Convective transport by filamentary structures in scrape-off layer plasmas

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High levels of turbulence and anomalous transport are ubiquitous in the boundary region of magnetically confined plasmas, experimentally observed in virtually all magnetic geometries and confinement regimes. Recent measurements indicate that the radial transport is caused by convective motions of filamentary structures which are elongated along the magnetic field lines and appear as blobs when viewed across the field lines. Such fast transient transport events seem to be what underlies the commonly observed large relative fluctuation levels, broad particle density profiles, and strong plasma–main chamber wall interactions. In this contribution we present new theoretical and experimental results revealing the important role of convective transport by localized structures, and explore its dependence with plasma parameters. We will conclude that turbulent interchange motions are the origin of the anomalous cross-field transport.

Using a two-field fluid model for interchange motions driven by the non-uniform magnetic field, it is demonstrated that an isolated blob structure can propagate a radial distance many times its initial size. In the collisionless limit, electric currents through sheaths at the divertor targets lead to strong dissipation of the blob structures. However, for collisional scrape-off layer plasmas, the parallel motions are impeded and the role of sheath currents is diminished. As a result, the perpendicular transport can be strongly enhanced. In the absence of sheath dissipation, the model predicts a maximum radial velocity V scaling as $V/C_s \sim (2\ell/R)^{1/2}$, where C_s is the acoustic speed, ℓ is the structure size and R is the magnetic field radius of curvature [1]. Numerical simulations show that the sheath dissipation strongly reduces the radial transport due to localized filaments.

The collisionality dependence of convective transport is supported by electric probe measurements from experiments in Ohmic TCV plasmas. These comprise scans in both line-averaged plasma density and plasma current. Here it will be demonstrated that increasing the plasma collisionality by altering either of these control parameters results in a broadening of the radial plasma particle density profile, increasing the fluctuation level and the radial convective flux to the main chamber walls. Yet the experimental data display a universal radial variation of the statistical moments of the particle and turbulent flux density fluctuations across a broad variation in these parameters, suggesting that radial interchange motions of filamentary structures prevail in all parameter regimes.

We finally present new results from interchange turbulence simulations, which have previously been shown to yield excellent agreement with the radial variation of statistical moments and temporal correlations obtained from probe measurements in high-density TCV plasmas [2].

References

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[2] O. E. Garcia, J. Horacek, R. A. Pitts *et al.* Plasma Phys. Control. Fusion **48**, L1 (2006)