Many-particle approach to the gyrokinetic theory

A. Mishchenko[1] and A. Könies[1]

[1] *Max-Planck-Institut für Plasmaphysik, EURATOM-Association, D-17491 Greifswald, Germany*

The gyrokinetic theory is a basic framework to describe microinstabilities, turbulence, and resultant anomalous transport observed in magnetically confined plasmas. Basic equations for the gyrokinetic theory are the gyrokinetic Vlasov equation and the equations for the electromagnetic self-consistent fields. Operating with the self-consistent field, the gyrokinetic theory is, in fact, a many-particle theory. However, the conventional derivation scheme Refs. [1] based on the Lie transform, considers rather a one-particle motion of the guiding center in a gyro-dependent self-consistent field. Formulated on the basis of the rigorous theory of the guiding center one-particle motion Ref. [2], the gyrokinetic theory remains semi-phenomenological in the treatment of many-particle effects.

We have developed a systematic first-principle approach to the many-particle formulation of the gyrokinetic theory (see Ref. [3]). Starting with a system of N charged particles in a strong external magnetic field and using the Lie transform technique (see Ref. [4]), we have separated the fast gyro-motion from the dynamics of the system in a way which is analogous to the conventional derivation of the one-particle gyrokinetic theory. The many-particle Hamiltonian function resulting from the Lie transform is used to derive the generalized gyrokinetic equation with the collision term in accordance with the well-established Born-Bogoliubov-Green-Kirkwood-Yvon (BBGKY) methodology. Finally, the microscopic expression for the self-consistent potential and the polarization density is obtained. It is shown that new terms appear in the gyrokinetic polarization which can not be derived in the conventional approach. An expression for the collision term is obtained in the Landau approximation.

References

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