

# Preface

About 30 years ago, the Cologne laboratories were founded with a design such that laboratory spectroscopy and appropriate interstellar observations would support each other by supplying new results. From the very early stage, the Terahertz spectroscopy has been one of the most important subjects of the laboratory, but it has remained to be one of the most poorly explored areas of the entire electromagnetic spectrum. It was our dream to have a space observatory, with which we can observe the spectra in Terahertz region without the strong attenuation of the radiation by the Earth's atmosphere.

It is a great pleasure of us to publish this textbook for the students who are learning molecular astrophysics at the occasion when the tremendous amount of new results for the interstellar molecules in the Terahertz region are reported successively from the Herschel space observatory.

In the first chapter of this book, the history from ancient days to now is briefly presented by Gisbert Winnewisser with the editorial help of Koichi M. T. Yamada.

In the second chapter, the molecules observed in the interstellar medium and circumstellar envelopes are reviewed by Karl M. Menten and Friedrich Wyrowski. Quite large number, more than 150, of molecular species have been detected up to today, and thus it is impossible to describe all of those molecules. We have limited ourselves to present only the selected molecules: molecules detected in the early stage, prototypical molecules, and those detected most recently.

The third chapter accounts for the molecular spectroscopy, which is the irreplaceable tool for the astrophysics. The basic theory for the spectroscopy of atoms, diatomic molecules, and polyatomic molecules are briefly presented in [Sects. 3.1–3.3](#); [Sects. 3.1](#) and [3.2](#) are contributions of K. M. T. Yamada, and [3.3](#) of Per Jensen with the appendix by K. M. T. Yamada. Since many text books have been published concerning to the molecular spectroscopy, the descriptions are limited to the very fundamental level.

The number of molecules with internal rotation observed in the interstellar space is increasing steadily. The spectra of such molecules are rather complicated and are of interest not only for astrophysics but also for molecular spectroscopy. [Section 3.4](#) is a contribution of Nobukimi Ohashi, which accounts for the internal

rotation problems with one- and two-methyl tops. Various methods for the energy calculation for such molecules are described in detail. The symmetry labeling of the energy levels are also discussed on the basis of permutation-inversion group. We wish to acknowledge Prof. Kaori Kobayashi's assistance to produce many of the figures in [Sects. 3.4](#).

In the fourth chapter, the most recent progress in the laboratory spectroscopy in Cologne is presented by Thomas F. Giesen, and the development of heterodyne mixers, the essential device for the radio observation, is reviewed by Karl Jacobs.

In the last chapter, the molecules observed in the interstellar space are listed on the basis of the Cologne Database for Molecular Spectroscopy (CDMS).

We would like to thank the Cologne students, post doctoral fellows, and all collaborators, whose enthusiastic and untiring efforts are essential for many of the beautiful results presented in this book. We would like to express special thanks to Helga Winnewisser, who has supported Gisbert mentally and physically during the preparation of this book.

On behalf of the contributors

August, 2010

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Interstellar Molecules

Their Laboratory and Interstellar Habitat

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2011, X, 230 p., Hardcover

ISBN: 978-3-642-16267-1