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Ion intrinsic rotation in a tokamak caused by momentum transport due to diamagnetic flow effects

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Ion toroidal angular momentum is redistributed in a tokamak by turbulence, and the momentum redistribution determines the radial profile of rotation. The momentum transport due to diamagnetic flow effects is an important piece of the radial momentum transport for sub-sonic rotation (Mach $\sim$ 0.1-0.2), which is often observed in experiments. In a non-rotating state, the diamagnetic flow and the ExB flow must cancel. The diamagnetic flow and the ExB flow have different effects on the turbulent momentum flux, and therefore induce intrinsic rotation. This momentum flux is evaluated using gyrokinetic equations that are higher order in poloidal rhostar, which include the diamagnetic correction to Maxwellian equilibria. To study the momentum transport due to diamagnetic flow effects, three experimental observations of ion rotation are examined. First, we found that a strong pressure gradient at the plasma edge results in a significant inward momentum transport due to the diamagnetic effect, which may explain the observed peaking of rotation in a high confinement mode. Second, a different direction of the momentum transport in terms of collisionality is found, which is qualitatively consistent with the observed reversal of intrinsic rotation by plasma density and current. Last, the dependence of the momentum flux on the current profile is found, and it may explain the rotation change in the presence of lower hybrid current drive, which is different in low current and high current discharges.