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Origin of the nonlinear destabilization of the double tearing mode and mechanisms

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Reconnection phenomena are ubiquitous and present a great challenge for fusion plasmas, as the generation of magnetic islands can worsen the transport inside the magnetic device, and for solar plasmas, as the generation and the eruption of solar flares can be critical for human life. Recently, we have investigated the dynamics of the double tearing mode (DTM) [1], an important current-driven instability that appear in advanced scenarios of tokamak plasmas [2] and that was considered as a possible mechanism for the trigger of solar flares [3]. In the intermediate regime, the DTM presents different regimes: a linear stage followed by a nonlinear slow-down, and finally an explosive growth of kinetic and magnetic energies.

To understand the trigger mechanisms leading to the final abrupt growth and subsequent collapse, we conduct a secondary instability analysis by solving the reduced MHD equations for the flux and the flow with an equilibrium containing deformed magnetic islands on each of the tearing layers. We show that there exists a critical size of the magnetic islands for which the nonlinear stage does not saturate but instead, a modulational-like instability is triggered, leading to the sudden growth of potential flows. A look at the energy transfers reveals that some energy is transfered from low modes (m=1) of the magnetic flux and abruptly evolving flows, nonlinearly generating a strong zonal field component that modifies the equilibrium current profile. A linear stability analysis shows that the resulting corrugated profile can destabilize new current-driven instabilities.

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Magnetic reconnection triggered by structure driven nonlinear instability and its application in understanding fusion and astrophysics plasma events

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It has been widely recognized that besides linear free energy source, which is usually well defined as one-dimensional equilibrium profiles of current, flow, pressure, nonlinear free energy source plays an important role in understanding various prominent plasma dynamics. For instance, in fusion plasmas, zonal flows, which exhibit large scale laminar type structures, are generated from micro-scale turbulence and give significant an influence on the maternal turbulence and related transport dynamics. Zonal fields are the large scale magnetic field counterpart generated from different scale fluctuations and also regulate the dynamics. Modulational process among such different scale fluctuations has been considered as the plausible generation mechanism [1].

Here, we extended such an idea in explaining the nonlinear destabilization process of the double tearing modes (DTMs), previously referred to as *structure driven nonlinear instability* leading to sudden explosive growth and subsequent full magnetic reconnection [2]. The DTMs, which are one of resistive modes and induced by two current layers, has received considerable attentions in magnetically confined fusion plasmas as well as space and astrophysics plasmas [3] owing to its violent dynamics.

Based on the simulation of two field reduced MHD equation and the detailed theoretical and numerical analyses, we found that modulation like secondary and also tertiary instabilities, but which are different types from those of the conventional above zonal modes, are successively triggered and lead to full magnetic reconnection and sudden explosive collapse with fast time scale [4]. This approach offers new insights in understanding complex nonlinear magnetic reconnection events and related phenomena.

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