Guiding Center and Gyrokinetic Orbit Theory for Large Electric Field Gradients and Strong Shear Flows*

I. Joseph
Lawrence Livermore National Lab, P.O. Box 808, Livermore, CA 94551, USA

It is important to understand the physics of edge transport barriers, yet the steep gradient region of the pedestal and scrape-off layer (SOL) of a tokamak can begin challenge the validity of standard guiding center and gyrokinetic theory. A gradient in the electric field directly modifies the oscillation frequency and causes the Larmor orbits to deform from circular to elliptical trajectories. In order to retain a good adiabatic invariant, there can only be strong dependence on a single coordinate at lowest order, so that resonances do not generate chaotic motion that destroys the invariant. When the gradient across magnetic flux surfaces is dominant, the guiding center drift velocity becomes anisotropic in response to external forces and additional curvature drifts must be included. The electric polarization density remains gyrotropic, but both the polarization and magnetization are modified by the change in gyrofrequency. The theory can be applied to shear flows that are even stronger than those observed in the edge transport barrier of a high-performance tokamak (H-mode) pedestal, even if the toroidal field is as small as or even smaller than the poloidal field. Yet, the theory retains a mathematical form that is similar to the standard case and can readily be implemented within existing simulation tools.

*Work for LLNL-ABS-780100 performed for US DOE under Contract DE-AC52-07NA27344.

[1] I. Joseph, Physics of Plasmas **28**, 042102 (2021); https://doi.org/10.1063/5.0037889