Non-equilibrium statistical mechanics tool for the study of space plasma; The Ehrenfest procedure in Earth's radiation belts and Superstatistics in magnetized plasma.

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An interesting problem in plasma physics, when approached from the point of view of non-equilibrium Statistical Mechanics, is to obtain properties of collisionless plasmas, through the Vlasov Equation[1]. From Classical and Statistical Mechanics, this equation corresponds to a fluid version of the Liouville theorem for the phase space density, when the Hamiltonian describes electromagnetic interactions and the effect of Coulomb collisions can be neglected. Even though the Vlasov Equation is a well-known theoretical approach in plasma physics, the obtention of solutions is a very difficult task, usually addressed using perturbative methods. In this work we present two ways of approaching the problem. First, from the point of view of obtaining macroscopic properties of the system. Through theoretical analysis and numerical calculations we show that starting from the Vlasov equation, and using a classical analog of Ehrenfest theorem[2,3], it is possible to derive relations for the expectation values of time-dependent observables[4]. For this case, considering charged particles trapped in a magnetic field dipole, the three adiabatic invariants are studied indirectly. Considering expression for pitch angle, average radius and magnetic moment we found dynamical equations that we contrast using test-particle simulations. Second, considering the origin of empirical distributions in modeling space plasma phenomena is not a settled issue, we also approach the problem from a microscopic point of view. We start from a linear approximation of the Vlasov Equation, and apply Superstatistics considerations to explore its scope and possible interpretation on dispersion relations for a magnetized plasma, extending Ourabah's previous analysis on electrostatic plasma waves[5].

References

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