Jane Clark

Viewing and Imaging the Solar System

A Guide for Amateur Astronomers

The Patrick Moore Practical Astronomy Series

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Springer

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Preface

This book is written because it has become clear to me that many members of astronomical clubs and societies have a vague idea how to observe the Solar System, but not much detailed knowledge. They have often never used a webcam for example, or if they have, they had a bad experience because it did not produce brilliant results first time.

There seemed to be room for a 'how to' book that did not attempt to take you to being a professional or world class amateur, but rather would give you enough information to encourage you to get going. Very importantly, it should also reassure you that it is OK to produce lousy photos at first. I did not learn this stuff overnight, and nor will you. You will learn it over quite a lot of nights. It does take a bit of determination to produce good results.

I have also completely omitted an important method of Solar System observation: drawing and sketching. This is because I have no skill in that field. I have the greatest respect and admiration for those who can do it, but it is not my thing. I have been a photographer for 40 years and regard it as my imaging medium, although I freely admit that drawing a scene on the Moon does make you think about what's there more than photography does. I became good enough as a teenager to win a handful of prizes for terrestrial photographs of a completely non-scientific nature. The pictorialist in me still occasionally surfaces, for example in Fig. 7.6.

There is something of a philosophical issue about using software to enhance astronomical images: what is 'really' there? Is it really more honest than making a drawing, where the artist has to decide what to include and exclude? I think the answer is, 'No it is not.' Astrophotography is a subjective medium.

My policy on referencing work has been roughly as follows. I have tried to give at least secondary sources, such as books, for other people's ideas, measurements and discoveries. This is much easier in fields where I do not participate, such as providing general information about the planets, because I did not learn any of this stuff by any means other than reading. It has been much more difficult to cite sources for the chapters on equipment and technique, because I learned only some of this stuff by reading. I gathered a lot of the information by watching what fellow astronomers were up to, and by trying out different telescopes etc. I suppose I am relatively gung-ho about trying a technique, and being patient and persistent when it all goes horribly wrong the first time. Therefore these chapters are quite light on citations.

Although astronomy is not an instant gratification game, over the last few years I have gained a lot of satisfaction from my astronomy. It has been worth the hassle, the frustration, the need for patience, the lost sleep and the getting cold. If I can infect you with some of my enthusiasm, I will have succeeded.

Bristol, UK Jane Clark

Acknowledgements

I would like to thank members of the various astronomical societies to which I have belonged, Norfolk and Norwich, West Norfolk, the Society for Popular Astronomy and now Bristol, for encouragement and advice over the years. In particular, although they have probably forgotten what they taught me, I would mention Freddy Rice and Adrian King for introducing me to many techniques, Sue Napper for introducing me to the idea of webcams, Darren Sprunt for much detailed advice, and Trevor Nurse for showing me about binoculars, and Robin Scagell for sending me some advice via the Society for Popular Astronomy’s bulletin board on how to process images of Jupiter with Registax. The small hints these people fed to a receptive enthusiast went a long way.

I would also like to thank the staff of Springer, notably Maury Solomon and John Watson, for encouragement with this book project. My personal life went through a very rough patch recently, and writing this book has been good therapy to help me rebuild my confidence.

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About the Author

Jane Clark is an English amateur astronomer who earns her living as an engineer. She has a Ph.D. in physics and an MBA from Warwick University. She completed 2 years of postdoctoral training at Case Western Reserve University in Ohio before returning to England to begin an industrial career. She became interested in both astronomy and photography as a teenager in the 1970s, photography much more seriously, although as her career progressed and family commitments increased, both interests lapsed. She acquired a telescope in 2006, shortly after completing her MBA, and quickly became hooked on observing. This experience made her realize that astronomy is a lot more fun than business administration. She is a member of Bristol Astronomical Society, and was a founder member of West Norfolk Astronomy Society. Jane gives talks on the Solar System to astronomy clubs, and other societies as diverse as the cub scouts and church wives' groups, and helps with the public outreach activities of her club in Bristol.

Chapter 1

How to Find the Solar System

The Solar System: An Obvious Concept?

Even a book for non-astronomers would not need to explain what the Solar System is. Everyone knows.

Well, almost everyone. Plus, we are still discovering the outer reaches of the Solar System. With those caveats, the principal members of the Solar System are as follows.

Analysis of Table 1.1 shows that it is meaningful to divide the Solar System up into regions. The rocky planets orbit within 2 AU of the Sun. There is then a much larger region from 5 to 30 AU occupied by the gas giants. People talk about an inner Solar System, containing rocky planets, and an outer Solar System, containing gas giants, conveniently divided by the Asteroid Belt. With the ongoing discovery of the inhabitants of the Kuiper Belt, this terminology may become obsolete. The gas giants may turn out to inhabit the middle Solar System.

We did not always know this information. The Solar System had to be discovered. It was not discovered overnight. Indeed dwarf planets further away than Neptune (TNOs, or trans-Neptunian objects) are still being discovered [14]. The alleged Oort Cloud, many times as far from the Sun as Neptune, has yet to be detected with any certainty. If you find it, apply to the King of Sweden for a Nobel Prize.

Much if not most of what we know about the planets has been discovered using space probes. As a result we live in a golden age of Solar System discovery, the like of which has not been seen since the heady days of Copernicus, Kepler,

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Table 1.1 Principal members of the Solar System [1]

Name	Type of object	Distance from Sun (AU)	Diameter (compared to Earth)	Mass (compared to Earth)	Brightness (magnitude)[a]	Years to Orbit Sun
Sun [2]	Star	–	109	333,000	–27	–
Mercury	Rocky planet	0.31–0.46	0.38	0.05	+5.7 to –2.6 [3]	0.24
Venus	Rocky planet	0.72	0.95	0.81	–3.8 to –4.9 [4]	0.62
Earth	Rocky planet	1.00	1.00	1.00	–	1.00
Earth's Moon	Satellite	1.00	0.27	0.01	–2.4 to –12.9 [5]	1.00
Mars	Rocky planet	1.52–1.66	0.53	0.11	+1.6 to –3.0 [6]	1.88
Asteroid Belt [7]	Belt of rocks	1.5–5 approx	0.04 to dust speck	0.0002 to dust speck	+∞ to +6.7	2–10
Jupiter	Gas giant planet with satellites	5.2–5.5	11.21	317.94	–1.6 to –2.94 [8]	11.86
Saturn	Gas giant planet with satellites and magnificent rings	9.5–10.0	9.45	95.18	+1.47 to –0.24 [9]	29.46
Uranus	Gas giant planet with satellites	19.2–20.1	4.01	14.53	5.9 to 5.3 [10]	84.01
Neptune	Gas giant planet	30.0–30.3	3.89	17.14	8.0 to 7.8 [11]	164.79
Kuiper Belt [12,13]	Small icy objects, a few of them several hundred miles across	30–500	0–0.18	0–0.002	+∞ to +13.6	200+
Oort Cloud	Hypothetical region, like the Kuiper Belt, but extending much further	All the way until the gravity from other systems takes over	?	?	?	Centuries+

[a]These values should be treated as approximate. Other authors quote slightly different values

Fig. 1.1 (**a–e**) The principal discoverers of the Solar System: Copernicus, Tycho, Kepler, Galileo and Newton. These men lived over a period from 1473 to 1727, more than a quarter of a millennium. The discovery of the Solar System was by no means an instant process. (**a**), Nicolaus Copernicus portrait from Town Hall in Thorn/Toruń – 1580 (Image courtesy of http://en.wikipedia.org/wiki/Copernicus#mediaviewer/File:Nikolaus_Kopernikus.jpg). (**b**) Tycho Brahe (Image courtesy of http://cache.eb.com/eb/image?id=83677&rendTypeId=4). (**c**) Kepler, 1610, artist unknown (Image courtesy of http://en.wikipedia.org/wiki/Kepler). (**d**) Galileo, portrait by Justus Sustermans (1597–1681) (Image courtesy of the National Maritime Museum, Greenwich). (**e**), Newton, portrait by Godfrey Kneller (1646–1723) (Image courtesy of http://commons.wikimedia.org/wiki/Isaac_Newton#mediaviewer/File:GodfreyKneller-IsaacNewton-1689.jpg)

Galileo and Newton. Looking back to the 1960s, when many of us first read astronomy books as a child, it is quite remarkable what scientists did not know about planets (Fig. 1.1) Some values of moon masses from the 1970s now look laughable [15]. This reflects the quality of the data, not the source.

The space probes did more to change popular perceptions of the planets than the scientists had managed in the previous 100 years. For example, the scientists very quickly discovered that life and canals could not exist on Mars, but the images of an arid desert from NASA were what really knocked this popular myth on the head. The first close-up images of Jupiter's Great Red Spot did the same.

For the first time, people could see that it was a giant whirlwind, and they did not need doctorates in science to understand what they saw.

Some nonsensical legends have proved to be harder to kill. For example: "If you could put it in a bath of water, Saturn would float." No, it would not.

First of all, the temperature of Saturn's upper atmosphere is rather colder than that of liquid water. Further, the gravitational pull of Saturn on any imaginary vat of water in some imaginary gravitational field would be significant; and finally, whatever created this gravitational field would be have to be large enough to rip Saturn apart. It would also have to be a rocky body like Earth, at such a temperature that water would be liquid. Unfortunately, Earth is the largest known body like that. The four planets bigger than Earth are gas giants, not rocky planets. The only bigger objects we know of are stars, which are gaseous and unfortunately rather too hot to sustain liquid water oceans. In short, there aren't any bathtubs to float Saturn in. (The properties of extrasolar planets are assumed from theoretical models. By great ingenuity, we have discovered quite a bit about them, and they tend to be low density objects, not high density rocky planets [16]. High density rocky exoplanets are only just being discovered at the time of writing. Who knows what will be found in the near future?)

Before printing was invented, knowledge did not diffuse through society to anything like the same extent as afterwards. The technology for copying books was a monastery full of scribes. The ancient Greeks did not even have monks. Therefore, when one of their number, Aristarchus, did discover that the planets and Earth orbit the Sun, almost no one found out. His knowledge completely failed to become mainstream.

Instead, the disastrously wrong model of Ptolemy became accepted, and even enforced on pain of severe penalties. The Church held Galileo under house arrest for years for questioning Ptolemy [17]. Ptolemy thought everything went around Earth. Once telescopes became available to astronomers, Ptolemy's theory of the universe rapidly lost what little credibility it still had.

It is often supposed that nothing further happened between the fall of ancient Greece and the time of Copernicus. The evidence does not bear out this view [18]. In fact, the data used by Ptolemy were gradually refined by medieval scholars. Copernicus knew that, and worked with better data than Ptolemy. The next great theorist, Kepler, worked with yet better data, collected by the Dane, Tycho Brahe. Galileo of course was the first great astronomer to use telescopes. Newton had data from much better telescopes, and invented the reflector telescope.

The data improved as time went on. This is an absolutely key point about astronomy. The theorists can always move faster than the observers. Theory usually catches up very quickly with new observations. The rate determining stage in making progress is almost always our ability to observe.

So what happened? Copernicus was really a refiner of Ptolemy, who had everything including Earth moving along circles-within-circles about an empty point in space [19]. Given that the world was then about as friendly to radical scientists as cats are to mice, Copernicus had the good sense not to publish until he was dying. His publisher put some conciliatory words at the front of the book to appease the ecclesiastical authorities, something to the effect that Copernicus wasn't actually telling the truth, just messing about. The ecclesiastical cat did not pounce on this particular mouse. He was soon to be dead anyway. Mind you, they didn't make this ecclesiastical canon a saint either.

Galileo declined to play the game of denying what he saw as the plain truth. Diplomat he was not. He got into big trouble, but this proved to be a Pyrrhic victory for the Church. It became plain that they had made fools of themselves, and scientists were not again persecuted until the totalitarian regimes of the twentieth century, but that is another story.

The real discoverer of the Solar System was not Copernicus but Kepler [19]. Johannes Kepler lived his life along the European fault line of the Reformation, between one round of religious wars and another. He escaped persecution, but his mother would have been burned as a witch had he not exploited his prestige as a professor to scare the witch hunters off. In other words, he lived in dangerous times.

Why then did he escape the fate of his contemporary Galileo? One of the main reasons may have been that Galileo was a very clear communicator, whereas Kepler was darn near incomprehensible. It took a man of the caliber of Isaac Newton to disentangle Kepler's writings and sort the wheat from the chaff [19]. Nobody knew that Kepler was a guy they should have felt threatened by. Even Galileo did not bother to answer Kepler's letters.

Anyway, what Kepler found out was that the planets, including Earth, go around the Sun, not in circles or circles-within-circles, but in ellipses – ovals. He also found out that the Sun is not at the center of these ovals, but at an abstruse mathematical point called the focus. An ellipse has two focuses or foci (depending whether you have read the bluffer's guide to Latin). They are not at the center of the ellipse. According to Kepler, one of the focuses of the planet's orbit is located at the Sun's center and the other is not. There is a good popular introduction to ellipses at http://www.coolmath.com/algebra/25-conic-sections/02_ellipses-intro.htm, although the planetary orbits are much more nearly circular than this diagram implies (Fig. 1.2).

Newton modified this. He realized that the Sun and the planet both orbit about a point called the center of mass (or in loose parlance, center of gravity) of the two bodies. For all planets except Jupiter, this center of mass is well inside the photosphere, the visible part of the Sun.

Kepler felt sure that there must be a simple(ish) physical reason why the planets do this. Newton found this reason: they are pulled by the same gravity that pulled the apple off the tree, allegedly onto his head.

Newton is not considered to be one of the world's three best-ever mathematicians for nothing. He showed that his laws of motion, plus his law of gravity, were enough to predict the movements of the Solar System bodies to within an accuracy that the best observers could measure. He also showed that the same is true for comets.

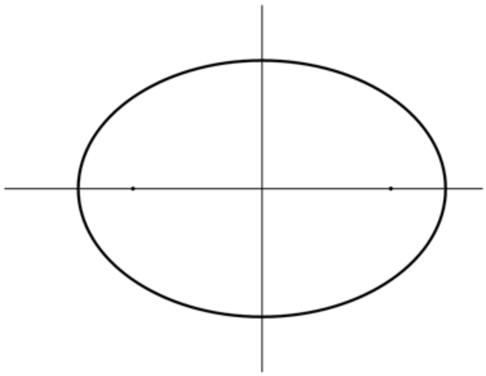

Fig. 1.2 An ellipse showing the two foci (the *dots*). When the two foci are both in the middle, the ellipse becomes a circle. In practice, the only planets whose orbits are obviously non-circular to the naked eye are Mercury and Mars. Even they have orbits much less oval than the ellipse shown (Diagram by the author)

The Naked Eye: A Stripped-Down Account

Some components of the Solar System are hard to miss. The Sun may be the only Solar System object that can be detected by blind people. You can feel its heat. Those of us fortunate enough to be sighted can easily see it. Henceforth we will assume that you have reasonably good eyesight.

The Moon is very easy to see with the naked eye.

'Naked eye' is really shorthand for 'without binoculars or a telescope.' In other words, it presupposes that you have access to glasses or contact lenses to correct your vision for focusing and eye misalignment problems. Of course, different people can see different things with the 'naked eye.' It is no consolation to the rest of us that a very few people can see the phases of Venus without optical help [20], or that our vision deteriorates with age. Vision quality is also dependent on gender. Women tend to have more color receptors than men. Henceforth, it will be assumed that your 'naked eye' is corrected with glasses or contact lenses if necessary.

If you wear varifocals, you will quickly discover that the distance-vision part of the lens has a 'sweet spot.' This is the one point at which a star looks sharp. Stars anywhere else in your field of vision are out of focus. To find this point, look straight ahead at a star and turn your head until the star becomes sharp. If you can't find this point you may need new glasses. The same phenomenon occurs with other types of glasses, but it is less pronounced than with varifocals.

Lest anyone should feel inferior because they need glasses, it should not be forgotten that even the Hubble Telescope, one of the most successful optical instruments known, needed a spectacle lens to correct a manufacturing boo-boo. When NASA finishes with it, I'm sure there would be no shortage of astronomy clubs willing to take it over. Let's face it – with that corrective lens, it's a *fabulous* telescope. So don't be ashamed of your spectacles.

Having said all this, five planets are naked-eye visible: Mercury, Venus, Mars, Jupiter and Saturn. Once a decade or so, a comet becomes naked-eye-visible for a while. Uranus is claimed to be marginally naked-eye visible, but the same question could be asked about that as about the Andromeda Galaxy. If it really is naked-eye-visible, how come the ancients did not discover it? They never had our problems with light pollution.

Nothing else in the Solar System is visible to the naked eye.

Flashlights

Astronomer's workstations are the red light district of their backyards. Why? Because your eyes' dark adaptation is not ruined by red light. It takes a good 20–30 min in the dark for your eyes to build up sensitivity. The mechanism involved is quite complex [21]. Eventually, you come to see really well in the dark, although you don't have much color vision at night.

White or blue light destroy your dark sensitivity in an instant. This is to protect your vision system from overload. You then need another 20–30 min to dark-adjust.

Red light does not affect all the dark adaptation mechanisms, so you regain your dark vision quite quickly after using a red flashlight. Even so, it is smart to point the light away from yourself, because even red lights emit some blue light. You could use bicycle rear lights. These days LEDS have replaced incandescent bulbs. They produce less unwanted blue light and use less power, so the batteries last much longer.

You can also buy red LEDs to clip onto the peak of a baseball cap. Although they free up your hands, peaked caps can be a pain at night. Yes, they can shield annoying streetlights, but they also make it hard to see the sky, and you get a lot of rude surprises when you bang the peak into a carefully aligned telescope and knock the wretched thing back out of line. That kind of thing is very easily done in the dark. The modern fashion for curved peaks also makes life difficult for varifocal eyeglass wearers. There are lens regions in varifocals that don't offer clear vision. Curved peaked caps mean that unless you adjust the cap carefully, you can only see out of the useless bits of your varifocals. Very irritating.

No doubt the fashion for curved peaks was dreamed up by some 12-year-old whiz kid who does not even know what varifocals are. But fashion is fashion. You have to have street cred.

Telescopes

Unfortunately, it's perfectly legal to be really stupid and look at the Sun through a telescope or binoculars. You will do that exactly once per eye, because you will be blinded and unable to do it again. Better still, don't do it at all. Ever. The visual receptors in your eye have no pain nerves, so you won't even feel that you have fried them. It takes no time at all.

Do you know who discovered this? Galileo, the first man to use a telescope for astronomy. He ruined his eyesight. Just to show that this danger is real, it is perfectly possible to melt a telescope eyepiece or a finder scope cross-hairs by pointing a scope at the Sun.

Portable binoculars are of limited use, except for the Moon. (In this book, Moon with a capital "M" will be used to refer to Earth's Moon, and moon with a small "m" will refer to planetary satellites in general.)

The instrument of choice is a telescope on a mount. A 6-in. (150-mm) telescope will find all the planets, and the brightest asteroids. In theory an 8-in. (200- mm) telescope will enable you to see Pluto from a dark site, but only just. Pluto and the asteroids are just dots in amateur telescopes, so you need to wait for them to move before you can identify them. They are really photographic objects.

Please stick to celestial objects, though. The story is told of a college professor who got into an interesting debate with the campus cops because the Moon was just above a girls' dorm from where he and his telescope were.

Telescopes are important enough to warrant a whole section to themselves, later in the book. We won't go through optical theory. We have no great preference among the various types. A telescope is a telescope, and all but the cheapest and nastiest will do the job.

Do resist the temptation to buy your kids inexpensive telescopes for astronomy. They really are awful, and a bad experience of stargazing can be worse than no experience. A reasonable minimum is the 3-in. (76-mm) telescopes that have recently become available. They retail for about £35–£50 in the UK and about $65 in the USA.

If you can find them, an 8-in. telescope will certainly show Neptune as a disk and a 6-in. telescope will show Uranus as a disk. They are both bluish in color. The astronomy magazines claim that they are binocular objects. If you know where to look, you can certainly see them in binoculars. But binoculars are close to useless for a first look to try to find them. You can't easily tell either planet from stars in 10×50 binoculars.

Which Constellations Are Likely to Contain Solar System Objects?

The diagrams in books usually show the Solar System as fairly planar. The planets and stuff all go round the Sun the same way, and all lie roughly on a plane.

This plane is called the plane of the ecliptic. From Earth it looks like a line going all the way around the sky. Figure 1.3 shows the constellations through which the ecliptic passes.

Not all 13 of these constellations will be visible at once. If the ecliptic is close to the horizon, as it is in your summer if you are away from the tropics, only a few of these constellations will be visible. Rather more will be visible in your winter, when the ecliptic runs high in the sky, again if you are away from the tropics.

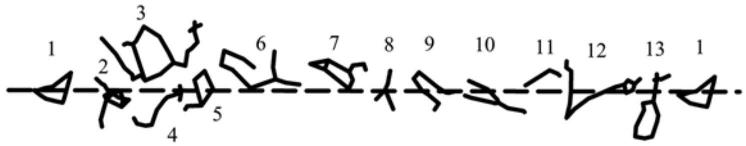

Fig. 1.3 Constellations through which the *ecliptic line* passes. Key: 1. Capricornus, 2. Sagittarius, 3. Ophiucus, 4. Scorpius, 5. Libra, 6. Virgo, 7. Leo, 8. Cancer, 9. Gemini, 10. Taurus, 11. Aries, 12. Pisces, 13. Aquarius. Capricornus is repeated to show how the *ecliptic line* runs right around the sky (Diagram by the author)

The constellations' orientations depend on where you are and the time of night. They rotate slowly through the night. They are drawn as they appear from the northern hemisphere. If you are in the southern hemisphere, these stick diagrams will appear to be upside-down to you. Of course, they do not suddenly invert at the equator. If you observe from close to the equator, they will appear to be turned on their sides compared to this figure.

British, northern Canadian and Alaskan readers are far enough north that they will not see the whole of Sagittarius and Scorpius. (Of course in summer in Alaska, the Yukon and Nunavut, it doesn't get dark enough either.) You have to be an awfully long way south in the southern summer for the corresponding phenomenon to occur. The Falkland Islands (pop. 3,100) are the southernmost populated English-speaking location at about 52°S. Castor, alpha Gemini, just about peeps over the horizon there in January. Even New Zealand is roughly antipodal to Spain, in the far south of Europe. The populated parts of the Southern Hemisphere are closer to the equator than those in the Northern Hemisphere.

The constellations through which the ecliptic passes are: Sagittarius, Capricornus, Aquarius, Pisces, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius and Ophiuchus. These are where you will find planets. The asteroids and dwarf planets may stray a constellation or two north or south of these, because their orbits are inclined at a few degrees to the plane of the ecliptic. Comets can be quite out of the plane of the ecliptic, and show up elsewhere in the sky.

Broadly speaking, if you are in the English-speaking parts of the Northern Hemisphere, the Solar System will tend to be to your south. The English-speaking parts of the Southern Hemisphere extend within the tropics. If that is where you are, the ecliptic constellations may be overhead or even to your south. Outside the tropics they will be to your north in the Southern Hemisphere.

If the only constellation you know is the Big Dipper (also called the Plough or Ursa Major) or Orion, don't bother looking there for planets. The only ones you will find will be outside the Solar System; and you will need some very fancy equipment to find them. Unfortunately, you will need to learn some more constellations. At the very least, you will need to learn to recognize them with a star chart or computer screen in front of you.

Two clues with the naked-eye planets (Mercury, Venus, Mars, Jupiter and Saturn) are that they are brighter than most stars and they do not twinkle except when extremely close to the horizon. Venus and Jupiter are brighter than any stars. The planets are also visible at dawn after the stars have gone, and become visible at dusk before the stars. So if you see a “star” that doesn’t twinkle, and it is in the general direction of the equator, there’s a good chance it is a planet. To the naked eye, Mars is noticeably orange. Venus and Jupiter are bright white. Saturn is slightly yellow, and Mercury can look yellow or white.

The name “planet” comes from a Greek phrase *aster planetes*, meaning ‘wandering star’ [22]. The planets move relative to the stars. This won’t help you on a single night’s observing, but over a few days the movement is quite noticeable. The nearer to the Sun the planet, the more it moves. Neptune only moves by about 3° over a year, so you will have to work hard to detect its movement. With a digital SLR and with a fair bit of care and patience, you can certainly record its movement, and in principle, could even work out its orbit [23]. Uranus doesn’t wander much either, but the naked-eye planets all do.

Mercury and Venus are closer to the Sun than us, so they are never far from the Sun in the sky. You only see Mercury at dawn and dusk, never in a dark sky. At high latitudes, such as in the British Isles, Mercury can be hard to find at all. Venus can be around for an hour or two after sunset or before sunrise, depending where in its orbit it is. You will not see Venus at midnight.

Mercury and Venus are called inferior planets, because they are closer to the Sun than us. All the other planets except Earth are called superior planets, because they are further from the Sun than us. This not very complex jargon does not carry any moral implications. Jupiter is not better or worse than Venus.

Maps and Software

Printed maps of the sky are fine when you are indoors, but they are not so good for outdoor use at night. They get covered in dew, you need a flashlight to see them, and you really need to hold them upside down to compare them with the sky. Holding a red flashlight at the same time, while trying not to step on whatever your kids left on the lawn that you did not see because it’s dark, is not conducive to a good observing experience.

So-called planetarium software is a lot easier to use. An example is a free package called *Cartes du Ciel*, downloadable for free from http://www.stargazing.net/astropc. There are other packages that come with some telescopes, and even some you can pay for (Fig. 1.4).

It’s obviously nicer if you have a laptop computer for this software, but a desktop one will do fine. Either way, take sensible precautions to keep water out of the electrics outdoors. Dewfall is not a huge problem for the computer and monitor, because they give off enough heat to stay dry. As laptops become more energy efficient, that may cease to be the case one day. For now the main electrical issues are the connections and the wiring.

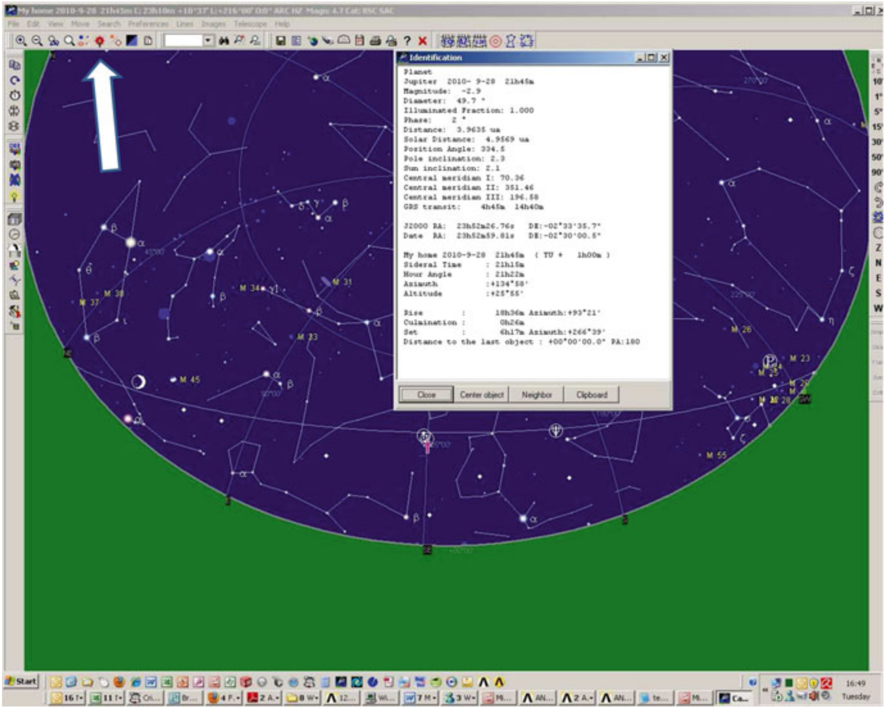

Fig. 1.4 A screen dump from Cartes du Ciel. The inset window contains the information you get about Jupiter when you click on it. Notice the *red* light bulb icon (*arrow*) (Image by the author)

Cartes du Ciel runs on Microsoft Windows™. If you prefer a different operating system, you will need to make sure it has a way to run Windows software. The *Cartes du Ciel* website says it runs on versions of Windows up to XP. It can be run under Windows Vista without problems.

One of its nicest features is the red light bulb icon. If you click on this, your whole computer switches to red-based colors. This makes it feasible to use this software outside in the dark. Your computer screen is more or less vertical, and the stars look the same way up as you see them in the sky. You can use dead time while exposing photographs etc. to sit and learn the sky from *Cartes du Ciel*. It is well worth the effort. Do also check how to dim your computer screen. Practice this in the light. Learning stuff in the dark on a cold night is always that bit harder (Fig. 1.5).

However, while you build up your knowledge, *Cartes du Ciel* will plot the ecliptic line if you ask it to, and will show the planets. It knows the time and date and will follow the movements of the planets. You can download add-ons to show asteroids. There are squillions of these, but it is inadvisable to display more than 20; otherwise you'd never see anything.

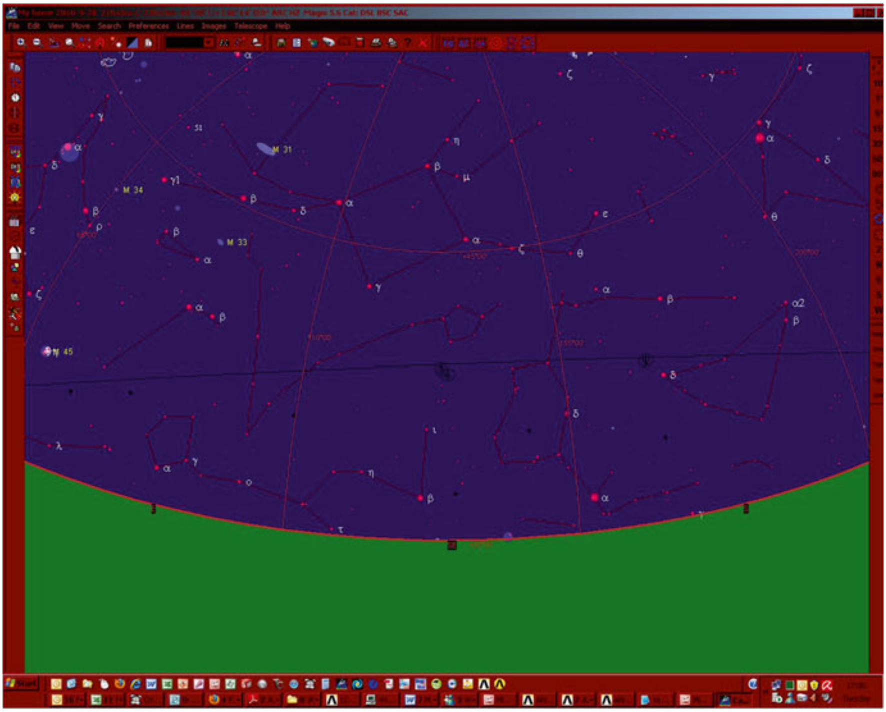

Fig. 1.5 A screen dump from Cartes du Ciel after the *red light bulb* has been clicked. Notice how Windows switches to *red*-based colors. It's a pity there is still a *green* horizon (Image by the author)

You need to program in your location using longitude and latitude. You can get these from www.muiltimap.com. Type in your address, and it will give you your longitude and latitude. This website works for the United Kingdom, the United States, Canada, Australia, New Zealand and South Africa. Once you have done this, *Cartes du Ciel* defaults to the time and date stored in your PC. You can override these to find out where Mars will be next week or whatever (Fig. 1.6).

You can even put in the dates when Galileo first observed the satellites of Jupiter, and reproduce the diagrams in his book. As it happens, he timed his observations to take place before the Moon rose. Presumably this was not accidental.

This is not the place for a *Cartes du Ciel* tutorial. The software is rich with capabilities and easy to learn (Table 1.2).

The naked-eye planets do not twinkle like stars. Their glow is constant as long as they are well clear of the horizon, where not even the Sun is undistorted sometimes.

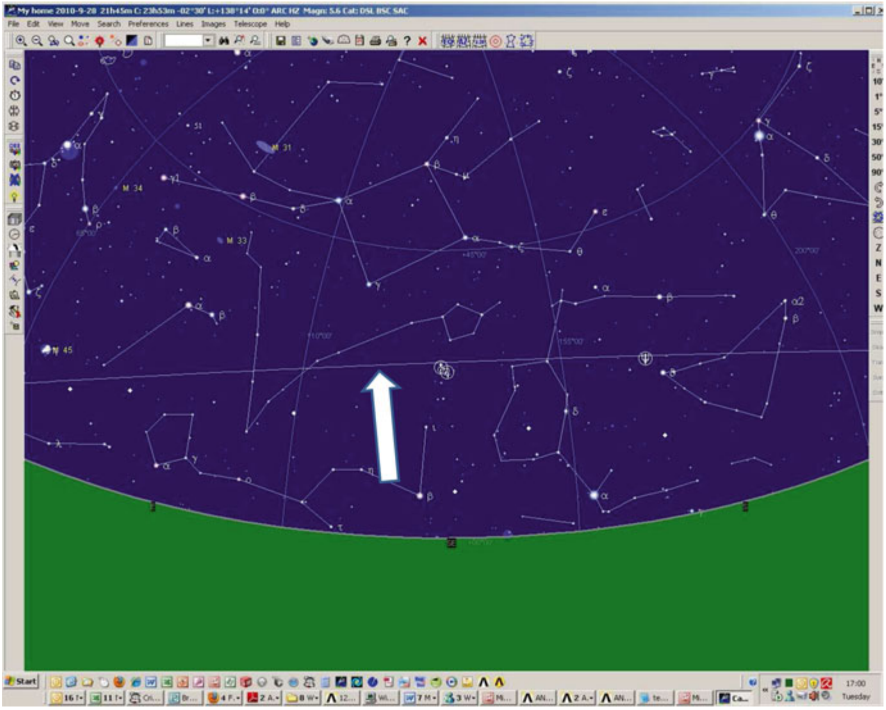

Fig. 1.6 A screen dump from Cartes du Ciel showing three planets along the *ecliptic line* (*arrow*). Three planets are shown by their symbols, which are listed in Table 1.2 (Image by the author)

Table 1.2 The symbols used for the planets. These mostly have ancient origins, although since Pluto was not discovered until 1930, its symbol is obviously not ancient. Since it is common, the comet symbol has been added

Planet	Symbol
Mercury	☿
Venus	♀
Earth	⊕
Mars	♂
Jupiter	♃
Saturn	♄
Uranus	⛢
Neptune	♆
Dwarf planet Pluto	♇
Dwarf planet Ceres	⚳
Comet	☄