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Effects of light impurities on the zonal flow structure

Janghoon Seo, H. Jhang, J.M. Kwon
Korea Institute of Fusion Energy
e-mail (speaker): seojh@kfe.re.kr

The zonal flow structure driven by the ITG (ion temperature gradient) mode in the presence of light impurities is investigated numerically with the gKPSP code [1] which is a nonlinear global delta-f gyrokinetic code. The effects of impurities on the ion heat transport are also presented. For this study, a simplified Poisson solver model for the plasma with impurities is developed. In developing this solver, Pade approximation and the small wavenumber assumption are used. From several benchmark tests for the linear ITG growth rate and residual zonal flow level, the newly developed solver shows a good agreement with the other codes and theoretical predictions. [2, 3] For simplicity, the adiabatic electron model is used and the collision is not included.

It has been known that the impurity can change the linear stability of ITG via the impurity density gradient [4] or the dilution effects. To isolate the nonlinear effect from those linear effects, a specified impurity density profile in which linear growth rates of pure and impure cases are almost identical is used as shown in Fig. 1.

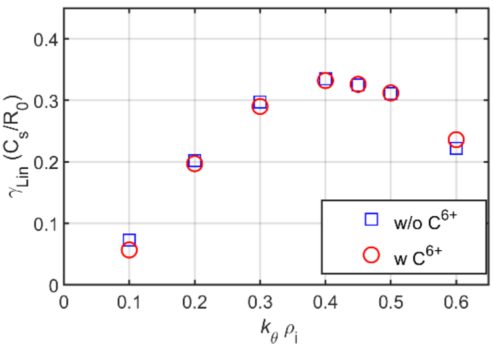

Figure. 1. Linear growth rates of ITG as functions of poloidal wavenumber k_θ multiplied by an ion gyroradius ρ_i . Blue squares represent pure cases and red circles stand for admixed cases with carbon impurities. The safety factor q is 1.4.

With the intermediate safety factor (q~1.4) case, the radially averaged ion heat flux for both of pure and impure cases is shown in Fig. 2.

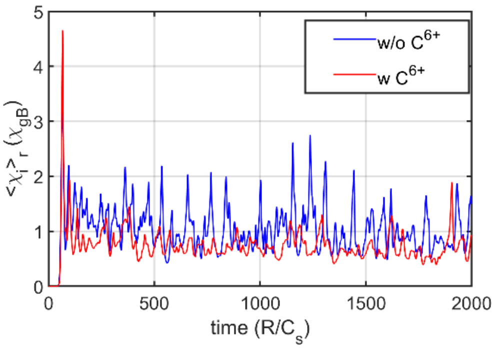

Figure. 2. The time history of radially averaged heat flux from nonlinear ITG simulations. Blue line shows the pure case result, while red line represents the impure case results.

In Fig.2, the impure case with carbon impurities show the significantly reduced thermal transport, compared to the pure deuterium case. This improvement of confinement with impurities is shown to be closely related to the enhanced staircase structures in the zonal flow patterns, which are shown in Fig. 3.

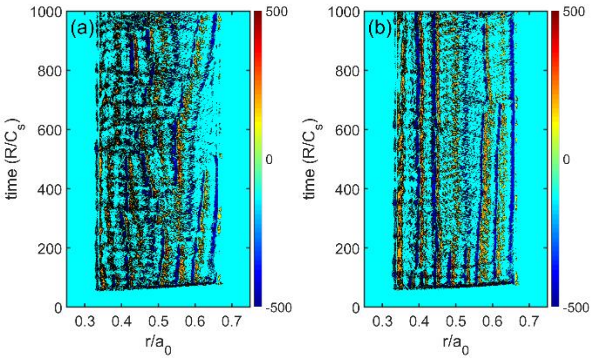

Figure. 3. Radial E_r shear pattern for (a) pure case and (b) nonlinear case. The safety factor q is 1.4.

The strengthened stationary zonal flow leads to the shortened radial correlation length of fluctuations, which is the main cause of the transport reduction. On the other hand, for the high safety factor (q~5.0) case, the effect of impurities on the staircase structure is weakened and the zonal flow is mainly dominated by the GAM (geodesic acoustic mode) activities.

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