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An Analytical Approach to the Turbulence-Relaxed State in Tokamak Plasmas

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Abstract: Starting from the continuity, temperature, and motion equations of the trapped electron fluid in general tokamak magnetic field with positive or reversed shear and the definition of Lagrangian invariant, $dL/dt\equiv(\partial_t + u\cdot\nabla)L=0$, where u is convective velocity, the trapped electron dynamics is considered in the following two assumptions: (i) the turbulence is low frequency electrostatic, and (ii) L is a functional only of the density n, temperature T, and magnetic field B, and the effect of perturbation potential φ is included in the convective velocity u, i.e., u is a functional of n, T, B, and φ. The Lagrangian invariant hidden in the trapped electron dynamics is strictly found: $L=\ln[(n/B)^{c_1}(T/B^{2/3})^{c_2}]$, where c_1 and c_2 are dimensionless changeable parameters and $c_1\propto c_2$. From this Lagrangian invariant the turbulent particle and electron thermal transport scaling laws are derived: $\langle n\rangle_\psi q(\psi)=$const. and $\langle T^{3/2}\rangle_\psi q(\psi)=$const., which, in the limit of large aspect ratio, reduce to $n(r)q(r)=$const. and $T^{3/2}(r)q(r)=$const., respectively. The latter two scaling laws are compared with existent experimental results, being in good agreement.

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Key words: tokamak, plasma, turbulence, Lagrangian invariant

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