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Leopoldo S. García-Colín
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The Kinetic Theory of a Dilute Ionized Plasma

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Contents

Introduction

The contents of this book are the result of work performed in the past three years to provide some answers to questions raised by several colleagues working in astrophysics. Examining several transport processes in plasmas related to dissipative effects in phenomena such as cooling flows, propagation of sound waves, thermal conduction in the presence of magnetic fields, angular momentum transfer in accretion disks, among many, one finds a rather common pattern. Indeed when values for transport coefficients are required the overwhelming majority of authors refer to the classical results obtained by L. Spitzer and S. Braginski over forty years ago. Further, it is also often mentioned that under the prescribed working conditions the values of such coefficients are usually insufficient to provide agreement with observations.

The methodology followed by these authors is based upon Landau's pioneering idea that collisions in plasmas may be substantially accounted for when viewed as a diffusive process. Consequently the ensuing basic kinetic equation is the Fokker-Planck version of Boltzmann's equation as essentially proposed by Landau himself nearly 70 years ago. Curiously enough the magnificent work of the late R. Balescu in both Classical and Non-Classical transport in plasmas published in 1988 and also based on the Fokker-Planck equation is hardly known in the astrophysical audience. The previous work of Spitzer and Braginski is analyzed with much more rigorous vision in his two books on the subject.

With this background in hand the question that came to our minds is why, if true, the full Boltzmann's equation had never been used in dealing at least with the kinetic theory of dilute plasmas. In their well known and comprehensive treatment on the kinetic theory of non-uniform gases, Chapman and Cowling never developed the theory as they did with ordinary gases. A further attempt was made in 1960 by W. Marshall in three unpublished reports issued by the Harwell Atomic Energy Establishment in

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Harwell, England. And also, none of all the authors in this field with the sole exception of Balescu who did it partially, took the kinetic equation of their choice to provide the microscopic basis of linear irreversible thermodynamics therefore, providing, among many other results, a microscopic basis of magnetohydrodynamics.

This is the main objective of this book. Starting from the full Boltzmann equation for an inert dilute plasma and using the Hilbert-Chapman-Enskog method to solve the first two approximations in Knudsen's parameter we construct all the transport properties of the system within the framework of linear irreversible thermodynamics. This includes a systematic study of all possible cross effects which except for a few cases dealt with by Balescu, today to our knowledge, have never been mentioned in the literature. The equations of magnetohydrodynamics, including the rather surprising results here obtained for the viscomagnetic effects, for dilute plasmas may be then fully assessed. We expect that this material will thus be useful to graduate students and researchers involved in work with non-confined plasmas specially in astrophysical problems.

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