Numerical methods for the gyrokinetic model

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Many problems in magnetic fusions plasmas require the use of a kinetic model, in particular the development and saturation of micro-turbulence generated by several instabilities. The kinetic Vlasov equation is posed in a six-dimensional phase space and the resolution of very small time and spatial scales is required, making a direct solution almost inaccessible with today's super-computers. However, due to the large magnetic field, the usual Vlasov kinetic model can be reduced to the so-called gyrokinetic model which is posed in a five-dimensional phase-space only and where the fastest time scale corresponding to the helical motion of particles around the magnetic field lines is removed. Moreover the presence of the magnetic field induces a large anisotropy of the transport along and across the magnetic field lines. This has the effect that the particle density has very small structures across the magnetic field lines and very large smooth structures along the magnetic field lines. Using this feature in the numerics enables again a considerable reduction of computing time.

The lecture will review the main numerical method for solving the gyrokinetic equation and how they make use of the specificity of magnetic fusion plasmas to be more efficient. These include the Particle-In-Cell (PIC) method tracking macro-particles representing the plasma, Eulerian methods (Spectral, Finite Differences, Finite Volumes, ..) solving the gyrokinetic equations on a phase space grid, and the intermediate semi-Lagrangian.