The isotope effect in tokamak turbulent transport. Observations and gyrokinetic modeling

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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 for anomalous transport of energy and particles in toroidal plasmas during the last decade. GAMs, which are excited in plasma due to nonlinear three-wave interaction of drift waves, in their turn, can influence the turbulent fluctuations and anomalous transport. Dependence of the GAM excitation level and, more general, long-range correlations on ion mass could be responsible [1, 2] for the isotope effect in tokamak anomalous transport [3] which is still unclear.

The talk presents results of comparative investigation of isotope effect in multi-scale anomalous transport phenomena performed both experimentally utilising highly localized turbulence diagnostics in comparable hydrogen and deuterium FT-2 tokamak discharges and theoretically with the help of global gyrokinetic modeling of these discharges [4]. Substantial excess of the GAM amplitude, radial wavelength and correlation length in a wide spatial region of deuterium discharge resulting in stronger modulation of drift-wave turbulence level is demonstrated by the both approaches [2]. In addition, larger turbulence radial correlation length is found at LFS in D-discharge in experiment and, finally, evidences for better particle confinement is found there. The modulation of GK particles and energy fluxes as well as of MHD particle flux at the GAM frequency [5] is shown by the GK code to be also stronger in deuterium. The GK modeling demonstrated comparable level of high frequency density and electric field fluctuations in hydrogen and deuterium discharges, while the mean values of the ion energy and particle fluxes provided by modeling show a systematic isotope effect at all radii. The isotope effect is also observed in the mean MHD particle flux, which indicates that relative phase of density and electric field fluctuations in deuterium is closer to π/2 than in hydrogen.

The obtained experimental and computational results possess potential for explanation of the transport isotope effect in experiments where GAMs are observed in wide radial domain of tokamak discharge, like in DIII-D, TCV or T-10. In the case of edge localization of GAMs, like in JET or Globus-M, the discussed mechanisms also can lead to growth of the confinement time in deuterium compared to hydrogen. The obtained results demonstrate productivity of comparative investigation of the anomalous transport phenomena in similar hydrogen and deuterium discharges using localized diagnostics and global GK modeling.

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References

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