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Martin Mobberley

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With 153 Figures

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Martin Mobberley
Denmara
Old Hall Lane
Cockfield
Bury St Edmunds
Suffolk UK
IP30 0LQ
martin.mobberley@btinternet.com

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To Damian Peach, Dave Tyler, Jamie Cooper, and Mike Brown, whose lunar and planetary imaging enthusiasm and daily e-mails spurred me on to write this book.

Preface

We Live in Exciting Times

I have been looking at the moon since 1968 when I acquired a humble childhood refractor made by Prinz. It was a 30-mm aperture instrument with a 10–30× zoom feature. I still have that telescope today and it still works well. Over the years I acquired bigger and bigger instruments and tried some lunar and planetary photography. But I could always see far more visually than I could photograph because the eye and brain are a remarkable combination and far superior to photographic film, at least for studying the moon and planets. In 1985 I caused much excitement at BAA (British Astronomical Association) Lunar Section meetings when I showed some videotapes I had taken with an experimental English Electric Valve CCD camera I had used to videotape the moon. Here was a quantum leap in imaging: something that could rapidly study the lunar surface and record details as well as the eye, at least on the bright, high-contrast moon. However, as the 21st century dawned, even newer technology came to the fore. It was awesome in its power, but affordable too: surely, a unique combination for amateur astronomy. The technology was the humble USB webcam, combined with an incredible software package called Registax, developed by Cor Berrevoets. The technical combination of a webcam with image stacking and processing tools, controlled by a modern PC is truly staggering. Any amateur can now take back-garden planetary images that reveal more than the human eye and would have been the envy of professional observatories only 10 years ago. I cannot remember a more exciting time to be in amateur astronomy. I hope this book may inspire a few more imagers to emerge and help breed the next generation of lunar and planetary imagers. It is now possible for anyone with a modest backyard telescope to capture stunning images and contribute real scientific observations. If this book helps produce just one keen planetary imager, I will feel it has been worth it.

Martin Mobberley
Suffolk, United Kingdom
December 2005

Acknowledgments

As was the case with my previous two Springer books, I am indebted to the outstanding amateur astronomers who have donated images to this new work. I feel humbled that such great names as Isao Miyazaki, Damian Peach, and Eric Ng (to name just three) have been so willing to share their images with others via my Webcam User's Guide. I am especially grateful to Damian as he has donated more images than anyone else to this work and it is only by his example, from the cloudy UK, that I was coaxed back to lunar and planetary imaging in the first place. While writing this work I was encouraged, on a daily basis, by e-mails from Damian, Dave Tyler, Mike Brown and Jamie Cooper as we all shared our nightly experiences regarding our webcams, telescopes, and the vagaries of the atmosphere and "seeing." So my special thanks go to those four as well as to David Graham, Mario Frassati, and Paolo Tanga, whose excellent Mercury and Mars maps are reproduced in these pages. The Frassati/Tanga Mars map is the most useful map for the webcam/visual user that I know of; it is superb, with every feature named but without being cluttered. But perhaps all our thanks should go to software genius Cor Berrevoets. Without Cor's Registax freeware, using webcams for planetary imaging would probably never have caught on at all.

In alphabetical order, the help of the following lunar, planetary, and image processing experts is gratefully acknowledged: Cor Berrevoets, Mike Brown, Celestron International, Antonio Cidadao, Jamie Cooper, Mario Frassati, Maurice Gavin, Ed Grafton, David Graham, Paolo Lazzarotti, Isao Miyazaki, NASA/JPL, Eric Ng, Gerald North, Donald Parker, Damian Peach, Christophe Pellier, Barry Pemberton (Orion Optics), Maurizio Di Sciullo, Paolo Tanga, Dave Tyler, Unisys Corp., and Jody Wilson (Boston University).

I am also indebted to my father, Denys Mobberley, for his tireless help in all my observing projects; to John Watson, for carefully reading through the original manuscript; and to the production staff at Springer for all their help, especially Jenny Wolkowicki and Chris Coughlin.

Martin Mobberley
Suffolk, United Kingdom
December 2005

Contents

CHAPTER ONE

The Solar System: A Brief Introduction

This is primarily a book about imaging the planets with webcams and is aimed at amateur astronomers who already have some basic knowledge of the solar system. However, we all have to start somewhere and it is quite possible that a few complete beginners will be attracted to this book, with virtually no prior knowledge of astronomy at all. This chapter is for the total novice. If you are familiar with the structure of our solar system, feel free to skip this introduction. If not, then start your adventure here. I have deliberately written this introduction to be as simple as possible, so that almost anyone will (hopefully) understand it.

We live in a solar system (Figure 1.1) comprising one Sun, nine planets, hundreds of thousands of asteroids, and well over one thousand comets. If I sound a bit vague about exactly how many asteroids and comets there are, well, that is deliberate. Firstly, no one knows. Secondly, if you count objects no bigger than large boulders or snowballs as asteroids and comets, there must be millions. Figures 1.2 through 1.7 show some of the solar system's major bodies.

Billions of years ago, material in our solar system started to drift toward a common center of gravity. The vast bulk of the material, comprising mainly hydrogen, formed the Sun. As soon as enough mass was present, nuclear fusion started and the Sun began to shine, illuminating the early solar system and announcing its presence as a star in this part of our galaxy. All of the stars in the night sky are Suns; some are bigger, some are smaller, but all of them are a huge distance away.

In passing, I would like to stress early on that you must *never, ever* stare at the Sun, even with the naked eye, and certainly never with a telescope (unless the telescope has special full-aperture solar filters and you are an expert; see Chapter 16 for more details). The Sun is dangerously bright and permanent eye damage can easily occur. You have been warned!

The distances to other stars (and, therefore, other solar systems) are measured in light years. The closest star to us, Proxima Centauri, is 4.2 light years away.

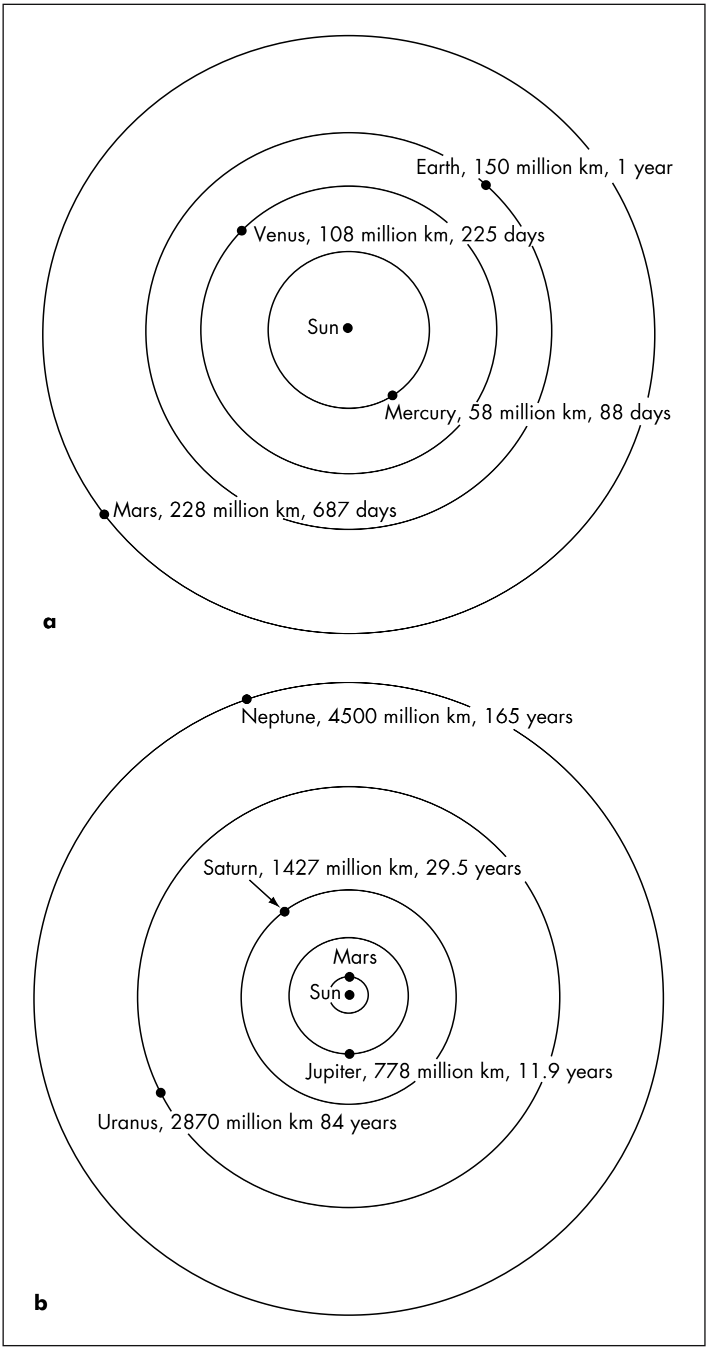

Figure 1.1. The orbits of the inner planets (top) and outer planets (bottom) are shown. Diagram: courtesy of Gerald North. Average solar distances are represented and Pluto is excluded due to space limitations.

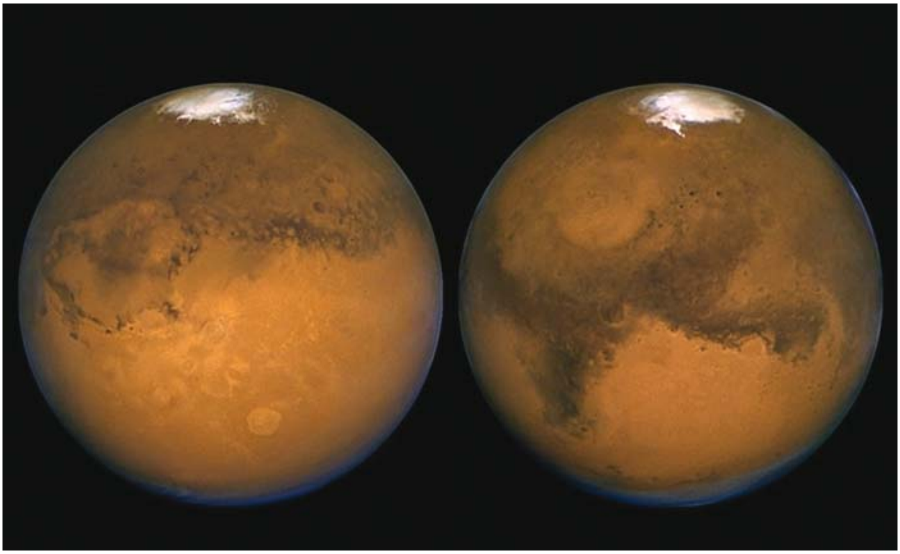

Figure 1.2. Mars, imaged at its closest to the Earth. Image taken by the Hubble space telescope on August 26, and 27, 2003. South is up. The Solis Lacus is shown on the left of the left-hand image; the Syrtis Major is shown on the left of the right-hand image.
Image: NASA/STScI.

Figure 1.3. The 33 × 13 km asteroid Eros, imaged by the NEAR/Shoemaker spaceprobe.
Image: NASA.

Figure 1.4. Comet Hyakutake from Tenerife on the night of March 24/25, 1996. Image: M. Mobberley.

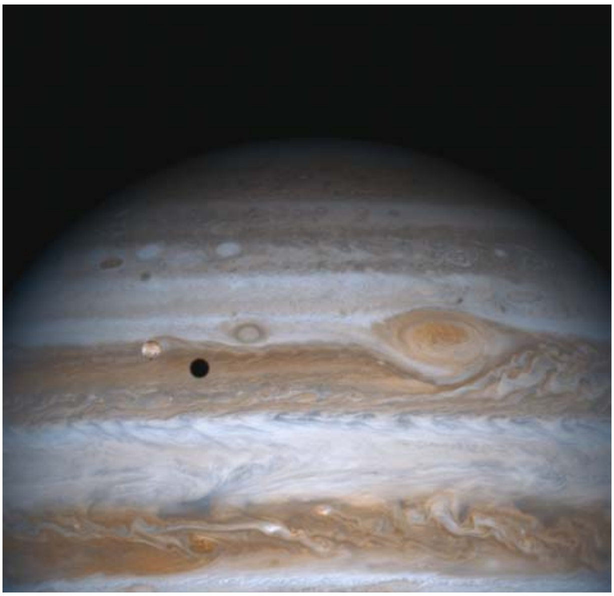

Figure 1.5. Jupiter, Io, and Io's shadow, taken by the Cassini space probe. Image: NASA.

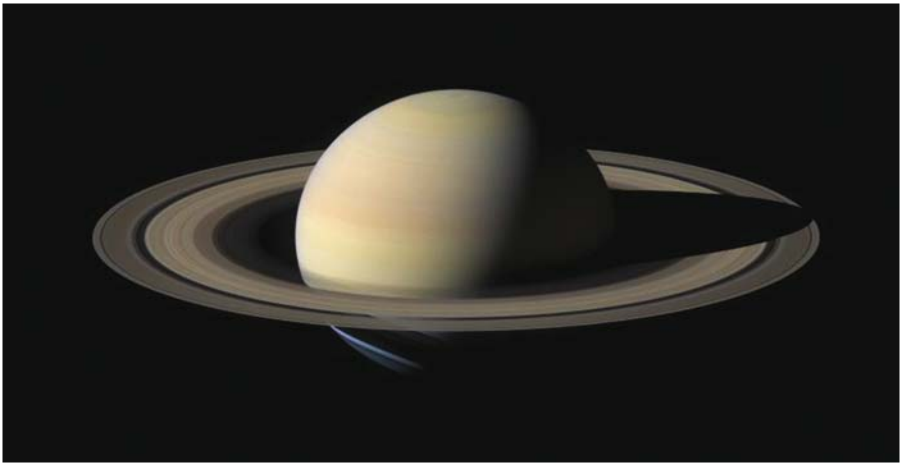

Figure 1.6. Saturn imaged by Cassini. Image: NASA.

In other words, it would take a beam of light, traveling at 300,000 kilometers per second, 4.2 years to get from here to that star. By comparison, light takes just over a second to get from the Moon to the Earth and just over eight minutes to get from the Sun to the Earth. As nobody knows (yet) how to travel faster than light, it can be seen that traveling to other stars in a reasonable timescale is pretty well impossible with current technology. One only has to look at the stars in the sky and see

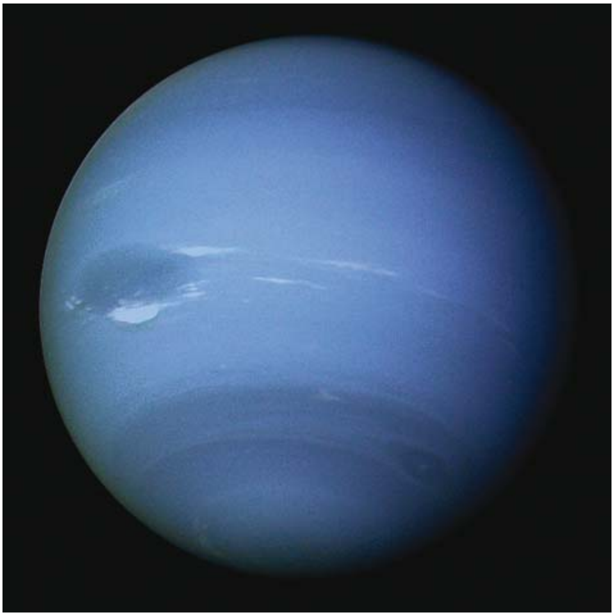

Figure 1.7. Uranus imaged by Voyager 2: Image: NASA.

how faint they are to appreciate how far away they are. Each one would be a blindingly brilliant Sun when seen close up.

In addition to the material that formed our Sun almost five billion years ago, the leftover chunks of heavy elements clustered together and became the planets and asteroids that we see today.

All of the planets in the solar system orbit the Sun in the same direction as the Sun rotates. But, whereas the Sun rotates in 25 days, the planets orbit the Sun in much longer periods. Looking from above the solar system almost everything orbits the Sun counterclockwise. The only real exceptions to this are the long-period comets, which can orbit the Sun in any direction and at any angle.

In order outward from the Sun, the major planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Most (but not all) of the asteroids or minor planets live in the asteroid belt between Mars and Jupiter. These are worlds smaller than our Moon, but there are hundreds of thousands of the smaller (kilometer-sized) ones. As one moves inward from Mars to the Earth and closer to the Sun, we encounter asteroids closer to home, too. These are classified as Amor, Apollo, and Aten asteroids, and some NEOs (Near Earth Objects) are considered a threat to the Earth. The most dangerous ones are called PHAs, or Potentially Hazardous Asteroids.

Locating the Planets

Finding the brightest planets in the night sky, when they are at their best, is not difficult. But it does require a bit of experience in knowing where north, south, east, and west are, and in recognizing the brightest constellations.

The inner planets, Mercury and Venus, are only ever visible in twilight just after sunset (in the west) or just before sunrise (in the east). Actually, Venus can be visible in a dark sky, but I am trying to keep things simple. Mercury is a bright object, but so low down in twilight that it is often very tricky to locate. However, Venus is unmistakeable. If you see a brilliant object that looks like a plane, in a dawn or dusk sky, but it is stationary, that is almost certainly Venus. Apart from the Moon, Venus is the brightest object you will ever see in the night (or twilight) sky.

Moving out beyond the Earth, the planet Mars, when at its best, can be a brilliant object, too. It can never be as bright as Venus, but is always one of the brightest star-like objects in the sky and is distinctly red in color, a dead giveaway to its identity. There is a trick here to finding planets if you are a complete beginner. Bright stars tend to twinkle rapidly, but bright planets do not because they are extended objects, not just tiny pinpoints of light. If you are looking for a planet but are confused by the star patterns, but also know that one of those bright things in "that direction" is a planet, just check if it is twinkling. When Mars comes close to the Earth it is unmistakeably Mars: it is red, not twinkling, but dazzling. But Mars has bright years and dim years (depending on exactly how far away it is) and in the dim years it is just another bright star.

Jupiter, the giant planet of the solar system, is always bright and never twinkles. It is never as bright as Venus but it is usually brighter than Mars. Through binoculars or a small telescope, its largest "Galilean" Moons are obvious: a line of four dots leading out from the planet, some to the right, some to the left.

Next we come to the most spectacular planet in the night sky. Saturn, when its rings are fully open, is an awesome sight. However, despite its appearance through a telescope, it is only as bright as the brightest stars and locating it can be a bit confusing for the beginner. Again, I would recommend the twinkle test if you are confused. As soon as you point a telescope at Saturn you know you have it. Nothing else looks like it! The rings are detectable even at 20× magnification.

The remaining planets in the solar system are not visible with the naked eye. Uranus and Neptune can be seen with binoculars, but finding Pluto requires a decent telescope. Even in the modern era, detecting any features on Uranus and Neptune is a major challenge. In recent years, some astronomers have queried whether tiny Pluto should really be classed as a planet or a big asteroid, but most astronomers prefer to leave it classified as a planet.

Table 1.1 lists the most important facts for the Sun and the major planets in our solar system. I have included our own Moon in the table, as it is a major observing target but, of course, it orbits the Earth, whereas the nine planets orbit the Sun. I have also included the largest minor planet, Ceres, in the asteroid belt, as the asteroid "representative."

So how do you find out where those planets are in the night sky tonight? The best guides can be found in monthly magazines like *Sky & Telescope* or *Astronomy*, or, in the **U.K.**, *Astronomy Now* or the BBC *Sky at Night* magazine. These magazines all feature a circular centerfold pull-out that you hold above your head to simulate the night sky. For those who prefer software, there is a

Table 1.1. Facts about our solar system

Object	Avg. Distance from Sun (millions of km)	Closest to Earth (millions of km)	Orbital Period (Year)	Diameter (km)	Rotation Period
Sun	N/A	149.6 (av)	N/A	1,391,980	25.4 days
Mercury	58	80.0	88 days	4,878	58.6 days
Venus	108	38.3	225 days	12,104	243.0 days
Earth	149.6	N/A	365 days	12,756	24.0 hours
Moon	149.6	0.238	Orbits Earth	3,476	27.3 days
Mars	227.9	56.0	687 days	6,794	24.6 hours
Ceres	400	250	4.60 years	950	9.0 hours
Jupiter	778	590	11.86 years	142,884	9.9 hours
Saturn	1427	1200	29.42 years	120,536	10.2 hours
Uranus	2870	2584	84.01 years	51,118	17.2 hours
Neptune	4497	4306	164.80 years	50,538	16.1 hours
Pluto	5906	4296	247.70 years	2,324	6.4 hours

The average distance from the Sun is given, but the actual distance extremes can be quite significant. For example, Pluto can come closer to the Sun than Neptune, but, on average, it is much further away. Pluto is probably one of the largest of the Trans-Neptunian asteroid-like worlds (sometimes called Kuiper Belt objects). The table above does not list any comets, although many short-period ones (orbital periods under 200 years) are present in the inner solar system. Long-period comets can have orbital periods of thousands of years and so only appear once, before returning to deep space, well beyond Pluto.

huge choice of so-called planetarium packages that will bring the night sky to life on your computer screen. These have the added advantage that you can zoom in on planets and reveal objects like Jupiter's Moons. You can also access masses of extra information on planets, stars, and galaxies by clicking your mouse on the object. The most popular planetarium software packages are those made by Starry Night (www.starrynight.com) and there are various levels of sophistication up to Starry Night Pro 5.0. Other packages are worth looking into as well. My favorite is Guide 8.0, produced by Project Pluto (www.projectpluto.com), which is both powerful and easy to use. For real experts, The Sky, from Software Bisque (www.bisque.com) is the ultimate package and it can integrate with CCD images and control telescopes. Redshift 5 (www.focusmm.co.uk) and Skymap Pro (www.skymap.com) also have loyal followings. However, for absolute beginners, a copy of one of the monthly astronomy magazines is probably your best bet.

Space Probes And Hubble

As well as observing the planets out of sheer fascination and actually seeing them with your own eyes, the images returned by planetary space probes throughout the last few decades have been truly staggering and are well worth tracking down on the web. While manned spacecraft have only traveled as far as the Moon, unmanned robotic spacecraft have traveled to every planet except Pluto. Traveling at speeds as fast as 60,000 kilometers per hour (17 kilometers per second), these probes still take years to arrive at the most distant planets, Saturn, Uranus, and Neptune, indicating just how large our solar system is and how slow our rockets are for interplanetary travel! We also have the Hubble Space Telescope images of the planets and ground-based images from professional observatories. This might all lead one to think that backyard images of the planets are of little scientific use, but nothing could be further from the truth. Space probes have a limited lifetime and a specific set of tasks to perform. It is very rare for any space probe to constantly monitor the whole surface of a planet in the way that an amateur astronomer (or network of amateur astronomers) can. Likewise, the Hubble space telescope has only maintained an occasional coverage of the planets and mainly when they have been at their best. Strange though it may seem, dedicated networks of amateur astronomers are best placed to study the planets, as even ground-based professional observatories tend to concentrate on imaging the most distant objects. Even today, if a dust storm erupts on Mars or two spots start to merge on Jupiter, it is the amateur astronomers who will be collecting the most images. So from your own backyard you can do real science, if you want to.

Of course, to make any serious observations you really need a decent telescope and, ideally, one of about 200 mm aperture or larger. For webcam work you need a PC and a webcam. The only other thing you need is enthusiasm and this book. I would like to think that there is enough information contained in these pages to really inspire a few people to become serious planetary imagers.

Good luck on your journey, but a word of warning. This hobby can become very addictive: you have been warned!

The opposition dates and sizes of the planets Mars, Jupiter, and Saturn are listed below. These are the best times to view these planets. An outer planet is at opposition when it is directly opposite the Sun in the sky. This occurs when it is closest to the Earth and it is crossing the meridian (i.e., is highest in the sky) at midnight.

MARS: 2007 Dec 24; 2010 Jan 29; 2012 Mar 3.

JUPITER: 2006 May 4; 2007 Jun 6; 2008 Jul 9; 2009 Aug 14; 2010 Sep 21; 2011 Oct 29; 2012 Dec 3.

SATURN: 2006 Jan 27; 2007 Feb 10; 2008 Feb 24; 2009 Mar 8; 2010 Mar 22; 2011 Apr 4; 2012 Apr 15.

CHAPTER TWO

Webcams, Plus a "Quick Start" Guide

This book is about observing the Moon and planets using webcams, those small, cheap little cameras that plug into your PC for live video messaging. If you are comfortable with PCs, software, and telescopes and want to get started imaging *now*, read the Quick Start Guide at the end of this section first. However, if you are less confident with imaging technology, but maybe fairly knowledgeable about telescopes, you will need to read on a bit further and, at some point, jump to the full webcam beginner's guide in Chapter 7. If you are new to astronomy *and* imaging, just read the book from start to finish!

To the complete novice, the low-tech webcam approach may well sound crazy. Or you may think I am just advocating astronomy on the cheap, for those with the tightest budgets. After all, there are plenty of expensive astronomical CCD cameras for sale: surely these are better? Well, from a mountaintop observatory enjoying perfectly stable air this might possibly be the case, but, in all other instances, the webcam rules supreme. In the century before digital imaging came along, the visual planetary observer with a quality telescope could see far, far more than the photographer could ever capture, even with huge professional telescopes and the sensitive emulsions of the 1980s and 90s. The reason for this was the Earth's turbulent atmosphere. When you look through a telescope at the Moon or planets they are invariably shimmering and distorting as if submerged in a bowl of water. This is the result of the light from the planet having to pass through the Earth's atmosphere. What a tragedy! For millions or hundreds of millions of miles the light from these planets has hurtled toward the Earth in good shape and then, in the last 30 kilometers, it is distorted by the swirling, turbulent air of our planet. It is like having a 10-meter-deep column of swirling water on top of your pristine telescope mirror! From a time perspective, the light has traveled from distant Saturn for more than one hour to get to the Earth and yet it is distorted only in the last 100 microseconds. Look through any decent-sized telescope at high magnification on a typical night and you can instantly see the advantage webcams possess. The atmosphere blurs, distorts, and ripples the planetary image, but, now and again, there is a fleeting moment of calm, when the atmosphere lets the light pass through to your telescope with little distortion. The eye can spot these good moments because it is imaging all of the time. When that good moment occurs, the observer spots it and the skilled planetary artist makes notes and draws a sketch, based on the best glimpses over many minutes of observing. That is how the keen-sighted planetary observer, with patience and a flair for drawing, worked for centuries. In the last century, a few photographs, or even a few CCD images, would rarely freeze the good moments. Indeed, a few snapshots will not let you even focus a normal CCD camera. Is the image blurred because it is out of focus or because the atmosphere is blurring it? It's impossible to tell. With a webcam like the Philips ToUcam Pro (see Figure 2.1) you can focus in real time, just like looking visually through an eyepiece.

Webcams may be inexpensive, but they have a huge technological advantage. The download speed is blisteringly fast. Even with the original USB 1 standard, the cheapest webcams can transfer 30 frames per second to your PC. This is more than enough to focus with and more than enough to outperform the human eye. However, even a webcam has limitations and we will examine these signal-to-noise considerations in more detail later. If you are still not convinced that a humble webcam, linked to a telescope, can achieve better results than any other detector, then just look at the pictures in this book. As a start, look at Figures 2.2 and 2.3. These are raw and processed webcam stacks taken by planetary imaging master Damian Peach with a 280-mm aperture Celestron telescope costing under $2,000. The final image could almost be mistaken for a Hubble space telescope

Figure 2.1. The Philips ToUcam Pro II, model PCVC 840K.

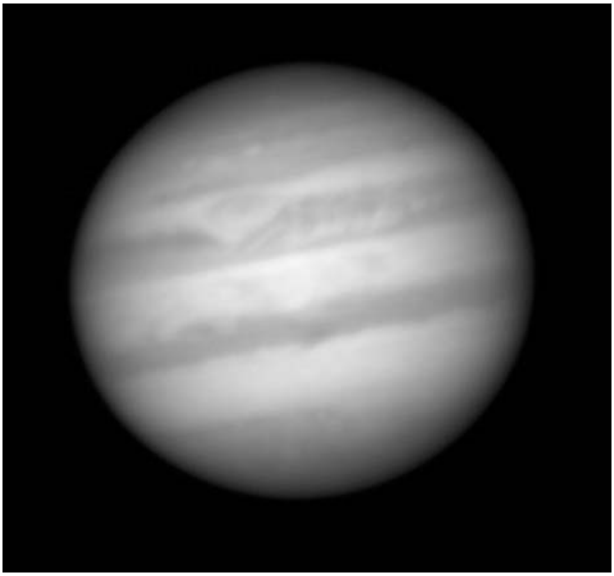

Figure 2.2. A raw stack of 600 webcam frames of Jupiter, taken by Damian Peach, with a Celestron 11 in Tenerife, Canary Islands.

Figure 2.3. The same image shown in Figure 2.2 has been expertly processed by Damian Peach, using techniques explained later in this book.

image, a telescope costing a billion dollars! The way I look at it is as follows: the webcam is the closest thing that technology has produced to the human eye. It captures images fast and is very light sensitive. Only years of research and development by CCD manufacturers like Sony and electronics manufacturers like Philips could produce such a superb, lightweight, quantum efficient, and inexpensive detector like the Philips ToUcam Pro webcam. In fact, the accumulated research has cost multi-millions of dollars, despite your own webcam costing $100 or less. The only downside to a webcam, compared to a custom CCD camera, is that the CCD chip is not cooled, so long exposures (even if the hardware and software allowed it) would be horribly noisy. However, the Moon and planets are bright objects and long exposures are not needed. We want short exposures to freeze the turbulence of our atmosphere and, in this regard, the webcam rules supreme. Suddenly, we can all get good pictures of the planets, even if we have no artistic ability and lousy eyesight!

Quick Start Guide

This Quick Start Guide is designed for those people who have limited knowledge of webcams or image processing but are comfortable with PCs and gadgets, have a telescope, and just want to get up to speed quick. In other words, they want to get some good lunar or planetary images in the next few days, without studying every chapter of this book. If you fall into this category, this section is for you.

Assuming you have a USB-equipped PC newer than 1998, you need to have the following, all of which can be ordered via the web:

1. A webcam, such as the Philips ToUcam Pro, Logitech QC Pro 3000/4000, or the Celestron NexImage. The supplied software can be used to save webcam AVI videos. PC accessory suppliers sell webcams, as does Amazon. Celestron dealers sell the NexImage.
2. A telescope to webcam adaptor (search the web). The NexImage comes with one.
3. Registax software from http://aberrator.astronomy.net/registax/. Again, the NexImage comes supplied with this, and basic instructions for using Registax are supplied with Registax' help files.
4. A Barlow or Powermate lens, preferably from Tele Vue, to enlarge your image scale. Aim at increasing your focal length to five meters to start with. So, if your basic telescope focal length is 1 meter, use a 5× Powermate. If it is two meters, try a 2.5× Barlow, etc.
5. Once you have all this equipment assembled, you simply install the software as directed (webcam and Registax), carry out some trials indoors (with the webcam lens in place) then connect the webcam and adaptor to telescope and start experimenting. A laptop is useful, as is a separate telescope to find the object. I would also strongly advice experimenting on the Moon first.
6. For more advanced techniques, finish reading this book!