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Impurity Mode Induced Turbulent Transport of Impurity Ions with Hollow Density Profiles and its Temperature Screening Effect in Toroidal Plasmas

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Abstract

Turbulent transport of impurity ions with steady-state or transient-phase hollow density profiles (HDPs)[1,2], which are widely observed in magnetically confined plasmas and desirable for fusion reactor, is self-consistently investigated. A full gyrokinetic description is employed for main and impurity ions. Instead of conventional ion temperature gradient (ITG[3], including impurity ITG) and trapped electron modes (TEMs), impurity modes (IMs), driven by impurity ion density gradient opposite to that of electrons[4,5], are considered. The impurity ion flux induced by IMs is shown to be approximately one order of magnitude higher than that induced by TEMs when both kinds of modes coexist. Main ITG and electron temperature gradient (ETG) are found to reduce influx of impurity ions significantly, resembling temperature screening effect of neoclassical transport of impurity ions. The simulation results such as peaking factor of the HDPs and the effects of main ITG are found in coincidence with the evidence observed in argon injection experiment on HL-2A tokamak[6]. Thus, the IM turbulence is demonstrated to be a plausible mechanism for the transport of impurity ions with HDPs. A strong main ITG, ETG, and a low electron density gradient are expected to be beneficial for sustainment of HDPs of impurity ions and reduction of impurity accumulation in core plasma[7].

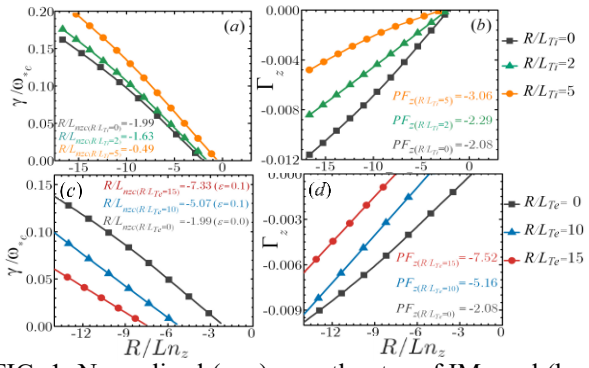

FIG. 1: Normalized (a, c) growth rates of IMs and (b, d) IMs induced impurity influxes versus R/L_{nz} with R/L_{Te}=0 (black squares), R/L_{Te}=10 (blue triangles), and R/L_{Te}=15 (red circles), R/L_{Ti}=0 (black squares), R/L_{Ti}=2 (green triangles), and R/L_{Ti}=5 (orange circles).

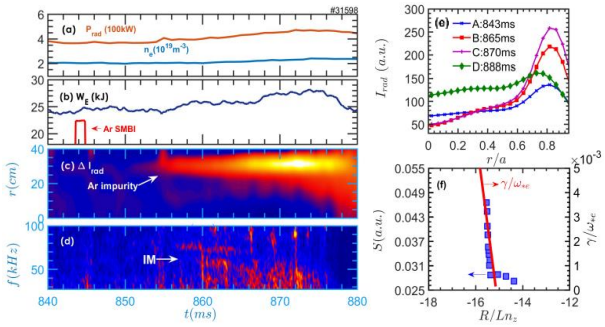

FIG. 2. Temporal evolution of (a) total radiated power (orange line) and line averaged electron density (blue line), (b) stored energy and argon injection pulse, (c) change of radiation intensity after argon SMBI, (d) coherence spectrum of density and electromagnetic fluctuations, radial profile of radiation intensity (e) at t=843,865,870,875,888ms, and (f) the integrated IM turbulence intensity compare with simulation results.

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