Astrophotography for the Amateur
Second edition

This is a much expanded and fully updated edition of the best-selling handbook *Astrophotography for the Amateur*. It provides a complete guide to taking pictures of the stars, galaxies, the moon, the sun, comets, meteors, and eclipses, using equipment and materials readily available to the hobbyist.

In this new edition, the book has been completely revised and now includes new chapters on computer image processing and CCD imaging, greatly expanded advice on choosing cameras and telescopes, completely updated information about films, a much larger bibliography, and many new photographs (including 43 new colour plates and more than 140 new black and white images) by some of the world's best amateurs, demonstrating the latest equipment and techniques.

Astrophotography for the Amateur has become the standard handbook for all amateur astronomers. This expanded and updated edition provides an ideal introduction for beginners and a complete handbook for advanced amateurs. It will also appeal to photography enthusiasts who can discover how to take spectacular images with only modest equipment.

An avid amateur astronomer since the age of 12, Michael Covington has linguistics degrees from Cambridge and Yale. Currently, he is engaged in research at the University of Georgia's Artificial Intelligence Center, where his work won first prize in the IBM Supercomputing Competition in 1990. His current research and consulting areas include logic programming, computational linguistics, and computer security. His other pursuits include amateur radio (his call sign is N4TMI), electronics, computers, ancient languages and literatures, philosophy, theology, and church work. He is the author of several books and over 200 magazine articles, mainly about computers. He lives in Athens, Georgia, USA, with his wife Melody and daughters Cathy and Sharon, and can be visited on the Web at http://www.ai.uga.edu/~mc.

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Preface

The purpose of this book is to tell you how to photograph the sky with simple techniques and affordable equipment.

Astrophotography is easier today than when I wrote the first edition of this book fifteen years ago. Telescopes are better built, and films have far less reciprocity failure. Many off-the-shelf consumer films are better than the Kodak Spectroscopic emulsions used by astronomers in the past.

Most cameras, however, have become less suitable for astrophotography and harder to use. Many of the newest cameras can't make time exposures without running down their batteries, and the beginning astrophotographer needs more advice about choosing a good camera. This has accordingly been added to Chapter 9.

Meanwhile, digital imaging has come on the scene, and two chapters have been added to cover it. I've had to be careful because digital technology is still changing rapidly. Nonetheless, digital image processing is our most promising new technique, and even if you don't have a computer, you can make digitally enhanced prints at a workstation at the local camera store. With digital technology, I've concentrated on underlying principles rather than specific equipment.

In this digital age, why do we still use film at all? Because it is still the most cost-effective way to acquire and store images. A color slide or negative is equivalent to at least 6 million pixels, considerably larger than presently affordable CCDs. Further, film can store up light in time exposures; non-astronomical CCDs generally cannot do this because of dark currents. Film images can be digitized and processed by the computer exactly as if they had come from CCDs.

I want to thank all the astrophotographers who allowed me to use their pictures – as well as many more who offered pictures that I wasn't able to use. Because this is an introductory handbook, not a gallery of fine astrophotography, many of the best astrophotographers are not represented here. In fact, I had to turn down a number of pictures because they were too good! Most of the pictures in this book were chosen to represent what any amateur can accomplish with a moderate investment of time and equipment.

Several people deserve special thanks. Douglas Downing provided early encouragement. Bob Lucas helped me punch the chassis for the electronic drive corrector in Appendix C. Eric Pederson did lots of careful E-6 processing in his minilab. Dennis Milon and Dennis Di Cicco, of *Sky & Telescope,* and the staff of *Astronomy* helped me locate contributors. Kodak answered seemingly endless technical questions. Simon Mitton, Adam Black, and their colleagues at Cambridge University Press have provided continuing help through three editions (first, revised first, and second).

In this new edition, special thanks are due to the astrophotographers on the Internet. Chuck Vaughn, Jerry Lodriguss, Robert Reeves, John Hermanson, Joe Marietta, Emery Hildebrand, Wil Milan, Gregory Terrance, and dozens of others have reacted to my ideas, answered questions, and suggested numerous improvements to this edition. I thank Kodak, Fuji, and Ilford for film samples and Meade Instruments, Tektronix, B&K Products, Cyanogen Productions, and Rigel Systems for lending me equipment and software.

My wife Melody drew nearly all of the diagrams and line drawings for the first edition; she is my "in-house art department." Our daughters Cathy and Sharon, themselves avid photographers, provided encouragement and assistance and took some of the photographs for this edition.

I also want to thank the many people who, at various times and places, helped me learn about astronomy and shared with me their appreciation for the sky, though they did not contribute anything specific to this book. I owe much to the amateur astronomical communities of Valdosta, Georgia, where I grew up; Albuquerque, New Mexico, where I spent an enjoyable summer in 1980; and the newly reactivated University of Georgia Observatory.

Perhaps the biggest difference between this and the earlier editions is the impact of the Internet. I wrote and revised the first edition in relative isolation, relying on published literature, my own experiments, and some correspondence with a few fellow amateurs. Thanks to the Internet, I've been able to write this edition amid constant discussion with dozens of experienced astrophotographers as well as numerous beginners. That has given me a much surer sense of where people's interests lie, what questions they are likely to have in mind, and what points are difficult or prone to misunderstanding.

Preparing the second edition was more work than writing the original. My employer, the University of Georgia, supported the effort even though it had little to do with my job. Although it was a backhanded kind of good fortune, I suppose I should also thank the numerous students who did not sign up for CS 857 in the fall of 1997, thus giving me time to work on the book.

I enjoy hearing from astrophotography enthusiasts on all levels. Readers with questions, comments, or suggestions for revision are welcome to write to me in care of the publisher, with the understanding that I cannot return photographs or other material unless postage is provided. I can answer letters in German, French, Spanish, and Italian if you are content with a relatively short reply.

Michael Covington
Athens, Georgia

Notes to the reader

Bibliography: References to books and articles are given in full on pages 318–324. Within the text, most references are cited either by author and title (e.g., Tirion's *Sky Atlas 2000.0*) or by author and date (e.g., Dragesco 1995).

Metric units: SI (metric) units are used throughout the book except for industry standards still defined in inches. Apertures of telescopes are always given in centimeters, focal lengths in millimeters, even when large; thus a 20-cm telescope is 20 cm in diameter but a 200-mm lens is 200 mm in focal length.

Symbols used in formulae

These symbols are used consistently throughout the book. As in calculus, Δ before a symbol indicates a change in its value; for example, δ is declination and $\Delta\delta$ is apparent shift in declination.

When the units in a formula are not specified, all quantities should be given in the same units. For example, if the focal length of a telescope is given in millimeters, the image size will also be in millimeters.

γ	Contrast of film or paper (gamma)
δ	Declination (like latitude in the sky)
$\Delta\delta$	Shift in declination (due to guiding problems)
$\Delta\rho$	Image rotation (due to guiding problems)
θ	Apparent size of celestial object (as an angle)
λ	Wavelength of light (in nanometers)
B	Subject brightness in arbitrary linear units
b	Diameter of blur circle (defocused point image)
D	Density (light absorption), logarithmic scale
d	Diameter of lens
F	Focal length of lens, telescope, or complete system
F_1	Focal length of telescope alone, ignoring projection lenses
F_2	Focal length of projection or compression lens
F_E	Focal length of eyepiece
f	f-ratio (F/d)
f_1	f-ratio of telescope alone, ignoring projection lenses
M	Magnification
m	Magnitude (total apparent brightness of celestial object)
m''	Magnitude per square arc-second (apparent surface brightness)
p	Schwarzschild exponent (a measure of reciprocity failure of film)
S	Film speed in ASA or ISO arithmetic-scale units
s_1	Distance from lens to subject
s_2	Distance from lens to image (focal distance)
Δs_2	Focusing error (error in s_2)
t	Exposure time (in seconds)
w	Width of image (on film) or width of film