THE OBSERVATION AND ANALYSIS OF STELLAR PHOTOSPHERES

Most of what we know about stars is learned from studying the light from their photospheres. *The Observation and Analysis of Stellar Photospheres* describes the equipment, observational techniques, and analysis used in the investigation of stellar photospheres. This third edition builds on the success of the previous editions, improving the presentation, and revising topics and results to keep up-to-date with the latest research. Exercises have been added for each chapter.

The first half of the book develops the tools of analysis and the second half demonstrates how they can be applied. Topics covered include radiation transfer, models of stellar photospheres, spectroscopic equipment, how to observe stellar spectra, and techniques for measuring stellar temperatures, radii, surface gravities, chemical composition, velocity fields, and rotation rates. Up-to-date results for real stars are included. Useful data can be found throughout the text and in the appendices, and there are extensive references to the primary literature.

This textbook is for advanced undergraduate and graduate students studying stellar atmospheres or stellar physics. It presents introductory material from the basics and develops it to a professional level. It is ideal for use on university courses, and also includes a wealth of reference material useful to research scientists.

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Professor Gray has published numerous papers in journals including *The Astrophysical Journal*, *Publications of the Astronomical Society of the Pacific*, *The Astronomical Journal*, *Nature*, and *Solar Physics*. He has written or contributed chapters to several books, and previous editions of this book have been used widely, including translations into Russian and Chinese. He has also edited three volumes of conference proceedings for the IAU. He is a member of the Canadian Astronomical Society, the International Astronomical Union, the Astronomical Society of the Pacific, Sigma Xi Honorary Society, and the American Astronomical Society.

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Preface to the first edition

The remarkable nature of stars is transmitted to us by the light they send. The light escapes from the outer layers of the star – called, by definition, the atmosphere. The complete atmosphere of a star can be viewed comprehensively as a transition from the stellar interior to the interstellar medium. And yet almost the whole visible stellar spectrum comes from a relatively thin part called the photosphere. Obviously we cannot disconnect the photosphere from the adjacent portions of the atmosphere, but in actual fact it is the only region we can study extensively for most stars. It is for this reason that the photosphere has taken its place as the central theme of this book.

Several books have appeared during the last decade dealing with the *theory* of stellar atmospheres. These works are for the most part excellent. It is to the material largely omitted by these books that the present treatise is directed. My students and I have felt for some time the need of a book that presents the basics of the field through the eyes of an observer and analyzer of stellar atmospheres.

An introduction to a subject, in my opinion, should be presented in a way that can be understood by a reader who has not studied the topic before. It follows that the material should be presented in as simple and straightforward a manner as possible. The Fourier transform (as covered in Chapter 2) is a unifying theme helping to accomplish this aim. Transforms lead naturally into the material on data collection, optical instruments, the instrumental profile, line absorption coefficients, velocity fields, and spectral line analysis. In addition, I have selected and developed topics that I consider to be important to those of us who look at stars and attempt to understand what we see. At the same time, I have tried to present the material in the least complicated manner. The word "complicated" is affixed to things that are difficult to understand. Complicated things consequently are often unsuitable topics for the novice. We should seek not the most general case conceivable, but the least complicated case that is serviceable (a version of the principle of minimum assumption).

The development of each of the main topics starts at an elementary level, proceeds with a discussion of the topic, and ends by pointing the direction to the more advanced literature. It should be easy to expand from this book into the areas holding an attraction for you. Realizing that astrophysics is a very dynamic field, I have documented (or otherwise made clear) the source of the material used in examples. When no source is indicated, the material is from observations or calculations of my own. The references in general have been selected because they are good illustrations of the material being discussed or because they have a basic lasting approach to the subject. I have also biased the referencing toward good starting points in the literature and toward review articles and journals to which the student is likely to have access. The references are listed at the end of each chapter and ordered according the author's name and date of publication.

The first two chapters contain preparatory material. The main theme starts in Chapter 3 with a discussion of spectroscopic tools. Generally the continuous spectrum topics are developed first, followed by the somewhat more involved subject of the line spectrum. From Chapter 14 (Chemical analysis) through to Chapter 18, the material is oriented completely toward analysis and deduction. These later chapters are closely interlinked with the preceding chapters.

The book is suitable as a text for a one-year course and as a reference to the more advanced reader.

Preface to the second edition

Wonderful growth has occurred in our understanding of stellar photospheres during the 15 years since the appearance of the first edition of "Photospheres." I have managed to retain the same chapter names and the general plan of the first edition, and many of the equation numbers are also the same. But a significant portion of the material is new or revised. A revolution in light detectors has given us hundreds of times greater efficiency in measuring stellar spectra; Chapter 4 on detectors has been re-done. The astronomical literature is burgeoning with new results on the structure of photospheres, chemical abundances, radius measurements, stellar rotation, and photospheric velocity fields. Many of these results have been incorporated in this second edition, of course. At the same time, I stayed with my original purpose of making this volume an introduction to the subject. Unhappily, this means leaving out numerous exciting topics. My book *Lectures* (Gray 1988) takes up some of these, and it is recommended as a second installment, after the material in "Photospheres" has been mastered.

More than ever, the reader should keep in mind the fundamental nature of the stellar photosphere: of interest in its own right, with marvelous and intriguing physics, yet the link between the interior and chromospheres, coronae, and interstellar surroundings, and the source of most of our basic information about stars and stellar systems.

Once again, I thank my students and colleagues for their help and patience.

Reference

Gray, D. F. 1988. *Lectures on Spectral-Line Analysis: F, G, and K Stars* (Arva, Ontario: The Publisher).

Preface to the third edition

Studies of stars continue to flourish. More detailed and sophisticated observations continue to be made, analysis tools are honed, understanding grows for more complex situations. The beauty of the stars is integrated more fully into our lives. I hope you enjoy the many revisions incorporated in this third edition of *Photospheres*: new figures, more complete data sets, re-organization of some of the material, a cleaner presentation of several topics, and some exercises and questions to help you probe the material.

I extend my thanks to J. Power for proofreading and to the many others who have guided my thoughts, given me corrections and suggestions, and contributed their efforts to knowing the stars.