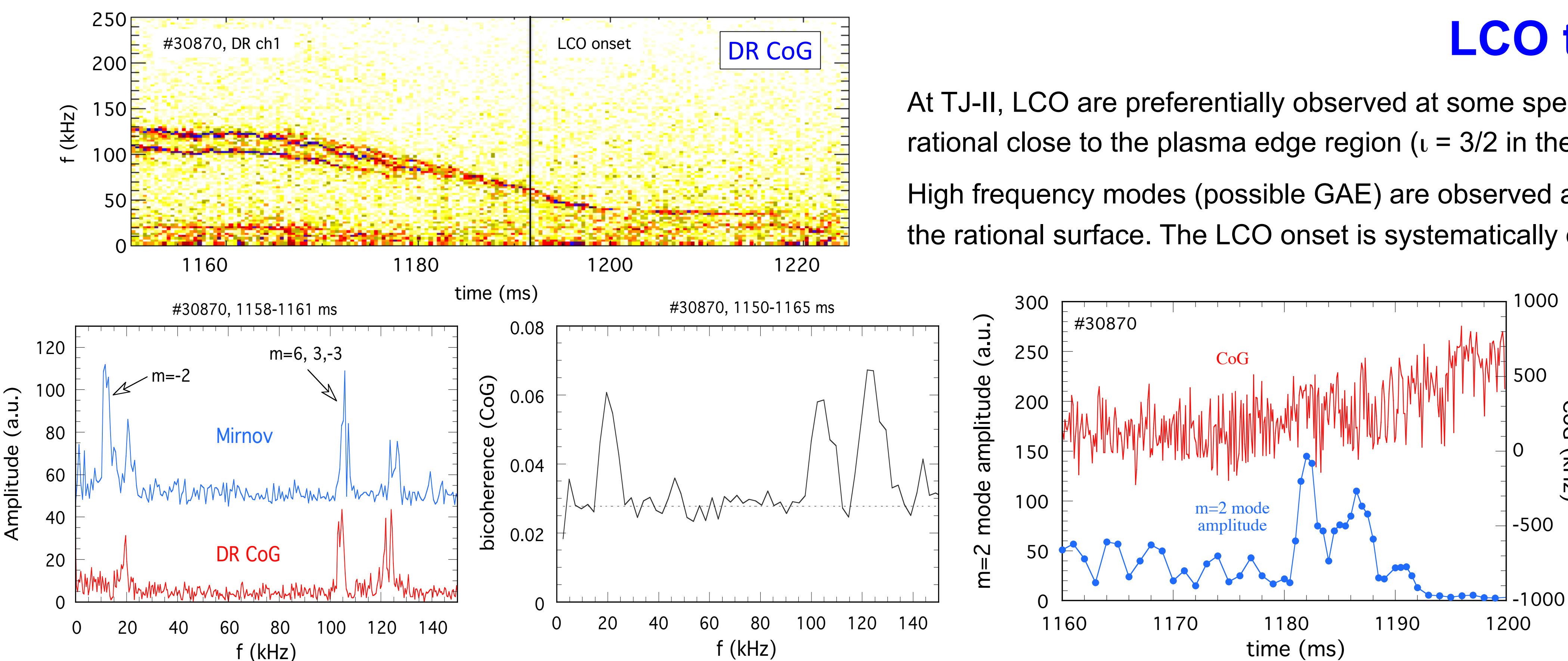
LCO temporal ordering and radial propagation



LCO triggering

At TJ-II, LCO are preferentially observed at some specific magnetic configuration, i.e. those having a low order rational close to the plasma edge region ($\iota = 3/2$ in the example)

High frequency modes (possible GAE) are observed accompanying the low frequency MHD mode associated to the rational surface. The LCO onset is systematically observed associated with the drop in the GAE frequency



The $m=2$ mode frequency stays constant but not its amplitude. The mode amplitude increases noticeably several milliseconds before the LCO onset. Simultaneously oscillations in the ExB flow (see CoG) are detected, ending up in the LCO phase, where the $m=2$ mode vanishes

These observations suggest the existence of an **interplay between the MHD mode and ExB flow as a precursor for the LCO onset** and therefore for the transition to H-mode

Conclusions

- The relation between the turbulence level and the ExB flow shows LCO with different temporal ordering depending on the radial propagation direction of the turbulence-flow front. LCO propagating inwards results in a CW LCO, as in the standard predator-prey model. LCO propagating outwards results in a CCW LCO. However, if the ExB flow shear is considered instead of just the ExB flow, the CW temporal ordering is recovered
- A pronounced increase in the amplitude of the MHD mode linked to the $m=2/n=3$ rational surface together with a modulation in the ExB flow are observed several milliseconds before the LCO onset. The results point to the interplay between the MHD mode and the ExB flow as a precursor for the LCO onset.