

Preface

This monograph attempts to provide a systematic and consistent survey of the fundamentals of the theory of free, linear, isentropic oscillations in spherically symmetric, gaseous equilibrium stars, whose structure is affected neither by axial rotation, nor by the tidal action of a companion, nor by a magnetic field.

Three parts can be distinguished. The first part, consisting of Chaps. 1–8, covers the basic concepts and equations, the distinction between spheroidal and toroidal normal modes, the solution of Poisson’s differential equation for the perturbation of the gravitational potential, and Hamilton’s variational principle. The second part, consisting of Chaps. 9–13, is devoted to the possible existence of waves propagating in the radial direction, the origin and classification of normal modes, the completeness of the normal modes, and the relation between the local stability with respect to convection and the global stability of a star. In the third part, Chaps. 14–18 contain asymptotic representations of normal modes. Chapter 19 deals with slow period changes in rapidly evolving pulsating stars.

The theory is developed within the framework of the Newtonian theory of gravitation and the hydrodynamics of compressible fluids. It is described in its present status, with inclusion of open questions.

We give preference to the use of the adjective “isentropic” above that of the adjective “adiabatic”, since, from a thermodynamic point of view, these stellar oscillations are described as reversible adiabatic processes and thus as processes that take place at constant entropy.

The subject requires the use of spherical coordinates, which are a particular type of generalised coordinates. Therefore, we adopt generalised coordinates in several sections and, in association with them, use notions of tensor calculus and Riemannian geometry.

In the chapters devoted to asymptotic representations of oscillation modes of stars, and slow period changes of oscillations in rapidly evolving stars, we apply two-variable expansion procedures and boundary-layer theory. These methods are convenient for perturbation problems involving two highly different length or time scales and thin boundary layers in which terms of differential equations become large because of singularities or vanish because of turning points.

It is our hope that the present comprehensive presentation may fill a gap for doctoral students and researchers who want to get more acquainted with the fundamental aspects of the theory of the linear, isentropic oscillations in spherically

symmetric stars. In order to facilitate their task, we give intermediate steps in the mathematical derivations. Furthermore, we refer to original scientific papers and reviews as much as possible. However, it is beyond the scope of this monograph to present an exhaustive list of all papers and reviews that have been published about the subject.

This monograph has grown from lectures given, and research done, for more than thirty years at the Katholieke Universiteit Leuven. I like to express my deep gratitude to the academic authorities for the possibilities they offered me. I also like to express my sincere thanks to the Belgian National Fund for Scientific Research, and the Flemisch Fund for Scientific Research, and especially its former Secretary general, Mr. José Traest, for their year-long support. Without them, this monograph would never have come about. I take the opportunity to thank my former students and collaborators for their interest. From their questions and feedback, I have learnt a lot.

I am heavily indebted to my colleague Dr. Christoffel Waelkens, Head of the Institute of Astronomy, for having allowed me to continue to use the facilities of the institute after my retirement, and for the enthusiasm he has continually manifested for this undertaking.

I am also much indebted to other colleagues. I especially mention my colleague Dr. Johan Quaegebeur of the Department of Mathematics for the precious help he provided in the domain of the functional analysis. My colleagues Dr. Christian Maes of the Department of Physics and Astronomy, Dr. Hans Van Winckel of the Institute of Astronomy, and Dr. Patricia Lampens of the Royal Observatory of Belgium helped me in the redaction and the correction of this and previous versions of the text. I thank them sincerely for their willing assistance.

The text of the monograph, with its mathematical parts, has been typeset, formatted, and composed by the L^AT_EX document preparation system, and the figures have been drawn by means of the WINDOWS version of the Maple VIII language. For this, I benefitted much from competent technical help of my colleague Dr. Lea Vermeire of the Campus Kortrijk of the university.

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Last but not least, my warm and special thanks are due to Dr. Tim Van Hoolst, who has had a very large influence on the final result.

The responsibility for all inaccuracies and errors which may still be found in this monograph rests exclusively with me.

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Theoretical Foundations

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