Unified transport scaling laws for plasma blobs and depletions

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In the scrape-off layers of tokamaks field aligned plasma pressure perturbations appear that transport particles and heat radially towards the vessel wall. The transport is driven by the interchange instability induced by the inhomogeneity of the confining magnetic field. These perturbations are generally called blobs. A similar phenomenon appears in the ionosphere of Earth. There the interchange instability is driven by the gravitational field. On the night side the recombination reduces the plasma density and so-called “bubbles” or depletions appear. These bubbles start to rise and in succession trigger turbulence in higher altitudes. This alters the reflection of radio waves and is known as the equatorial spread-F phenomenon. Thus, our work is relevant for a broad audience.

We present the first universal study of the dynamics of small and large amplitude plasma blobs and depletions. The derived analytical expressions for both acceleration and velocity of these structures unify previous theories valid in limited parameter regimes [1, 2, 3]. Remarkably, we find that the dynamics of blobs and depletions behaves like the one of stones and bubbles immersed in water.

We show how to use mass, energy and entropy invariants of the governing drift-fluid equations to derive our transport scaling laws. Invariants present restrictions on the dynamics of the system. This underlines the basic observation that energetic consistency is an important feature of a model. Our numerical simulations [4, 5] conserve these invariants and excellently confirm our analytical findings over five orders of magnitude.

References