Preface/Acknowledgments

Pardon the 'D' in the author's name on the cover (it stands for "Dale" by the way). I'm the *other* Brian Warner. The *real* Brian Warner is the famous and distinguished one. He's the author of High Speed Photometry and Cataclysmic Variable Stars. There is another Brian Warner. He goes by the stage name of Marilyn Manson. I've received some pretty strange phone calls late at night from some of Manson's fans. "No, I'm the *other* Brian Warner." The disappointment at the other end was nearly devastating. So, I use the 'D' to make sure it's clear who I am and so that you won't think I'll break out into song at any moment.

The real Brian Warner and I do have something more in common than our names: a deep interest in lightcurves. My interest is not so much in cataclysmic variables (CVs for short) but asteroids and eclipsing binaries, close contact binaries specifically. When I was in Junior High school, with Galileo some would say, I had hopes of being a professional astronomer someday and specializing in close contact binaries. Many years have passed and I'm not a professional astronomer. However, I am still fascinated by and work those binaries from time-to-time as a nearly full-time amateur astronomer.

My first efforts in asteroid lightcurves began in the 1970s when I worked with the late Terry Schmidt at his Tiara Observatory in South Park, CO (Yes - *the* South Park). Terry had moved from near Chicago to be under the dark skies of Colorado. It was my great fortune to leave my small telescope out on the porch, have him see it, and have him knock on the door. It started a 25-year friendship with Terry as my astronomy mentor, ending only with his sudden passing in 1993. One of my three asteroid discoveries, 34398 Terryschmidt, is named in his honor.

Terry was fascinated by asteroids and comets but meteors were his greatest interest. We spent many nights at Tiara doing meteor shower studies. The temperatures ranged from balmy +40's Fahrenheit to bone numbing –30's. He never seemed bothered by the cold. Me, I think Phoenix in summer is just about right. Terry started me down the path to asteroid lightcurve work by having me write down the readings from the photometer as he called them out. Three numbers every three minutes for hours on end. It was not the most exciting way to do astronomy but back I came time and time again. Some 35 years after our first meeting, I'm still at it but under much more comfortable surroundings. The advances in CCD cameras and telescope/camera automation allow me to gather data from one or two targets all night long while I sleep. That was another thing; Terry was self-employed. He didn't have to get up the next morning and go to work.

Since 1999, I've managed to accumulate approximately 60 asteroid lightcurves and have them published in the *Minor Planet Bulletin*. I wish it was more but the weather is rarely kind and the convenient electronic equipment that populates many an amateur observatory has sometimes been not so convenient by breaking down. Still, it has been a lot of fun.

I've come under the wing of a new mentor, Dr. Alan Harris. Alan was with JPL for many years and is one of the recognized leaders in asteroid research. You'll see his name in many a publication. What you won't necessarily see is his passion for science and his willingness to pass it on to others (nor his skill at making Scottish shortbread). Most important – to me at least – is that he does not draw a harsh line between amateur and professional astronomer.

That line is fuzzy at best these days but there are those who would have it sharply defined and not allow crossing from one side to the other. Not Alan; not Richard Binzel of MIT; not Ted Bowell of Lowell Observatory; not Arne Henden of USNO-Flagstaff; not many other professionals who have extended their trust and expertise with overwhelming patience to amateurs willing to listen, to learn, and to work at doing the best possible science. It is to these professionals, in all senses of the word, that I in part dedicate this book.

This book is my attempt to encourage those with even modest CCD equipment to give asteroid and variable star lightcurve work a try. More so, it will try to do so by example and not all theory. There will be formulae and theory enough in other books (and some at the back of this book). I do recommend that you get at least a passing understanding of the underlying theories of good astronomical photometry. It's hard to produce good science when you don't understand what to do and even more so when you don't know why. When you have that understanding, you can build on your experiences much faster and soon reach a level of expertise that will make your work of value to the study of asteroids or variable stars.

I won't go into great details about photometry in general. What I will do is try to give you the details you need to develop and implement a program with a specific purpose. That being to obtain lightcurves of asteroids or variable stars and to analyze them such that you can report what you've learned in publications with general access to amateurs, e.g., *The Minor Planet Bulletin* for asteroids and the IBVS or JAAVSO for variable stars (I'll decipher those acronyms later). In short, this is a guide on the "what's" and, more so, the "how's" of photometry for the purpose of obtaining lightcurves. I use the term "***lightcurve photometry***" for this, to distinguish from other photometry work such as building catalogs and standard references.

There's much satisfaction to be gained from taming the lightcurve of an asteroid or using your data to create a binary star system in a computer program. Naturally, you can and should extend that by publishing your results. There are too many versions of Alan Harris' "dusty filing cabinets" filled with unreported data. It's anybody's guess as to what could be learned if that data was made available in one form or another.

I'm going to assume you have a *basic* understanding of common astronomy terms and of those associated your equipment. I'll also assume you've used that equipment at least a little; otherwise this book would soon burgeon to encyclopedic size. Throughout the book, I'll be using software that I wrote – MPO Connections, Canopus, and PhotoRed – to provide the examples. There are many other excellent packages for measuring images and generating data. In fact, the MPO programs support importing data from those programs so that you can merge observations from several observers even if they're not using the same software. I will include some details on how to do some of the work in other programs so as not to exclude those who chose to use them. I'll say it now and later, the best program for the job is the one you like and use.

On the other hand, I would be remiss not to give my software a bit of a plug here, in the "personal section" where it's allowed. The advantage of the MPO software, I believe, is that it is written for the purpose of measuring images for lightcurves and analyzing the resulting data. It includes features that make theses processes more efficient and exacting. For example, MPO Canopus includes Alan Harris' "industry standard" Fourier analysis routine for period analysis while PhotoRed gives you the tools to determine extinction and transforms values

and apply them to the data in Canopus. Also, Canopus exports data files that are compatible with the formats used by Binary Maker and the Willson-Devinney program used to model binary star systems from lightcurve data.

One of the points I wanted to keep in mind throughout is to make the book as readable and as uncomplicated as possible. That's not an easy task as some of the work *is* a bit complicated. Make no mistake; I didn't develop all of this information on my own. In addition to my experiences and work, I have relied considerably on the work of others to provide the information included on these pages. If Newton advanced science by standing on the shoulders of giants, I can't imagine the size of the shoulders I used.

Along those lines, I will formally thank a number of people. First is Bob Stephens of Santana Observatory, Rancho Cucamonga, CA, who has been a friend and even mentor in his own way for several years. You can blame him in part for me writing this book. Next is Bob Koff, Antelope Hills Observatory, Bennett, CO, who has given me many ideas and suggestions for making the MPO software more useful to variable star observers. Bob and Bob (known as Bob the Younger and Bob the Elder respectively) also took the time to read drafts as they drifted from the computer from time to time and offered many suggestions to improve the final text. They can take credit for what's good and I'll take full responsibility for any and all errors or omissions.

I thanked before but will again, Alan Harris, Richard Binzel, and Arne Henden. I'll add here Petr Pravec of Ondrejov Observatory, Czech Republic, for his invaluable help over time and Dirk Terrell of Southwest Research Institute, Boulder, CO, who helped clarify some points about binary stars and entries in the glossary.

Finally, I thank and dedicate this book to my wife, Margaret Miller, a superb violist, excellent music teacher, and most patient and tolerant friend.

About Web Addresses

I can't remember the number of books, even those that would be considered recent, that had URLs to Web sites that were not valid by the time I read the book. It seems "host hopping" is a popular sport on the Internet. Because of this, I was reluctant to include Web addresses in this book. However, I threw caution to the wind and did include some. I took into consideration the likelihood that the address would change in the foreseeable future. If an individual's Web site, I did not include it – save for some rare instances. I did include addresses for those groups and organizations that I thought would not be changing their URL anytime soon.

If a URL does prove outdated, do a Google search to find the updated URL and accept my apologies for leading you astray.

Getting From Here to There

There's a line of philosophy that says you can never get from "here" to "there" because once you are "there", it becomes "here." My dad often confused me in a similar way but it involved "tomorrow" and "today". The plans for going to the beach, he'd say, had been cancelled since he'd said we'd go to the beach "tomorrow" but it was "today." This all sounds like it comes from the same people who wonder about falling trees in the forest.

I won't pull my dad's joke on you. I will tell you that getting from where ever you are now to the point of being able to find the definitive period and amplitude of a lightcurve and, if your target is a variable star, of building a reasonable model of that star, is not always a direct path. The process of getting images, measuring them for the data, building a lightcurve from data covering several nights, and then finding its period and amplitude is not sharply defined in all cases. What you do in the early stages, such as taking images, can have a direct impact on the later stages, i.e., analyzing the period. To talk about the generalities of photometry without consideration for the measuring process, or how you'll break down the data, is very difficult at times. So, that means introducing terms or methods that won't be discussed in detail until a later time. If I didn't put some things off, the trip from "here" to "there" would have so many diversions that you *and I* would get lost.

You'll find a number of terms that appear in Italics, e.g., *extinction*. That means you'll find a definition of that word in the glossary. Use that to give you a quick idea of what's meant until you get to the full discussion and how it affects the overall process. Don't be put off by the new terms and concepts: They'll soon be familiar and roll off the tongue with ease.

At the end of each major section, I'll give a summary of how what was in the section affects other parts of the over all process. Then, after going over all the basics, from photometry through analysis, you'll find some step-by-step outlines of exactly how you'd proceed to get the images and analyze the data you need for your lightcurve work.