Coupling experimental and computational studies of the isotope effect in turbulent particle transport

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The interaction between geodesic acoustic modes (GAMs) and drift-wave turbulence has been an important area of experimental and theoretical research on anomalous transport in toroidal plasmas during the last decade. GAMs are excited in plasma due to nonlinear three-wave interaction of drift waves and can, in turn, influence the turbulent fluctuations and anomalous transport. Dependence of the GAM excitation level and, more generally, long-range correlations on ion mass could be responsible [1, 2] for the still unresolved isotope effect in tokamak anomalous transport [3].

The talk presents results from both experimental and computational investigations of the isotope effect in multi-scale anomalous transport phenomena. Comparable hydrogen and deuterium discharges in the FT-2 tokamak are studied experimentally utilising highly localized turbulence diagnostics and theoretically in the framework of global gyrokinetic modeling [4].

Both approaches show an increase in amplitude, radial wavelength and radial correlation length of the GAM in the deuterium discharge compared to the corresponding hydrogen plasma in a wide radial region, resulting in stronger modulation of drift-wave turbulence level. The simulations also show more pronounced modulations of particle and energy fluxes as well as of MHD particle flux at the GAM frequency for the deuterium discharge [5].

In experiments, larger radial correlation length for turbulent fluctuations and, most importantly, evidence of improved particle confinement is found at the LFS of the deuterium discharge. Even though the gyrokinetic computations produce similar levels of high frequency fluctuations in density and electric field for both deuterium and hydrogen, the mean particle and energy fluxes are also systematically lower for the simulated deuterium plasma. This contradiction can be explained by the relative phase of density and electric field drift-wave fluctuations, as it is closer to $\pi/2$ for the heavier isotope.

The obtained experimental and computational results possess potential for explaining the transport isotope effect in experiments where GAMs are observed in a wide radial domain of a tokamak discharge, like in DIII-D, TCV or T-10. In the case of edge-localised GAMs, as in JET or Globus-M, the discussed mechanisms can lead to growth of the confinement time in deuterium compared to hydrogen. These results also demonstrate the productivity of coupling localised diagnostics and global gyrokinetic modeling in investigating the anomalous transport phenomena.

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[2] A. D. Gurchenko, et al., 25th IAEA Fusion Energy Conference (2014) IAEA-CN-221/EX/11-2Ra.

[3] U. Stroth, 1998 Plasma Phys. Control. Fusion **40** 9.

[4] S. Leerink et al. 2012 *Phys. Rev. Lett.* **109** 165001

[5] A. D. Gurchenko *et al* 2015 *EPL* **110** 55001