

THE OBSERVATION AND ANALYSIS OF STELLAR PHOTOSPHERES

Fourth Edition

This textbook describes the equipment, observational techniques, and analysis used in the investigation of stellar photospheres. Now in its fourth edition, the text has been thoroughly updated and revised to be more accessible to students. New figures have been added to illustrate key concepts, while diagrams have been redrawn and refreshed throughout. 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. This textbook is for starting graduate students or advanced undergraduates; in addition to its use in university courses, it includes a wealth of reference material useful to researchers.

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David F. Gray

Frontmatter

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Fourth Edition

DAVID F. GRAY

Western University, Ontario, Canada



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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 to 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, reorganization 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.

Preface to the Fourth Edition

Welcome again in this fourth edition to the wonderful world of stars and stellar spectroscopy. As you work your way through this material, you will gain insight into how stars behave and how we deduce their physical characteristics. If you are not careful, you will soon find yourself becoming emotionally attached to stars. And why not? There are many interesting subdisciplines in modern astronomy, but when we gaze into the dark night sky, it is the panorama of *stars* that makes our hearts beat faster.

Twinkle, twinkle on, oh bright little star,
we see your light travelling oh so far.
The light you send us we work to decode,
analyzed and studied in spectroscopic mode.

Your light spread out in a glorious rainbow,
reveals your nature in a wonderful light show.
From continuum on through each spectral line,
send us your secrets about how you do shine.

As we learn more about just what you are,
you're ever more awesome, oh bright little star.
Twinkle, twinkle on in the dark night;
inspire and teach us with your little light.

My heartfelt thanks to the friends and colleagues who have helped, guided, and encouraged me over the years.

You will notice the quaint watermark, “from David F. Gray Stellar Photospheres,” on many of the figures. Should you choose to use figures from the book in talks, lectures, or websites, this watermark will help you remember where the figures came from.

May your journey to understand stars be pleasant and fulfilling.

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