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Bayesian Derivation of Plasma Equilibrium Distribution Function for Tokamak Scenarios

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A parametric distribution function has been proposed as equilibrium distribution function (EDF) for charged particles in fusion plasmas, representing, e. g. , supra-thermal particle distribution produced by additional external heating sources in tokamak experiments.
This EDF describes an equilibrium because it exclusively depends on constants of motion (COMs). Assuming an axisymmetric system with no equilibrium electric field, the EDF depends on the toroidal canonical momentum P_phi, the kinetic energy w and the generalized pitch angle lambda=mu/w where mu is the magnetic moment. For a given equilibrium magnetic field these COMs are suitably expressed in guiding center (GC) coordinates. COMs are useful variables for describing and classifying GC orbits, as shown in this work for the general case.
It is shown that, by varying the EDF control parameters, it can represent anisotropic equilibria for Neutral Beam Injection, Ion Cyclotron and Electron Cyclotron Resonance Heating scenarios. Moreover it can also represent isotropic equilibria for Slowing-Down alpha particles and core thermal plasma populations.
The purpose of the work is to present the derivation of the EDF from first principles and general hypothesis.
The present derivation is probabilistic and makes use of the Bayes Theorem.
The joint probability to find a GC in a specific state is obtained from Bayesian inference. The posterior probability density function (pdf) is proportional to the product of the prior pdf (e. g. the population described by a Maxwellian) multiplied by the conditional pdf which is the product of Birnbaum-Saunders pdf, concerning the magnetic moment, multiplied by a Gaussian pdf, describing the GC velocity.
The bayesian argument, used in the present derivation, allows us to describe how far from the prior pdf (e.g. Maxwellian) the plasma is, based on the information obtained from magnetic moment and GC velocity pdf.

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