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Generation of intrinsic parallel flows from drift turbulence with broken symmetry

G. R. Tynan[1,2], R. Hong[1], J.C. Li[3], S.C. Thakur[1], R. Hajjar[1], P.H. Diamond,[2,3]
[1]Center for Energy Research & Dept. of Mech. and Aerospace Engineering, University of California San Diego, USA,
[2]Center for Fusion Science, Southwest Institute of Physics, Chengdu, CHINA,
[3]Center for Astrophysics and Space Sciences, University of California San Diego, USA
email: gtynan@eng.ucsd.edu

Detailed measurements of intrinsic axial flow parallel to the magnetic field with no momentum input have been carried out in the CSDX linear plasma device and have been compared to theory. The results present a direct demonstration of the causal link from the density gradient to drift-wave turbulence with broken spectral symmetry and subsequent development of the axial mean flow in a cylindrical magnetized plasmas. As the magnetic field strength in the device is raised the time-averaged, or equilibrium, density gradient steepens. This increased density gradient leads to the development of collisional drift wave turbulence as shown in early work [Burin:2005]. The drift wave turbulence generates an azimuthal Reynolds stress that drives the radially sheared azimuthal mean flows as discussed elsewhere [Holland:2006]. Here we show [Hong 2018a, 2018b] that the turbulence also leads to the development of a parallel stress that gives rise to the development of a radially sheared parallel (i.e. intrinsic) flow. The turbulent drive (Reynolds power) for the azimuthal flow is an order of magnitude greater than that for axial flow, suggesting that the turbulence saturation level is set primarily by azimuthal flow shear regulation. Direct energy exchange between axial and azimuthal mean flows is insignificant suggesting that axial flow is parasitic to the turbulence-zonal flow system. A parallel momentum balance analysis shows that the axial flow is driven primarily by the axial turbulent stress generated by that system (Fig. 1). The Reynolds stress arises from the broken symmetry of radial and parallel velocity fluctuations. Analysis of experimental results shows that the non-diffusive, or residual, part of the axial Reynolds stress is driven by the density gradient. This stress is due to a dynamical asymmetry in the drift-wave turbulence arising from a weak seed parallel flow shear generated by a weak parallel electron pressure gradient. The stress then amplifies the seed shear flow, resulting in the observed time-stationary shear flow, consistent with theory [Li:2016, Hajjar:2018]. The results provide insight into a novel mechanism to break drift turbulence symmetry that does not rely upon radial electric field shear or upon magnetic shear effects.

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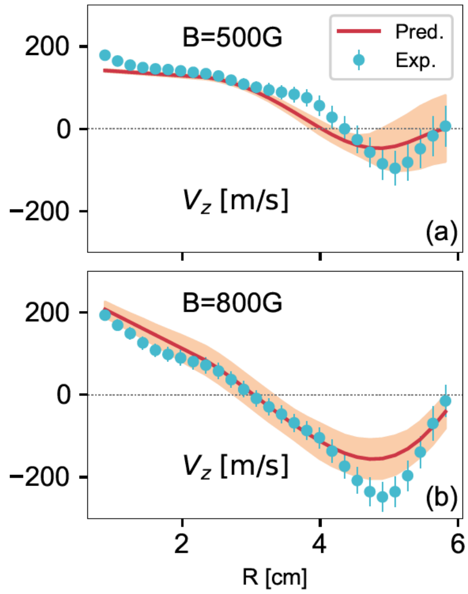

Fig. 1: Measured and predicted parallel flow profiles for (a) 500 G and (b) 800 G Argon discharges. A parallel momentum balance carried out using the measured parallel Reynolds stress, axial pressure gradient and flow dissipation leads to the development of a radially sheared parallel main ion flow consistent with experiments. See e.g. Hong:2018a, 2018b.

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