Introduction to Astronomical Photometry, Second Edition

Completely updated, this Second Edition gives a broad review of astronomical photometry to provide an understanding of astrophysics from a data-based perspective. It explains the underlying principles of the instruments used, and the applications and inferences derived from measurements. Each chapter has been fully revised to account for the latest developments, including the use of CCDs.

Highly illustrated, this book provides an overview and historical background of the subject before reviewing the main themes within astronomical photometry. The central chapters focus on the practical design of the instruments and methodology used. The book concludes by discussing specialized topics in stellar astronomy, concentrating on the information that can be derived from the analysis of the light curves of variable stars and close binary systems. This new edition includes numerous bibliographic notes and a glossary of terms. It is ideal for graduate students, academic researchers and advanced amateurs interested in practical and observational astronomy.

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Introduction to Astronomical Photometry

Second Edition

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Preface to first edition

The book which follows has grown out of my experiences in carrying out and teaching optical astronomy. Much of the practical side of this started for me when I was working with Professor M. Kitamura at what is now the National Astronomical Observatory of Japan, Mitaka, Tokyo, in the mid seventies. Having already learned something of the theoretical side of photometric data analysis and interpretation from Professor Z. Kopal in the Astronomy Department of the University of Manchester, when I later returned to that department and was asked to help with its teaching programme I started the notes which have ultimately formed at least part of the present text. I then had the pleasure of continuing with observing at the Kottamia Observatory, beneath the beautiful desert skies of Egypt, in the days of Professor A. Asaad, together with a number of good students, many of whom have since gone on to help found or join university departments of their own in different lands of the world.

In recent years – particularly since moving to Carter Observatory – another dimension has been added to my experience through my encounters with that special feature of the astronomical world: the active amateur! In previous centuries many creative scientists were, in some sense, amateurs, but in the twentieth century the tide, for fundamental research at least, has been very much in the direction of government, or other large organization, supported professionals, no doubt with very persuasive reasons.

Nevertheless, some features of contemporary life suggest that this tide is not necessarily conclusive in its effects. If there is one feature in particular, I would cite the personal computer. The range of possibilities for participation and active investigation which are now available to individuals on their home desk tops is already staggeringly large, and continues to increase, while the real costs of sophisticated electronics fall and demand grows as more people discover these potentialities for themselves.

A particular concept, which may become increasingly significant in the future development of astronomy, is that of the 'PC-observatory'. Much of the more routine side of observational data collection can be put under the control of a personal computer. Automatic photometric telescopes (APTs), of up to half-metre aperture class, have been developed and operated by amateurs in their backyards. Data can be gathered by the tended robot, while the human designer has the freedom to ponder and relax in the way that humans are wont. I have seen this in action right here in Wellington, but do not doubt that at least similar capabilities exist in very many other places.

In the early eighties I started a correspondence with Professor M. Zeilik of the University of New Mexico, who shared my interest in the photometry and analysis of eclipsing binary systems. This later developed into exchange visits, and in the environment of Dr Zeilik's active research and education programme, at Albuquerque and Capilla Peak, I began to appreciate more fully the momentum of the electronics revolution and its impact on optical astronomy and the propagation of information.

Enthusiasm and capabilities are thus already nascent in good measure, and against this background the appearance of a book with entry-point information, guidelines on equipment and methodology, astronomical purposes – general and specific, leading, it is hoped, towards definite new contributions in the field – seems opportune.

Introduction to Astronomical Photometry is then a textbook on astronomical photometry (essentially in the optical domain) intended for university students, research starters, advanced amateurs or others with this special interest. It avoids jumping directly into technical or formally presented information without some preparation. Each chapter is rounded off with a section of bibliographical notes. The book starts with an overview, and moves on through a historical background and glossary of terms. Then comes a chapter on the underlying physical principles of radiative flux measurement. Colour determinations and temperature and luminosity relationships are also examined here. From this base more wide-ranging questions in current astronomical photometry are approached. The central two chapters deal with principles of photometer design, including recent advances, and some common data-handling techniques for system calibration from standard star observation and the generation of light curves. The remainder of the book presents applications of photometry to selected topics of stellar astrophysics. Curve fitting techniques for various kinds of light curve from variable stars, including close binary stars, spotted and pulsating stars, are followed through. Inferences drawn from such investigations are then advanced.

There is a large number of people to whom I feel thankful for helping this book to be realized. Some of them I have mentioned already, but even if I didn't, I am sure the formative influence of Zdeněk Kopal would soon become clear to readers of the subsequent pages. Indeed, many of them were written whilst I shared his welcoming office during my sabbatical leave of 1990. Professor F. D. Kahn was principal host during my stay in Manchester, and his hospitality and that of his department helped make that year very special for me.

That period of leave, which gave me the time to collect things together, was essentially enabled through the generous support of the Carter Observatory Board, and approved by its Director, Dr R. J. Dodd, who also helped with remarks on the text. Useful comments were also provided by Dr J. Dyson (Manchester), Dr J. Hearnshaw (Christchurch) and Mr J. Priestley (Carter Observatory). Interest and encouragement were expressed by Dr M. Zeilik, and his colleagues and students at UNM, Albuquerque, with whom my leave started in 1990, by Drs B. Szeidl and K. Oláh during my August sojourn at the Konkoly Observatory (Budapest), and as well by Drs M. de Groot and C. J. Butler of the Armagh Observatory, where I similarly visited later that year.

Among the many others who I would like to acknowledge, though space unfortunately restricts, Mr T. Hewitt of the Computer Centre at Manchester University, who introduced me to the wonderful world of PCTEX, surely deserves mention. He helped this text materialize in a very real sense. I also thank John Rowcroft and Carolyn Hume for help with the diagrams.

Last, but not least, to my family and wife Patricia – thanks.

Preface to second edition

Some years ago professional colleagues suggested that a new edition of *An Introduction to Astronomical Photometry* could be useful and timely. The decision to act upon this did not come, however, until the warm and conducive summer of 2003, in the stimulative environment of north-west Anatolia, once home to great forefathers of astronomy, such as Anaxagoras and Hipparchos. The former set up his school at the surely appropriately named Lampsakos, just a few miles from where the present authors are working: the latter hailed originally from what is now the Iznik district of neighbouring Bythinia. Eudoxus too, after learning his observational astronomy in Heliopolis, moved back to Mysia to found the institute at Cyzicus (today's Kapu Dagh), while Aristotle's thoughts on the heavens must have also been developing around the time of his sojourn in the Troad, after the death of Plato. In such surroundings it is difficult to resist thinking about the brightness of the stars.

But that was just the beginning. It quickly became clear that the proposed task could not be lightly undertaken. There were at least three main questions to clarify: (1) what branches of modern astronomy can be suitably associated with photometry; (2) what level of explanation can be set against the intention of an introduction; and (3) who could become involved with what aspect of the subject? An approximate size and scope were originally based on the model of the first edition. Improvable aspects of that were known from the start; however, what was not then realized very clearly was just how much development had taken place in astronomical photometry over the last decade or so. This concerns not just the specific headings of the original text, but the growth of a large number of related new topics.

Among the striking new developments has been the increasing size and number of automated telescopes: up to the one metre class and beyond, and also the widening use of computer controlled CCD detectors, together with continued development and application of purpose-oriented filter systems.

Data accumulation has increased tremendously, while millimagnitude precision is regularly achieved in many observatories. The fantastic rise in capacity of modern data processors has allowed huge new surveys to be undertaken, with a consequent pressure for swift and effective analysis procedures based on realistic models.

As always, compromises are entailed; but, in response to such challenges, one entirely new chapter was produced, dealing with the timing of variable star phenomena and the astrophysical implications of such information. As well, four new sections and 14 subsections were added to other chapters of the original. Other parts, although listed under their original headings, have all been amended to some extent: in a few cases by almost complete rewriting.

A deliberate choice was made from the outset to give the content a more decidedly academic orientation than the first edition, although the aim of outreach is still present. It is hoped that many of the active amateurs making a real and recognized contribution to modern astronomical photometry will still find the balance helpful, even if only for consultation. In professional contexts, it is well to note that the book is still described as an *Introduction*. Chapter 4 tries to sketch some of the broad and exciting scope of current astronomical photometry, but of necessity, discussion of many worthy topics is very curtailed. The final five chapters select particular questions of stellar astrophysics for introductory analysis.

It is a pleasure to feel gratitude to the people who have helped the preparation of the second edition, though it is hard to list all their names. The rector, staff and students of the University of Çanakkale, Turkey, deserve grateful acknowledgement. In particular, members of the Physics Department have provided warm and collegiate help. Especially we thank Volkan and Hicran Bakış for very much appreciated practical assistance.

In New Zealand, Dr Denis Sullivan gave welcome support, especially through his facilitation of library and computer facilities at the Victoria University of Wellington. That university's library staff were invariably helpful in searching out information and resources. Drs Murray Forbes and Tim Banks, former Physics Department students, have also been helpful with information. The Carter Observatory's Honorary Research Fellowship to EB is recognized with thanks.

Last, but not least, to our families and close friends – many thanks.