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Global kinetic effect on the collisionality dependence of the neoclassical toroidal viscosity in the superbanana-plateau regime

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The neoclassical toroidal viscosity (NTV) caused by a non-axisymmetric magnetic field perturbation is one of the key issues for the prediction and control of the plasma performance and/or stabilities, since it can play an important role in a momentum balance which determines a plasma rotation. However, there remains a severe discrepancy with regard to the NTV prediction; the so-called superbanana-plateau theory based on a simplified bounce-averaged model predicts collisionality-independent, or the resonant NTV [K. C. Shaing et al., Plasma Phys. Control Fusion 51, 035009 (2009)], while a global drift-kinetic simulation by FORTEC-3D [S. Satake et al., Phys. Rev. Lett. 107, 055001 (2011)] shows a collisionality dependency of the NTV.

In this study, we investigate the cause of the discrepancy using two different types of global kinetic simulations; one is FORTEC-3D which is based on drift kinetic equation and solves it using the delta-f Monte Carlo approach, and the other is GT5D which solves the gyrokinetic equation based on the Eulerian full-f approach. We demonstrate that the two global kinetic simulations reproduce similar collisionality dependencies of the NTV over wide ranges of the collisionality, indicating that the collisionality dependency of the NTV is common in the global kinetic simulations. It is found that a theoretically predicted resonant structure in the velocity space, which generates the collisionality-independent NTV in the superbanana-plateau theory, vanishes in the global kinetic simulations. The following two mechanisms are discussed as possible causes for the loss of the resonant structure, which may lead to the non-resonant and collisionality dependent NTV: 1) the magnetic shear dependency of the toroidal precession drift frequency, and 2) trapping/detrapping processes of perturbed particle orbits.

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