Introduction to Planetary Photometry

This handbook introduces planetary photometry as a quantitative remote sensing tool, and demonstrates how reflected light can be measured and used to investigate our solar system. The author explains how data gathered from telescopes and spacecraft are processed and used to infer properties such as the size, shape, albedo, and composition of celestial objects including planets, moons, asteroids, and comets. Beginning with an overview of the history and background theory of photometry, later chapters delve into the physical principles behind commonly used photometric models and the mechanics of observation, data reduction, and analysis. Real-world examples, problems, and case studies are included, all at an introductory level suitable for new graduate students, planetary scientists, amateur astronomers, and researchers looking for an overview of this field.

MICHAEL K. SHEPARD is Professor of Geosciences at Bloomsburg University of Pennsylvania, specializing in remote sensing, planetary photometry, and asteroid studies. He is the author of the popular science book, *Asteroids: Relics of Ancient Time*, articles for popular science magazines like *Sky and Telescope*, and a guest science columnist for the regional *Press-Enterprise* newspaper. He has previously worked at the Smithsonian Air and Space Museum in Washington, DC and the Jet Propulsion Laboratory in Pasadena, CA.

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MICHAEL K. SHEPARD
Bloomsburg University

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For Samantha, Ellen, Alexander, and Benjamin

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Preface

Planetary photometry is the science that deals with measuring the brightness of an object within the solar system, determining how that brightness varies with illumination and viewing geometry, and discovering what this can tell us about the object. With the exception of the rare physical specimens we obtain, we see planets only through the eyes of telescopes or the cameras of our robotic emissaries. It is an old and revered field, but it is arcane. Much of the field is based upon papers written more than a century ago, with methods, units, and terminology that were originally based upon the needs of stellar astronomy, and only later applied to lunar and planetary studies. There is a confusing array of terms that mean different things to different people. Like old cities, the design is ad hoc, and if we could do it over again, we would probably design things differently. But it is what it is, and any who want to use or understand it must undergo an initiation into its argot.

There are few books that deal with the subject for the practicing planetary scientist. Hapke's (1993, 2012) classic is the best reference, but it would rightly be considered a somewhat advanced text, and there are topics of practical interest that it doesn't include. As a graduate student and later as a practicing scientist in the field, I found that much of what I wanted to know could only be found by reading dozens, if not hundreds of papers. Like Samuel Johnson, I found that "A man will turn over half a library to make a book."

Planetary photometry is not a sexy science, but it undergirds nearly every planetary discovery based on the use and comparison of telescopic and spacecraft observations. And though it seems innocuous, more than one researcher has been bitten by not considering how lighting and viewing might affect their observations. I wrote this book to introduce the basic concepts and principles and serve as a guide, if needed or desired, for more advanced studies.

I assume only modest mathematical background, equivalent to the first year or so of college mathematics. I discuss the physics behind many of the

concepts of planetary photometry, but generally do not delve deeply into them. Other books do that well already. However, because the derivations for many important photometric equations are rarely included in the literature, I walk the reader through many of these – a type of hand-holding that I often wished for when first encountering some of this material. I illustrate many concepts with examples and include a number of problems, with answers available online at www.cambridge.org/photometry.

After digesting this book, you should be able to converse with experts in planetary photometry without embarrassment, and have a good sense of the potential limitations of your or others data where photometry plays a role. And if the desire should take, you should be ready to tackle more advanced books on the subject.

Acknowledgments

I am the beneficiary of many fruitful discussions with a long line of experts in this field, chief among them Paul Helfenstein and Bruce Hapke. And although I have never worked directly with them, I have greatly benefited from reading the works of Yuri Shkuratov and his many colleagues at Kharkov University, and am grateful for their long tradition of excellent photometric and polarimetric work. Similarly, work by Kari Lumme, Ted Bowell, Jay Goguen, Joe Veverka, Kari Muinonen, Jian-Yang Li, Michael Mishchenko, and Bonnie Buratti are nourishing staples in my photometric library. I would also like to thank Ray Arvidson, Bruce Campbell, Ed Guinness, Jeffrey Johnson, Will Grundy, Deborah Domingue, David Paige, Emily Foote, Bob Nelson, Patrick Pinet, and Ed Cloutis as colleagues in a variety of my work in this field over the years. I am also indebted to the marvelous librarians at Bloomsburg University: Andrea Schwartz, Charlotte Droll, Linda Neyer, and Michael Coffta.

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A Note on the Symbols and the Text

The mathematical symbols used by the host of referenced works are often inconsistent between writers. While some symbols have been used repeatedly and become traditional, others have not. I have attempted to be self-consistent, but note that there are simply too many physical variables for the limited number of standard Roman and Greek letters available. In several instances, I have reused symbols. In those cases, I have attempted to make the meaning clear to prevent confusion.

Throughout the text, a number of words are in **bold**. This is to indicate a term of some importance. Proper names are also in **bold** the first time they are introduced. *Italics* are used to emphasize a point; they are also used for the title of books or papers being discussed.