Preface

No astrophysical theory can be tested without data, and those that deal with predictions of visible objects in the universe often require observational data. The precise and accurate measurement of electromagnetic data is called photometry. In this volume we discuss from both physical and historical perspectives, the elements and practice of astronomical photometry applied to the electromagnetic spectrum from the near ultraviolet to the middle infrared, roughly between 200 and 20,000 nm or 0.2 and 20 μm.

The history of astronomical precision begins with the ancient Greeks, among whom Hipparcos ($\sim$190 – $\sim$120 B.C.) provided the first quantitative measurements of stellar "magnitudes" in a catalogue. Photometric precision progressed very slowly until the development of the telescope and the first measures of comparative brightness of the Sun and Moon. Only with the end of the nineteenth century did the precision of astronomical visual photometry reach the 2% level, although not frequently. The application of photography provided a greater degree of objectivity to detections, but brightness measurements from photographic plates were still relatively subjective until the development of measuring engines at the beginning of the twentieth century. Even so, the lack of uniformity of the plates' glass and emulsions, coupled with atmospheric effects, conspired to prevent breakthroughs to greater precision. Photoelectric photometry did achieve greater precision, but again, only in the teeth of intrinsic difficulties. CCD photometry, starting in the 1980s gradually became dominant as CCDs became the detectors of choice at most observatories, but there, too, many problems that plagued the photographic plate era returned, with the additional difficulty of the need to calibrate the spectral or passband sensitivities of what have become ensembles of millions of individual detectors.

The highest precision with which an astronomical brightness measurement can be made is 0.0001 magnitude currently, about 0.01% of the value of the measurement. In practice, such precision is difficult to achieve.

The historical developments are outlined and the methods of achieving the highest possible precision in each era are discussed, along with their limitations. A balance is kept between discussions of hardware and software, between techniques and achievements, and between the science of detection and measurement and the astrophysics for which the photometry is carried out.

In the course of this exposition, we discuss both "absolute" and "relative" photometry, the techniques for doing precise photometry under less than pristine skies, and the techniques to provide the best possible results in cases where the skies are indeed "photometric." References are made to calibrations for both ground- and space-based surveys, although we do not discuss in this volume the important topic of astronomical surveys per se, which deserves its own extensive treatment. There are treatments also of the ever important techniques of spectrophotometry and polarimetry, and, in all the fields of astronomical photometry, the promise of further improvements is explored.

This volume on the past, present, and future of photometry combines the views of past and present and perhaps future members and officers of the International Astronomical Union's Commission 25 on Photometry and Polarimetry. The opportunity to combine these views came about through sessions convened at a Historical Astronomy Division meeting held simultaneously with its parent organization, the American Astronomical Society, in Long Beach, California in January, 2009. Almost all of the authors who contribute here presented their views at that meeting, but the present papers are far more than a recapitulation of those necessarily brief presentations. The present writings are expansive and have been made as extensive as their authors required to present full exposition.

The authors of the several papers presented here have related the history of photometry as it leads to their particular work. Thus: at the outset, Sterken, Milone and Young describe the development of photometry from the ancient Greeks down to the CCD age and follow the schools of thought that have led to passband systems to classify stars, account for interstellar reddening, and find their fundamental properties. The papers by Milone and Pel, Ambruster et al., and by Howell, emphasize the high precision attainable by differential photometry, primarily. The Milone and Pel paper considers the advances from visual to photoelectric photometry of individual stars, discussing many of the instruments and techniques that led to these advances, and highlighting the contributions and legacy of Theodore Walraven. The Ambruster et al. paper builds further on that discussion to describe the independent development of a highly successful pulse-counting differential photometer. Howell's work emphasizes the very sharp rise of the precision of CCD photometry. Several papers discuss the challenges of CCD photometry and suggest ways to improve its accuracy. Landolt demonstrates how the work of the twentieth century pioneers of UBV photometry such as Harold Johnson has led to the precise and accurate broadband system that can be labeled the Landolt $UBV(RI)$ system. Wing demonstrates how his 8-color system developed from the early attempts by Johnson, Morgan, and Keenan to classify stars. In the course of doing this, he is able to make a fine distinction between photometric systems that provide a true spectral classification and those that do not. Milone and Young show how the careful consideration of passbands can improve on the legacy of Johnson in the near and intermediate infrared and can lead to very high precision as well as accuracy. Adelman looks at the varying successes of spectrophotometry of the past and how progress is being made to increase the accuracy as well as the precision through new instruments. Cohen discusses all-sky calibration programs, extending from the UV through the intermediate infrared. Both authors discuss the difficulties in the use of Vega as a calibrator, now known to be a flawed standard. The paper by Bastien describes the equally lengthy history of what may be the most precise form of photometry, polarimetry. There is, inevitably, some repetition of the historical developments from paper to paper, but the variety of lessons learned from those separate discussions demonstrates how examining many particular points of view can lead us to a well-rounded appreciation of the development of our science, and of the future that we can envisage for it.

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