

Preface

The physics of dense gases and nonideal plasmas, along with the physics of matter with high energy density, form together a growing field. The physics of dense gases is connected with the name of the pioneer Johannes Diderik van der Waals from the Netherlands (Nobel Prize 1910). The foundations for the theory of nonideal plasmas were laid 50 years later by another pioneer from the Netherlands, Peter Debye (Nobel Prize 1936), with the introduction of the screening concept. So it should be no surprise that the quantum statistics of dense gases also began in the Netherlands with the work of Uhlenbeck and Beth in 1936/1937. Important contributions to the physics of real gases are due to subsequent work by Mayer, Fuchs, Kirkwood, Bogolyubov, Yvon, Born, and Green. This development culminated in the van der Waals Centennial Conference in Amsterdam 1973 and international conferences on statistical physics organized by the IUPAP.

The physics of nonideal plasmas, otherwise known as strongly coupled plasmas, began with the work of Debye and Hückel, Onsager, Falkenhagen, Bjerrum, Eggert, and Saha in the 1920s and culminated in the 1960s. The first conference on “Strongly Coupled Plasmas” was held in 1977 in Orleans la Source, France, and was followed by a series of conferences under this name. A parallel series called “Physics of Nonideal Plasmas” started in 1980 in a village near Rostock, and then continued biennially, with the latest in Almaty, Kazakhstan, in 2015. The physics of extreme states of matter is still in *status nascendi*. The increasing interest in dense gases and plasmas is connected with the fact that more than 99% of the visible Universe is evidently in this state, and a large part of this exists at extremely high energy density. We are only just beginning to explore the world outside the narrow window of the little solid state planet on which we live. In order to understand our place in the Universe, we have to extend research to dense gases and plasmas including exotic states.

In this view, we feel like part of a large international collaboration which includes many researchers, universities, and very big research organizations such as CERN in Geneva, DESY in Hamburg, UNILAC and SIS in Darmstadt, ITEP in Moscow, SPS, LHC, and so on. A second group of big international collaborations like COBE and subsequent projects is concentrating on the study of astrophysical

objects. This is also at present at the forefront of international research. It is based on new possibilities for observing distant objects from satellites and rockets. Many exciting insights have come recently from this field.

However, this book is definitely not about big colliders, telescopes, and space missions. Our aim is to explore the basic physics and in particular the quantum statistical thermodynamics and kinetics of states of matter, starting from dense gases and nonideal plasmas and ending with matter at high energy densities. We are convinced that thermodynamics and quantum statistics are still the main foundation on which even the most advanced research is being built. In spite of the development of so many modern concepts, the seemingly old concepts of thermodynamics and transport are still the basis for the whole field.

The body of the present book is based on lectures at universities and presentations at seminars and international conferences. Furthermore, the book draws upon many original publications and in particular on a long collaboration between the present authors which started in the 1970s. We mention in particular:

- The courses of lectures on quantum statistics and plasma physics given by Werner Ebeling at the University of Rostock between 1970 and 1979, at the University of Paris VI in 1977, at the Humboldt University in Berlin, between 1980 and 2001, and in guest lectures in Minneapolis 1986, Moscow 2003, and Krakow 2005. The latest full lecture cycle was given at Humboldt University in Berlin by Werner Ebeling in collaboration with Thorsten Pöschel and several former coworkers, including Dieter Beule, Andreas Förster, Lutz Molgedey, Jens Ortner, Waldemar Richert, and Ilya Valuev, and several former students and aspirants, including Jörn Dunkel, Hendrik Hache, Stefan Hilbert, Dirk Holste, Ines Leike, Ulf Leonhardt, Burkhard Militzer, Thomas Pohl, Saltanat Sadykova, Friedemann Schautz, Michael Spahn, Mario Steinberg, and others.
- Lecture courses given by Vladimir Fortov at the Moscow Institute of Physics and Technology on extreme states of matter on earth and in the cosmos (Fortov 2008, 2009, 2011).
- Presentations of the present authors at a series of international conferences, such as the IUPAP conferences under the headings “Statistical Physics” (STATPHYS), “Strongly Coupled Coulomb Systems” (SCCS), and “Physics of Nonideal Plasmas” (PNP).
- The long-standing collaboration between the authors and their colleagues in Berlin, Rostock, Moscow, and other research centers around the world, resulting in many shared articles and several shared books since the 1980s.

Following the personal interests of these authors, which go along the same lines in the tradition of quantum statistical thermodynamics in Berlin, Rostock, and Moscow, we concentrate on the development of fundamentals and applications to gases and plasmas, including dense nonideal and exotic gases and plasmas. Most of the existing textbooks and monographs on quantum statistics have some bias toward condensed matter and solid states.

This book is written at an intermediate level and addressed to students and young scientists at an advanced level. We include a few results obtained only recently. In

general, the book should be accessible to students of the higher semesters, doctorands, and young researchers in the field. We have tried to be self-contained, repeating, and explaining the most relevant tools.

During their careers, the present authors, or at least some of them, have actually met several of the pioneers of the quantum statistics of dense gases and plasmas, such as Alexander A. Abrikosov, Nikolay N. Bogolyubov, Alexander S. Davydov, Hans Falkenhagen, Michael Fisher, Vitali L. Ginzburg, Günter Kelbg, Yuri L. Klimontovich, Rolf Landauer, Joel Lebowitz, Joseph E. Mayer, Ruslan L. Stratonovich, Alexander A. Vedenov, Yakov B. Zeldovich, and others. These people influenced our views through their advice and personal discussions, and so we must express our gratitude to them. In particular, we are grateful to Günter Kelbg, Yuri L. Klimontovich, and Yakov B. Zeldovich. Furthermore, we are very grateful for a long and very fruitful collaboration with many colleagues in the field, including David Blaschke (Wroclaw), Michael Bonitz (Kiel), Alexander Chetverikov (Saratov), Dietmar Ebert (Berlin), Viktor A. Gryaznov (Chernogolovka), Holger Fehske (Greifswald), Yuri B. Ivanov (Moscow), Wolf D. Kraeft (Greifswald), Dietrich Kremp (Rostock), Pavel Levashov (Moscow), Genri Norman (Moscow), Gerd Röpke (Rostock), Ronald Redmer (Rostock), Heidi Reinholz (Rostock), Manfred Schlanges (Greifswald), Boris Sharkov (Moscow), Werner Stolzmann (Kiel), Sergey Trigger (Berlin), and Manuel G. Velarde (Madrid). We should also mention that the last two chapters were written in close collaboration with A.S. Larkin, who provided the main contributions to the results. Particularly sincere thanks go to Thorsten Pöschel, who actively participated in the lectures at Humboldt University in Berlin and wrote lecture notes describing the basic tools of quantum statistics, which will appear separately.

In conclusion, let us express the wish that the present book might contribute to the general education of the present generation of physicists in the field of dense fluids. Two of the authors are theoreticians, while the other (V.E.F.) took part in many pioneering experiments in the field, including experiments with extreme pressures generated by shocks or laser beams which helped, e.g., in experimentally confirming plasma phase transitions. V.E.F. has also been in charge of major international research projects and experiments. When running these and other big research projects in our field, we have reached the conclusion that physicists of the younger generation need more knowledge and ability to solve problems involving dense gases, nonideal plasmas, and extreme states of matter. We hope the book will help them to understand the problems and methods of a rather new and fascinating field.

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