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Scientific Astrophotography

How Amateurs Can Generate and Use Professional Imaging Data

Gerald R. Hubbell

Springer

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ISSN 1431-9756

ISBN 978-1-4614-5172-3

ISBN 978-1-4614-5173-0 (eBook)

DOI 10.1007/978-1-4614-5173-0

Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2012950859

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Printed on acid-free paper

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Foreword

We are living in a Golden Age of Astronomy when discoveries are made daily by professional and amateur astronomers alike. The measurement of the position, distance, composition, and change of celestial objects is at unprecedented levels, and amateur astronomers, using their modest equipment, are making high-quality measurements that, just decades ago, only their professional counterparts could have made with large observatories and instrumentation that cost millions.

Since the beginning of astrophotography, there has been a continual stream of scientific breakthroughs and discoveries. Indeed, the roots of astrophotography as a scientific tool were pioneered by amateur astronomers in the mid-19th century, beginning with an image of the Moon, the first astronomical image ever, made by chemist and pioneering photographer, John William Draper in 1840.

Twenty years later in 1863, chemist William Allen Miller and amateur astronomer Sir William Huggins obtained the first photographic spectrogram of a star. And 20 years after that, John Draper's son, Henry Draper, took the first deep sky image in 1880 of the Orion Nebula. In 1883, amateur astronomer Andrew Ainslie Common imaged nebulosity and stars that were too faint to be detected through his visual telescopic observation of the Orion Nebula with his home-built telescope.

And from that momentous image of the Moon, taken less than two centuries ago on a daguerreotype plate, to the astroimages made today on modern CCD sensors, advances in imaging technology and instrumentation, and the dedication, skill, and imagination of amateur astronomers have been intertwined to produce countless innovations and discoveries that have affected everyone on Earth. The truly exciting part of all this is that with the affordable modern tools available now, we will see many more breakthroughs and discoveries through astronomical imaging by amateurs—and you can be part of it.

That said, one of the ironies of amateur astronomy today is that while all the equipment, techniques, and access are available to go beyond stargazing and make

Fig. 0.1 The intrepid amateur astronomer (Courtesy of Jedediah Hubbell)

some lasting scientific contribution or even a discovery of a new object, it still seems too far out of reach. This is in part because of the lack of a comprehensive source of information that ties everything together to guide amateurs toward defining and accomplishing their goals. We need a manual that shows how to choose the right combination of components in building the astronomical imaging system (AIS), and to coach us through the methods and skills required to have our data accepted and reviewed. That is precisely what Jerry Hubbell has given us with this book.

The structure and methods described in *Scientific Astrophotography* provide you with the opportunity to take a fresh approach to this discipline of study and put what you have learned from a book to use in a real-world activity. And because this is a scientific endeavor, you will be learning on a high level that will not only challenge you, but prepare you to collaborate and contribute to science and the scientific community in a meaningful way.

Hubbell lays down a roadmap to penetrate and methodically correct the root causes of problems often encountered when acquiring images that will allow you to obtain high-quality data that can be used in research. But he doesn't stop at critical thinking and problem solving. The book also has detailed descriptions of how to complete each step along the way, full descriptions of how and why things work the way they do (including the math), and forms to record your notes, which are so critical in research.

Overall, *Scientific Astrophotography* is a compelling work in the history of technical photographic publications, and it is noteworthy that this is Hubbell's first book on the subject, culminating his own learning experience in making astrophotographs,

which began only a few years ago. Even though Hubbell is a relative newcomer, he delivers with the expertise of someone who has practiced for decades. The book is written as though Hubbell were with you, giving you encouragement, inspiration, and all the technical advice you could hope for.

For the beginner, Scientific Astrophotography may seem daunting at first because of the sheer amount of information to digest. But if you read it through completely, and then review and practice in portions, you'll find that this book will help keep the beginner from developing bad habits that have to be "unlearned." For those who are familiar with astrophotography, this book will allow you to compare Hubbell's methods with what you are doing now to find the nuggets of information that will help you improve or become better organized. And for the expert who is tasked to teach research astronomy for a school or astronomy club, you'll find Scientific Astrophotography a worthy addition to your curriculum.

Even if your initial desire is to make beautiful images of celestial objects, the methods described will most certainly give you the foundation to produce professional-quality images that you can later process to make the "jaw dropping" deep sky images that you often see gracing the gallery sections of the astronomy magazines. But these same raw images could be used by a professional researcher who just might need to compare his data, taken of the same area of the sky around the same time that you acquired yours, to verify his finding. And this works both ways...if you see something new in your images that you don't see in the professional reference imagery freely available online, you may have some exciting news to share.

However, making a discovery is not the ultimate aim of this book. Hubbell's philosophy on why we should be engaged in science and why we should become practicing scientists is shared throughout these pages, and is perhaps the most important message of all.

Scott W. Roberts
Founder and President, Explore Scientific LLC
Springdale, AR

Preface

Welcome to *Scientific Astrophotography: How Amateurs Can Generate and Use Professional Imaging Data*. I started developing this book in the summer of 2011 to meet the needs of the Rappahannock Astronomy Club (raclub.org) membership for a practical, how-to guide for learning and using the charge-coupled device (CCD) cameras available today for astrophotography. One of the primary missions of our club is to be an enabler, providing access to tools and educational materials that enhance the members' ability to experience all that is offered today in this "golden age" of amateur astronomy. This book was developed to provide the tools and information to enable the RAClub membership to move into the exciting world of scientific astrophotography. I hope this book fulfills those needs for astronomy clubs and amateur astronomers everywhere.

Intended for the beginner and the experienced astrophotographer alike, this book provides the basic material necessary to understand the factors that contribute to taking excellent astrophotographs for use in collecting scientific data. The book also provides step-by-step procedures and exercises to gain the skills needed to perform at the level necessary to obtain professional level scientific data. For the experienced astrophotographer, this book provides the distilled knowledge and procedures needed to quickly get you up and running with new configurations and instruments in the field with your telescope. I took it upon myself to document the highlights of the myriad books, magazines, articles, Internet sites, and owner's manuals available to the beginning astrophotographer. I also chose to take an engineering approach to the issue of learning how to design, build, and operate an Astronomical Imaging System (AIS) to perform scientific astrophotography. I thought that this approach would provide the necessary discipline and structure to minimize an all-too-frequent result—the frustrated beginning astrophotographer who puts his equipment in the back of the closet after not being able to progress past the initial disappointing levels of quality. It is also important to recognize that

the material and techniques in this book are as applicable to obtaining “pretty picture” astrophotographs as they are to obtaining scientific imaging data.

As I did further research for this book, and adjusted the contents accordingly, I recognized that writing it gave me the opportunity to document my approach to building my own personal observatory and AIS. I had always considered my initial purchases of equipment and tools as a necessity for me to learn the diverse sets of ideas, techniques, skills, and knowledge available to the amateur astronomer today. In this respect, my initial AIS *is* a prototype learning environment for scientific imaging. This book documents my journey over the past few years in learning how to perform astrophotography for scientific purposes. It allows me to focus on what is necessary going forward, the engineering issues associated with designing my observing program, and the AIS needed to cost-effectively implement and pursue that program. I am confident that it will also fill that need for the reader.

My observing experience since my early teens has been mainly in the visual realm. When I first started, I did some very rudimentary astrophotography using eyepiece projection and a Polaroid camera. Because of the very modest instruments that I had acquired, my observing focused on the bright objects in our solar system, such as the Moon, Jupiter, and Saturn. I still fondly remember setting up my 60-mm Tasco on its very impressive manual German equatorial mount (GEM). I graduated to a larger telescope during the late 1980s (a Meade 10-in. 2120 LX5 Schmidt-Cassegrain Telescope (SCT)) acquired through Company 7 (a dealer located in Laurel, Maryland), still only using this telescope visually.

Through all the years since then, I have always wanted to learn how to image minor planets (asteroids), determine their position, and calculate their orbits. That to me was the ultimate in practicing science for the amateur astronomer. It was not until the fall of 2008 that I was able to find the time to get into the latest astronomical technology and start down the path of learning what it takes to track down those wily asteroids and, in the process, learn how to create excellent astrophotographs. So just 4 years ago, I was a beginner as many of you are now. You may have followed the same path as I did or may have started out wanting to do astrophotography as your primary goal. Either way, this book is intended to help you reach your astrophotography goals.

Some aspects of scientific imaging can be unforgiving when trying to reach and maintain a high level of quality. However, although the route to high-quality imaging can be a difficult one, if the road taken is well traveled and a disciplined approach is maintained, then all it takes is a little patience, stick-to-itiveness, and practice. Spectacular success is possible for those who go down that well-traveled road.

Acknowledgments

I want to thank all those who have encouraged me in this endeavor, not the least of which is my wife, Michelle, my best friend and the love of my life. She has put up with my long hours at the computer and the telescope in the middle of the night with all the support and love I could ever wish for. I also want to thank my daughters, Amber Hubbell for her work on the first cut review of the manuscript and Rachel Konopa for doing the illustrations for the book—It was pretty special being able to count on her substantial graphic art skills in illustrating this book.

I want to thank my fellow RAClub members, specifically Linda Billard for her expert editing and valuable feedback on my writing, and Bart Billard for his expert technical review; the quality of the book is due to their hard work. Linda has helped me improve my writing and I am forever grateful for that. I also want to thank David Abbou, Brenda Conway, Scott Busby, and Brian Westby for their reviews of the manuscript. I also appreciate David's image contributions to the book. Thanks also go to another RAClub member, Dr. Myron Wasiuta, for his feedback on various subjects discussed in the book. Myron's insight into this subject, as one who has taught astronomy professionally and also as a very experienced amateur astronomer, was invaluable.

I want to specially thank Scott Roberts for writing the Foreword to this first edition, his review of the manuscript, and valuable feedback on various topics in the book. Scott has a wealth of knowledge of the hardware used by the amateur astronomer and his input contributed greatly to the book. I have come to consider Scott a very good friend; he is a leader and innovator, and I appreciate his insights on the amateur astronomy industry. I have found that he will do just about anything for anyone who is looking to get into astronomy, and he does a substantial amount of outreach work through the Explore Alliance (www.explorealliance.com) and other groups.

I have been very fortunate to meet several other people who are leaders in the amateur astronomy community and have provided me with valuable insight into this wonderful hobby. Chief among them are Professional Astronomer Dr. Mike Reynolds of Florida State College, Mike Simonsen of the American Association of Variable Star Observers (AAVSO), Rich Williams of the Sierra Stars Observatory Network (SSON), and Tom Field the developer of RSpec spectroscopy analysis software. Each of them is a leader in their specific area of expertise, and we are very fortunate to have them among us.

Finally, I would very much like to thank Megan Ernst and Maury Solomon for their help and support. I also want to thank Maury and Springer for giving me the opportunity to have my first book published. I would not have been able to get this book to the high level of quality it is in without the help of the aforementioned people. Regardless, I take full responsibility for any errors that may remain.

Personally, learning and performing scientific astrophotography has enabled me to flex my technical skills and allowed me to combine my love of science and technology with the skills, knowledge, and innovation necessary to make excellent images. This has led me to discover great things about the universe in a very personal way. There is nothing like making that very precise, difficult, and time-consuming observation of a faint 16th magnitude minor planet, or monitoring that dim variable star, with the realization that you are the only one on Earth who has done that measurement that adds to the sum of human knowledge. Learning astrophotography gives you the ability to see further and fainter, and to personally discover the wonderful, subtle aspects of the observable universe. This is a very humbling and profound pursuit on which you embark—I wish all of you the very best in your scientific imaging endeavors.

Clear skies!

Jerry Hubbell
Lake of the Woods Observatory (MPC I24)
Locust Grove, VA
June 2012

About the Author

Jerry Hubbell, currently President of the Rappahannock Astronomy Club (raclub.org), has been an avid amateur astronomer since he was a teenager. However, he developed his passionate interest in astrophotography, and in particular, astrophotography that supports scientific investigation, only about 4 years ago. In that short time, Jerry has become known as a superior astrophotographer, amateur scientist, and mentor to other amateurs who want to foster scientific investigation in the amateur ranks. His career as a nuclear Instrumentation and Controls (I&C) and software engineer for Dominion Virginia Power has trained him well for the attention to detail and precision required for scientific astrophotography. In this book, Jerry refers often to everyday examples from ordinary life, his job, and aviation. He is also a pilot for the Virginia Defense Force Aviation Battalion, the Commonwealth's military reserve. His Six Sigma Black Belt training is evident in his careful but accessible step-by-step explanations of how to build your astronomical imaging system, choose your astronomical targets, design a plan to photograph them, avoid the pitfalls, and apply the appropriate methods to obtain scientifically relevant data suitable for contribution to the larger scientific community. As an active member of the Association of Lunar and Planetary Observers (ALPO) and the American Association of Variable Star Observers (AAVSO), and as the owner of a certified observatory location I24 for the IAU's Minor Planet Center, Jerry practices what he preaches in performing his scientific astrophotography. He has had several images published in the ALPO's Lunar Section newsletter, *The Lunar Observer*, and his work has been acknowledged in *Sky and Telescope* magazine. Jerry's minor planet observations have been published in the scientifically peer-reviewed *Minor Planet Circulars*, *Minor Planet Circulars Supplement*, and *ALPOS Minor Planet Bulletin*.

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