Lecture Notes in Physics

U. G. Jørgensen (Ed.)

Molecules in the Stellar Environment

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Preface

The region of a star where the spectrum is formed is called the atmosphere. It consists of the photosphere (where most of the visual and infrared light comes from), the chromosphere (a somewhat hotter layer above the photosphere where, in cool stars, most of the ultraviolet light is produced), and sometimes a corona (the very hot outermost region). Stars with an "average" (effective) temperature in the photosphere of less than around 4000 K are called "cool". The low luminosity cool stars include the M dwarfs, some white dwarfs, and the brown dwarfs. All these are stellar types that often can be as old as the universe, and they can provide us with important and detailed information about things as different as the conditions in the early universe, the unseen mass in the galaxies, and of course stellar structure and evolution itself. The high luminosity cool stars are called red giants. They are often larger than the Earth's orbit around the Sun, and a wind of gas and dust from their uppermost layers can be so strong that the mass of our Sun would be expelled in less than 100,000 years. These stars continuously enrich the interstellar medium with material from the nucleosynthesis deep in their interior. New stars and planets forming from the interstellar clouds are therefore built "of the ashes of the red giants". In fact about half of all the elements that surround us come from this process (2/3 of all the elements heavier than iron, and a few of the lighter and more abundant ones too; the rest of the elements come from supernovae). Nevertheless, there is no theory capable of explaining how the material is blown out of the red giant stars. Part of the wind-material can gather temporarily in shells around the stars. Dense shells of gas and dust around red giants are known as circumstellar envelopes. All these phenomena are collectively referred to in this book as the stellar environment. It has not yet been possible to construct a unified model for this part of a star.

The gas in cool stars is dominated by small molecules (like CO, H_2O, HCN) which slowly grow into bigger molecules (like carbon chains and polyaromatic hydrocarbon rings) and grains (like silicon carbide and graphite dust) in the outflowing gas. A major obstacle to constructing a unified model for the stellar environment in cool stars has been the severe lack of data for the molecular physics and chemistry that prevail at the high temperatures and/or low pressures of the stellar environment. It is the aim of the present book to review the status and knowledge of the theory, observations, and experiments relating to both the astrophysical and the chemical aspects of this problem, and to stimulate work in the area where data and progress are most needed. One problem that any

scientist entering this field will immediately discover is that "the two sides" – the chemistry and the astrophysics – each speak their own language. It is this problem which in the first chapter of the book is described as "the two villages". Each chapter in the book has therefore been aimed at presenting both the basic concepts and the underlying theory, together with the most recent knowledge and progress. This aim is described in the first chapter as creating "a bridge between the villages" – i.e., the ability to pass knowledge from one of the communities to the other.

I am thankful to all the authors for their patience with me when I returned their manuscripts for the n'th time claiming that we need more "stones on the bridge" in order to "make it easy to pass from one of the villages to the other" – i.e., in order to make the concepts from one of the disciplines understandable for scientists and students from the other discipline. It is my hope that the book will be used as such a bridge between molecular chemistry and stellar astrophysics.

The idea of the book (and the IAU Colloquium 146 upon which it is based) arose from discussions between Georges Graner, Mike Seaton, Rainer Wehrse and myself during a fruitful meeting on atomic and molecular opacities in Venezuela in the summer of 1991. The project was well received by the host institutes in Copenhagen (the Niels Bohr Institute and Nordita), and the financial wherewithal was secured by generous support from the International Astronomical Union (on recommendations by commissions 14, 29, and 36), the Danish Natural Science Research Council, the Augustinus Foundation, the Carlsberg Foundation, and Knud Højgaard's Foundation. I gratefully acknowledge this support, as well as the work done by the scientific organizing committee (consisting of Georges Graner, David L. Lambert, Björn O. Roos, Takashi Tsuji, Rainer Wehrse, and myself) and the local organizing committee (consisting of Ben Mottelson, Bernard Pagel, Peter Thejll, and myself). Particular thanks are due to Peter Thejll without whose continuous effort the organization of the conference would have been impossible.

Copenhagen, November 1993 Uffe Gråe Jørgensen

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