Measurement and Simulation of Fast Ion Phase-space Flow Driven by Alfvén Instabilities

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Fast ion phase-space flow, driven by Alfvén Eigenmodes (AEs) is measured by an imaging neutral particle analyzer [1, 2] for the first time. Important features predicted by the MEGA code [3] are observed. The flow appears near the minimum safety factor of R~2.0 m at the injection energy (~82kV) of deuterium neutral beams, and then moves radially inward and outward by gaining and losing energy, respectively. The flow trajectories in phase space align with the constant magnetic moment surfaces and constant $E - (\omega/n)P_\zeta$ surfaces, where E, P_ζ are energy and toroidal canonical momentum of ions; ω and n are angular frequencies and toroidal mode numbers of AEs. It is found that the flow is so destructive that the thermalization of fast ions is no longer observed in regions of strong interaction. That is, with increasing AE amplitude by adding beam power, the fast ion profile is stiff and Te increase is not observed. Calculations of the relatively narrow phase-space islands by ASCOT5 code [4] reveal that fast ions must transition between different flow trajectories to experience large-scale phase-space transport. Understanding of the phase-space migration paths has important implications on the mitigation and control of fast ion loss in nuclear fusion devices.

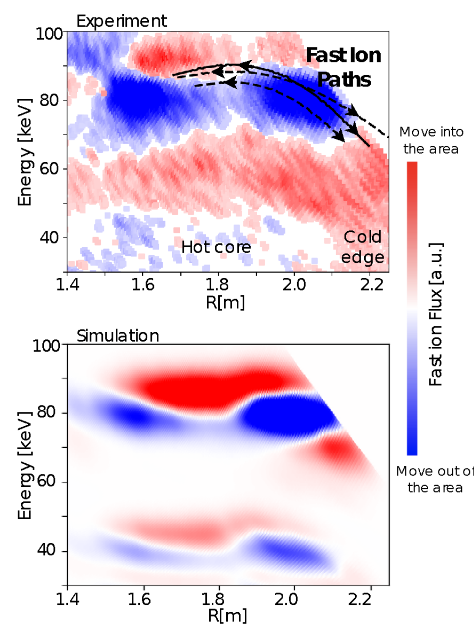

Fig 1: (a) The measured fast ion, velocity-space flow images by the imaging neutral particle analyzer. The blue color stands for the source of the flow and the red region is the destination of the flow, along with the reconstructed flow trajectories associated with the Alfvén waves (lines). (b) The simulated phase space flow images using MEGA code.

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