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Statistical Mechanics of Collisionless System

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It is generally believed that the dynamics of collisionless systems is well described by the Vlasov equation, which successfully applied to a wide variety of collisionless kinetics. However, the basic statistical mechanics for a Vlasov system is still yet to be established to this date. This is mainly due to the lack of a collision term in the Vlasov equation; collisions are blieve to play the essential roles in the relaxation process in ordinary gases.

The first attempt of the statistical theory for a Vlasov system has been made by Lynden-Bell[1] in the field of stellar dynamics, to explain the distribution of starts in a galaxy. He emphasized the importance of the phase space volume conservation and constracted a statistical theory based on it. The resulting equilibrium distribution becomes a supersosition of Fermi-Dirac distributions with velocity dispersion inversely proposional to the initial phase space density. This result has inconsistency as Lynden-Bell himself admitted at the end of the paper. There have been several attempts to improve it[2], however, they are not sufficient in the author's opinion (see Nakamura[3]).

In the present study the author proposes a more refined statistical theory of a Vlasov system, mainly with its applications to collisionless plasmas in mind. The theory is based on the "maximum entropy principle" proposed by Jaynes[4], which is now well accepted as one of the methodrogies to establish statistical mechanics. Though the author would not say this is the ultimate version of the collisionless statistical mechanics, the defects of the previous theories are greatly improved. The resulting equilibirum is a single Maxwellian distribution generally found in actual collisionless plasmas.

Keywords: Vlasov Equation; Statistical Mechanics; Maximum Entropy Principle.

References

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