Michael O'Brien

A Deep Sky Astro-photography Primer

Creating Stunning Images Is Easier Than You Think!

The Patrick Moore
Practical Astronomy
Series

The Patrick Moore Practical Astronomy Series

Series Editor

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The Patrick Moore Practical AstronomySeries is a treasure trove of how-to guides for the amateur astronomer. The books in this series are written for hobbyists at all levels, from the enthusiastic newcomer to the veteran observer. They thus go far beyond more general, popular-level books in both scope and depth, exploring in detail the latest trends, techniques, and equipment being used by amateur astronomers around the world.

You will find herein a diverse list of books on constellations, astronomy catalogues, astrophotography, eclipse chasing, telescope equipment, software, and so much more. All books in the series boast full-color images as well as practical sections for putting your newfound knowledge to use, including star charts and target objects, glossaries, hands-on DIY projects, troubleshooting walk-throughs, and a plethora of other helpful features.

Overall, this series bridges the gap between the many introductory books available and more specialized technical publications, providing digestible, hands-on guides for those wishing to expand their knowledge of the night skies.

A Deep Sky Astrophotography Primer

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Springer

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Michael O'Brien 27th September 2021
Lancashire
UK.

The following list of people and companies have very kindly allowed me to use images or screenshots from their software.

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Chapter 1

Introduction

This book is designed as an introduction to the wonderful field of amateur astrophotography. Most amateurs enter this field after visually observing and wanting to produce images that they can keep and share as they explore the amazing universe that we find ourselves inhabiting. This may be done for purely aesthetic reasons as the objects that we may take images of have a striking beauty all of their own. It may also be that the images are being taken in order to use them in an area of study; whilst the basics of taking these images are similar there are subtle differences. This book is aimed getting you to a level of astrophotography where you are knowledgeable enough to take the type of images that you are interested in. For lots of people this will actually be a mixture of both, images that they can print and frame or use on a website and images that they will use in some area of study.

In order to achieve this you will learn about all the things that make up a successful telescope imaging system, and I will give a brief introduction into processing the images that you have taken time and effort to capture.

All of this has been made possible by the advances and availability to amateurs in the fields of computers, digital imaging, filters and software. It has advanced amateur astrophotography to the point where the images taken by amateurs from light polluted back gardens now rival and in many cases are better than the images taken by professional observatories on mountain tops in the 1970s.

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_1,

This does come with a cost however both financially and in terms of the investment in learning how to use such sophisticated equipment. This should not be seen as an obstacle or difficulty but as an opportunity to learn new skills that will enable you to fully appreciate and get the most out of the equipment you are using.

The Impact of Computers

Computers have had an impact in every aspect of amateur astrophotography from electronic star charts to fully automating a telescope system such that it looks up a list of objects to image that night. It finds the first object centers it in the field of view, finds a suitable guide star and locks onto it selects a filter checks focus and then starts taking the images changing filters and refocusing as necessary.

It is now possible to control your telescope using either a smart phone, tablet computer or a laptop from inside your observatory or from a comfy chair in the house or anywhere else in the world for that matter. It's really great to have the choice of spending your imaging time out with the telescope or in the warm as the mood or need takes you.

We are at a point in time where the amateur astrophotographer with relatively standard equipment located under urban skies can take images of most objects in professional catalogues down to magnitudes vastly fainter then it is possible to visually observe. It is also possible to take part in citizen science projects and contribute to our understanding of the way the universe works.

Fully automated supernova hunts in other galaxies and taking images of some gravitational lensing artifacts are easily within reach of the serious astrophotographer.

Whilst not a deep-sky project along with my own deep sky imaging I have just started to participate in the "Target asteroids" project run by NASA to both analyze professionally taken asteroid images and to submit my own images to be used for research and refining information on orbital parameters and determine their parent asteroid families. This is part of the OSIRIS-REX 800 million dollars 7 year mission to return a sample from the asteroid Bennu to Earth and will then be followed by at least 2 years of sample analysis.

Bennu was discovered on 11th September 1999 and is a member of the group called PHA or potentially hazardous asteroids and comes close to earth every 6 years and has been chosen due to its earth like nearly circular orbit and a 6 degree inclination to earth's orbit.

Bennu has an almost circular orbit and its diameter which is 492 meters also results in it having a slower rotation speed that is suitable for the OSIRIS REX spacecraft to approach and extend a telescopic sampling arm which will employ a touch and go technique. The spacecraft will aim and fire a jet of nitrogen gas which will kick up small rocks and dust which will be collected for return to earth.

As you can see it is an exciting and very rewarding time to be an amateur in the field of astrophotography.

Michael O'Brien March 2020

Aims of This Book

Before we go any further it is important to know that the quality of the results that you will achieve are not only dependent on the equipment you have available but also to a larger degree on your knowledge and skills.

Any astrophotographer who looks back at images that he or she has taken just a year before will notice a big difference in the quality of the images when compared with more recent ones.

This is even applicable if they are taken with exactly the same equipment. This is simply due to the fact that you continuously learn how to push the equipment to perform better as you learn and refine new techniques.

You will see the biggest differences in the early days of imaging and the first images that you proudly show to family and friends will rapidly be surpassed by better and better ones. This isn't to say that it will become matter of fact because you will strive to image harder and more difficult targets which will draw on your current experience and push you to develop it even further.

This book has been written to enable you to take high quality deep- sky images using your own equipment avoiding many common mistakes and with the least amount of frustration so that you have a leg up on the learning curve that you are starting.

How to Achieve Successful Imaging

You will follow a structured path with each session building on the previous one and with each step explained so that it is easy to understand. Following this path you will not only make faster progress but you will also understand your system thoroughly and will therefore be better equipped to get the most from it. You will also develop the skills and knowledge to help you when things don't go as planned. Doing things this way means that you can start with a very basic level of knowledge and work at your own pace to take your imaging to the level that you wish to achieve.

A Basic Overview of the Steps Required to Setup and Use an Astronomical Imaging System

1. Setting up an imaging system quickly and efficiently.
2. Leveling the mount, not essential but advisable.
3. Providing power to your system safely.
4. Setting the latitude and longitude.
5. Setting the time accurately and why it's important.
6. Polar aligning the mount.
7. Setting an accurate home position.
8. Performing a 3 star alignment.
9. Finding the first object and observing it visually.
10. Fitting a camera to your telescope and using it to take your first image.
11. Focusing your camera.
12. Determining the exposure time to use when taking images.
13. Doing a quick stretch or process to allow the images taken to be assessed.
14. Assessing the first images and working out how to improve them.

Advanced Operation

1. Focusing a camera accurately with a Bahtinov Mask.
2. Correct use of a comma corrector.
3. Improving polar alignment.
4. Combating light pollution with filters.
5. Reducing star trailing and extend exposure time by Auto guiding.
6. Locate and center objects by using plate solving.
7. Combating Dew.
8. Take RGB and narrowband images and the basic steps needed to process and combine them.

You will also find where appropriate a description of the tasks that you will need to carry out in order to complete the setup steps easily. The items listed are either necessities or will make the task easier to complete. I have included descriptions of how to setup and use the software I use to a basic level that will allow you to produce great images quickly and easily.

I have included photographs and illustrations to show how to setup the mount and identify the controls to be used during the setting up process as this is something you will be carrying out for real in the dark. I have given suggestions of suitable objects to take your first images of including charts to help find them. There is advice on how to determine exposure times and also processing the images that you take. I have written a chapter on troubleshooting when things are going wrong that aims to guide you to ask the questions that will hopefully lead you to a solution to the problems that you are having. I have also listed some common problems and their possible solutions which may also help. In short I have done my best to give you the benefit of my experience which will hopefully make your journey into astrophotography shorter and easier.

Chapter 2

A Brief Overview of Deep-Sky Imaging Equipment

The process of imaging a deep-sky object is in theory very simple. It involves a telescope or a basic camera and lens that tracks the movement of the object across the sky for as long as it takes to gather enough light to produce an image.

A deep-sky imaging system therefore has to be capable of accurately following the path of an object across the sky. This is the job of the telescope drive system. The drive has to be aligned with the polar axis of the earth, as it is the earth's rotation that we need to counteract. This all has to be done very accurately for extended periods of time. Otherwise, tracking errors will show up as star trails and blurry images that lack the fine detail we are trying to record. Fortunately, even at the budget end of equipment, it is possible to produce fantastic results.

Deep-Sky Imaging Setups

The following is a description of imaging setups capable of producing truly remarkable results. Which of them is the most suitable for you depends on the objects that you are interested in imaging. Like any hobby, it is best to start with basic equipment so you can decide if it really is for you. I would therefore suggest that you start with either the basic *Wide-Field Imaging System* or *The Minimal Deep-Sky Imaging System*. These are both excellent

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starters that will teach you the basic skills needed to setup and align an imaging system and are capable of producing great results.

Wide-Field Imaging Setup

- Camera and lens
- External interval timer if your camera is not equipped with one
- Simple equatorial drive system
- Tripod
- Power Supply

The picture in Fig. 2.1 shows an autoguider, which is desirable but not completely necessary. This type of setup does not have to be aligned quite as accurately as a full imaging setup, as it generally uses a shorter focal length, meaning the images will be of a lower magnification and tracking errors will not be quite as obvious. A wide-field imaging setup can also be quicker to set up and is not as heavy as a full imaging setup. It can therefore be very

Fig. 2.1 Wide-field imaging setup. (Credit: Dave Fielding)

handy for star parties or even on holiday, where space and weight may be limited. In its smallest form a camera with a wide-angle lens and one of the many new lightweight drives is an economical, easy, and effective introduction to astrophotography. For these reasons, many astrophotographers have a wide-field system in addition to their usual deep-sky imaging system.

For deep-sky imaging, a wide-field setup is more suited to larger objects, such as M31, the Andromeda Galaxy, and M33, the Triangulum Galaxy. The Rosette Nebula, North America Nebula and Pelican Nebula are also great targets, to name just a few.

This setup will indeed image many of the smaller deep-sky objects, however, to see them in any great detail requires a longer focal length system hence—a telescope—due to the small size they will present on the imaging chip of the camera. You can appreciate this limitation using a Field of View app or webpage calculator, which will show an accurate representation of how a given object will fill the frame of your camera. This is very simply done by entering the focal length of the lens or telescope and camera and then choosing an object you are interested in imaging.

Here is the address of an online FOV Calculator/Telescope simulator:

https://www.skyatnightmagazine.com/astronomy-field-view-calculator/

Minimal Deep-Sky Imaging Setup

- Camera
- Telescope
- Equatorial drive system
- Solid tripod
- Power supply

A minimal deep-sky imaging system can also be a good starting point for the aspiring astrophotographer. The setup needs to be done with care and accuracy to get the best results. It is capable of taking excellent images and carrying out serious work if desired. Many astronomical objects will be within reach of this type of setup depending on your local sky conditions. It is a great start for the experienced visual astronomer looking to transition to imaging, and you may even have most of the requirements already.

This is also a good choice of imaging setup for taking to dark sky locations and star parties. It is however slightly more advanced. The main difference between this and the wide-field imaging setup is that this one enables you to image smaller and fainter objects due to the higher magnification and greater light-gathering power of the telescope. Many more objects are within its capabilities. This type of system forms the backbone of an imaging setup and can be expanded on and upgraded as required.

This setup requires a very good polar alignment and an accurate telescope drive, which limits the duration of exposures that can be taken before star trailing starts to become a problem. It also relies on the object to be located and positioned in the frame manually. This will require practice and possibly a technique called star hopping, which is explained later.

Basic Deep-Sky Imaging Setup

- Telescope
- Camera
- Drive system preferably GoTo
- Autoguider (this can be standalone or requires a computer)

A basic deep-sky imaging setup uses a GoTo drive to help locate objects for you and has an autoguider that is locked onto a star to send corrections to the drive and keep the object from drifting in the frame. The GoTo telescope drives are generally controlled by the use of a handset. This however has started to change, and it is becoming more common to have drives that connect to a mobile phone or tablet computer and are controlled by the use of an app. This method of control is usually carried out by a wireless connection using a Wi-Fi hotspot generated by the telescope drive.

These additions make it much easier to find an object to be imaged, and much longer exposures can be taken. This in turn means that much fainter objects can be imaged without star trailing. This is the level at which so many images are successfully taken by astrophotographers the world over.

Note that the system still requires an accurate polar alignment and also some form of star alignment that synchronizes the sky with the telescope controller. The object may need to be positioned in the center of the camera frame manually depending on the GoTo accuracy. One method to improve the accuracy is to slew the telescope to a nearby bright star, center that in the field of view and use the synchronize function, and then make the short slew to the object being imaged. This will result in accurate slews to the required object.

Advanced Deep-Sky Imaging Setup

- Telescope
- Imaging Camera

- USB filter wheel
- USB focuser
- GoTo Drive system
- Camera for Autoguiding
- Computer

The advanced deep-sky imaging system differs from the others in that it uses a computer to control the telescope instead of a hand controller, which becomes redundant. This is achieved using a special computer cable that typically plugs into the handset controller socket on the telescope drive system and then a USB port on the computer. This allows the telescope to have many more functions available than are built into the handset. The system may then be capable of locating and centering objects in the field of view, and choosing a guide star locking onto it for autoguiding, then taking the desired images. It can also focus and change filters under computer control. In its most advanced form, it can also be capable of following an imaging sequence or script containing a list of objects, the exposure times and the filters, when to check the focus working autonomously until all the required images have been captured (Fig. 2.2).

As you can see, moving away from the hand controller to computer control adds massively to the telescope system capabilities by allowing you to use a multitude of programs to control many or all aspects of your imaging

Fig. 2.2 Advanced imaging setup

system. There are several commercial software packages available, but many of the popular programs can be used free of charge under a GNU license.

This is definitely a system suited for a more permanent setup of the dedicated imager, as it requires a lot of initial setting up. Additionally, the software elements can seem a little daunting at first, but they are actually quite straightforward if you follow the instructions carefully. There is also a vast amount of help available online if you get stuck. Once that is all out of the way, the entire system is relatively easy to run. However, it does require a logical approach to use and some problem solving when things don't go according to plan. I have written a guide to problem solving in Chap. 10: Troubleshooting.

This type of setup is capable of very high quality imaging once it has been fully mastered and can image most objects, dependent on the local sky conditions. It can carry out fully automatic imaging runs without any intervention by the imager.

A setup like this can take a few years to fully master and tune to reach its full potential. It is the ultimate challenge and joy of amateur astrophotography.

Chapter 3

Light Pollution and the Night Sky

Our ancestors used the cycle of constellations as a seasonal guide, helping them decide when it was time for activities such as planting, harvesting and stocking up supplies for the cold winter. It was of great importance to their daily lives that they understood the sky and what it was telling them (Fig. 3.1).

To the naked eye at night, there should be around 2500 stars visible from any point on the earth. Sadly, due to light pollution, this is no longer the case. The visible Milky Way has now been lost to one third of the people who live on this planet, disappearing into the fog of artificial and in many cases unnecessary light that now shrouds our towns and cities.

We often think that we need brighter lighting outdoors to see well in the dark, but this couldn't be further from the truth. People simply don't give their eyes enough time to adapt to low light levels, and having a constant light source around makes it impossible. As a result, year after year, artificial lighting has increased globally by around 6%. Much of that light is directly or indirectly sent skywards and scattered in the atmosphere, producing sky glow. The huge amount of light pollution that we now produce is easily seen from satellites and the International Space Station. According to a study carried out in the 2016 *World Atlas of Artificial Night Sky Brightness*, in the United States and Europe, 99% of people live under light-polluted skies.

For the author, the worst recent change has been the recent adoption of LED street lighting, which has changed the night sky from an orange to a silver glow. This might not sound like it much, but the impact is immense.

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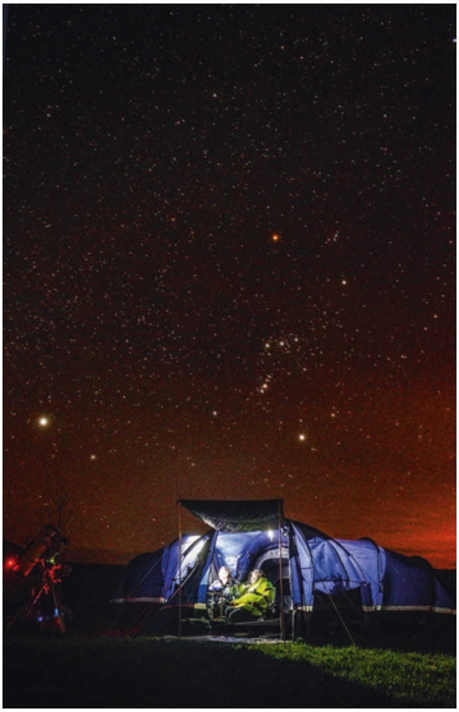

Fig. 3.1 The night sky from the Galloway Star Party, Scotland. (Credit: Dave Fielding)

The old sodium lights could be filtered out quite easily for visual astronomy and imaging, as they emitted light in a very narrow part of the visible spectrum. On the other hand, the new LED street lights emit light across the whole visible spectrum and cannot be so easily filtered out. Additionally, many of the street lights being fitted use less environmentally friendly Led lights that emit light more strongly in the blue region of the visible light spectrum. This is problematic because blue light scatters most widely—it is the reason why our daytime sky is blue. So even if a light fitting is well directed and shielded, it will still produce more scattered light than one using a white LED with a lower blue component in its output.

This may sound like doom and gloom, but through the use of filters and modern equipment available to the amateur, you can still produce fantastic images.

I find myself having to depend heavily on filters, especially narrow band filters, which as the name implies only allow a very narrow band of the visible spectrum of light to pass through. The first time you use them, particularly the Hydrogen Alpha and Oxygen III filters, it is a real eye opener. Objects that would ordinarily be much too faint and saturated by light pollution become spectacular vistas to be enjoyed. The sheer sizes of some of the objects that can be seen in H-alpha are amazing.

As amateurs, we need to keep abreast of the latest technologies to combat increasingly poor skies. If we do this, we will be able to both enjoy the spectacles of the night sky and contribute to our knowledge of it for a long time to come.

Measuring Light Pollution

Typically, amateur astronomers measure light pollution using the Bortle scale, which classes how dark a site is using a scale that ranges from 1 through to 9, as in Table 3.1.

The Costs of Light Pollution

It has been estimated by the Dark Sky Association in Tucson, Arizona that up to one third of all the lighting in the USA is wasted.[1] This comes at an annual cost of around $2 billion and produces 14.1 million tons of carbon dioxide per year.

Table 3.1 The Bortle scale

Bortle scale	Sky type	NELM[a]	Description
1	Excellent	7.6–8.0	M33 obvious with direct vision
2	Typical dark	7.1–7.5	M31 & M33 visible to the naked eye
3	Rural	6.6–7.0	M33 only visible with averted vision
4	Rural/ Suburban	6.1–6.5	M33 difficult with averted vision; M31 still visible
5	Suburban	5.6–6.0	M31 shape is detectable, as is the Orion Nebula glow
6	Bright suburban	5.1–5.5	M31 only seen as a faint smudge
7	Suburban/ Urban	4.6–5.0	Brighter constellations are easily recognizable
8	City	4.1–4.5	Dimmer constellations missing main stars
9	Inner city	4.0	Only brightest constellations are seen and are missing stars

[a]Naked eye limiting magnitude

1 https://www.darksky.org/light-pollution/energy-waste/#:~:text=IDA%20estimates%20that%20least%2030,plant%20875%20million%20trees%20annually

The good news is that there is plenty of space to improve things and reverse the current trend, but it will take a determined effort to achieve this. In Northumberland, UK, the National Part Authority is encouraging residents and businesses to take advantage of a £4000 grant to help with the cost of adapting or replacing outside lighting fittings that could be contributing to light pollution and impacting on their dark skies. They have also reported on their website that they have brought in over £25 million in dark sky tourism to the region. That alone should make others ask what they can do to get a slice of the dark sky tourism market.

On an individual basis, there are many things that can be done, which are outlined in this chapter. Using the following guidelines should show you how you can do your part and save money as well as reduce emissions. The following calculators allow you to enter details of you lighting and will tell you the cost and savings when changing to energy efficient bulbs and reducing the time they are on.

USA calculator: https://www.inchcalculator.com/lighting-energy-cost-calculator/

UK calculator: https://www.energylightbulbs.co.uk/energy-calculator.html

Setting Up External Lights

The first thing to ask yourself is whether you really need external lighting. In most cases, the answer is probably no. Instead, try installing reflectors on driveways to help when parking a car. These don't need power and are only illuminated by your cars lights when needed.

If you still feel for whatever reason that you do need to fit external lighting, be kind to the environment and only have it active when it's actually needed by the use of timers or movement detectors. Try to mount lights lower down so that they illuminate a more concentrated area. In addition, use a light fitting that can fully shield the bulb and is directional in nature, able to be angled down so as not to cause unnecessary glare and scatter. Use a low-power bulb and a dimmer where possible, as it will save you money and reduce light pollution. Warm-colored bulbs do not emit as much blue light which also reduces scattered light.

If you are unsure, get advice from the IDA[2] or Cfds[3] or a local astronomical society.

2 International dark sky association.

3 Commission for dark skies.

Effects of Light Pollution

While the following is not directly related to astrophotography, it will provide you with ideas to help defend your local skies.

We humans long ago adapted to the cycle of day and night. Our bodies adhere to a circadian rhythm, an internal process that regulates our sleeping and waking cycle. These natural body clocks can easily be disrupted by the introduction of artificial lighting, reducing sleep quality and patterns and resulting in tiredness and reduced performance. In particular, such disruptions are thought to affect melatonin production, which is essential for inducing sleep, helps boost the immune system and lowers cholesterol. Melatonin levels are important as well for the correct functioning of the thyroid gland, pancreas, ovaries, testes and adrenal glands.

The American Medical Association has warned that nighttime lighting, especially when rich in blue light, contributes to these health issues and should be limited.[4] Most new mobile phones, tablet computers and laptops now have a special screen mode that reduces the blue light emitted by displays during nighttime hours to help reduce these effects.

An alarming Harvard study conducted in 2017[5] showed that there may actually be a link between increased artificial lighting, melatonin production and breast cancer rates. So far it has only been found in premenopausal women who are smokers, but is nevertheless worrying.

Animals and insects are adapted to the natural rhythm of day and night in an even more specialized way than humans, and we are still at a very early stage of understanding the full impact that light pollution is having on different species. For one, it may well disrupt mating and breeding rituals—we have all seen the way that insects are drawn to artificial lighting. In a recent paper on light pollution and insect decline, it was estimated that up to 40% of insects will go extinct in the next several decades.[6]

The effects of artificial lighting extend to plants. This comes indirectly through the related effects on insect populations and pollinators that allow the plants to reproduce, and directly through changes within a plant's chemistry.

The duration of uninterrupted darkness each day is one of the factors governing the developmental processes in flowering plants such as shoot growth, flowering and time spent dormant via a photosensitive pigment in

4 https://www.ama-assn.org/press-center/press-releases/ama-adopts-guidance-reduce-harm-high-intensity-street-lights

5 https://www.hsph.harvard.edu/news/press-releases/outdoor-light-night-breast-cancer/

6 https://www.sciencedirect.com/science/article/abs/pii/S0006320719307797

the plant called phytochrome,[7] or cryptochrome.[8] This pigment reacts to both red and infrared light. It has been found to respond to even very brief illumination, thereby disrupting the plant's natural cycle.

What Else Can I Do?

Work with your local community to foster interest in protecting the night skies. See if there are any public stargazing events in your area, and if not, consider setting one up yourself! Speak to friends, neighbors and business to make them aware of the problem and how simple and inexpensive the solutions are. Watch out for new housing, industrial or road-building developments and make your voice heard.

Additionally, consider checking out these resources and participate in some of the following citizen science projects.

Globe at Night: www.globeatnight.org

The Globe at Night project aims to raise awareness of light pollution as a global problem. It invites participants to submit their own observations using either a smartphone or computer. The site contains a number of different ways you can get involved, including a dark sky ranger program.

Cities at Night: https://citiesatnight.org/

The cities at night project uses images that have been taken by the astronauts aboard the ISS and mosaics them together to produce very high resolution images of the planet as seen from space at night. Looking through the images gives you a better sense of the scale of light pollution around the world. You may also participate by helping to identify unknown cities using a simple slideshow interface.

How Many Stars?: http://hms.sternhell.at/hms.php?page=pages/main&lang=English&country=Worldwide

This project studies the number of stars visible from your location and is very quick and easy to participate in.

7 Smith H., Morgan D.C. (1983) The Function of Phytochrome in Nature. In: Shropshire W., Mohr H. (eds) Photomorphogenesis. Encyclopedia of Plant Physiology (New Series), vol 16. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-68918-5_19

8 Su, J.; Liu, B.; Liao, J.; Yang, Z.; Lin, C.; Oka, Y. Coordination of Cryptochrome and Phytochrome Signals in the Regulation of Plant Light Responses. Agronomy 2017, 7, 25. https://doi.org/10.3390/agronomy7010025

Stars for all: https://stars4all.eu/

This website has tons of information on light pollution and projects that you can become involved in. A must-visit.

Loss of the Night: App available for Android and IOS devices

You can use the Loss of the Night app to submit data about the sky from your location to a growing database. The app directs you to various stars and has you report if they are visible or not from your location. It is quick and easy to use, even for the novice.

Star Parties and Light Pollution Etiquette

Sadly, there are many astronomers and astrophotographers whose only real option is to travel to recognized dark sky sites or attend star parties. Star parties are larger gatherings of astronomers, usually on campsites or in remote areas. They are a great option if your local skies are not very dark or are obstructed, and they are a great place to learn and make new like-minded friends.

At such events, it is essential for everyone's enjoyment that etiquette is followed so that both imagers and visual astronomers can be in close proximity without disturbing each other unnecessarily. For instance, visual observers can be badly affected by the screens used to control imaging systems, and imagers can be affected by the careless use of headlamps. Here are some tips to keep in mind.

1. Try to use red light in general since this wavelength does not scatter so easily.
2. When using a red light headlamp, use a low-power setting and keep it angled towards the ground to avoid directly dazzling other people or shining onto imaging systems, which may be running unattended nearby.
3. Shield active laptops and monitors.
4. Be aware that even lights or screens inside a tent can be a nuisance to others.
5. If you have equipment in an area where other people might be walking past, mark it with the faint illuminated tent pegs. It will prevent equipment from being a trip hazard and possibly from getting damaged. Cables should also be positioned carefully so as not to be a hazard.
6. There is often a ban on the use of handheld lasers, which can be blinding and can also ruin images being taken if the beam even briefly passes through the field of view where someone is imaging.

7. If you need to get things out of a car after dark, use your keys to unlock it as this won't flash the indicators. Make sure all interior lights have red filters over them or preferably are turned off.

Dark Sky Sites

A dark sky site is an area that has very dark skies which are unspoilt by light pollution. These for obvious reasons are typically away from heavily populated areas. To be suitable for use by a typical astrophotographer a dark sky site should also have at least a good clear southern horizon and relatively easy access for vehicles. It is also helpful to have an area of hardstanding where the telescope can be set-up. Some areas may even have power available such as suitably placed holiday homes or dedicated astronomy centers.

This is a list of a few of the established dark sky sites situated around the world.[9] In addition to these locations it is always worth contacting the local astronomical society in the area that you plan to visit for advice on the best spots to image from. Local societies will have a better working knowledge of the area and may direct you to unpublished and lesser known sites.

USA

Cherry Springs State Park, Pennsylvania
https://www.darksky.org/our-work/conservation/idsp/parks/cherrysprings/
Natural Bridges National Monument, Utah
Grand Canyon National Park, Arizona
Maryland Earth to Sky Park & Bare Dark Sky Observatory, North Carolina
Headlands International Dark Sky Park, Michigan
Geauga Observatory Park, Ohio
Chaco Culture National Historical Park, New Mexico
https://www.nps.gov/chcu/planyourvisit/nightsky.htm
Clayton Lake State Park, New Mexico
https://www.darksky.org/our-work/conservation/idsp/parks/claytonlake/

9 The International Dark Sky Association (IDAS): https://www.darksky.org/

Death Valley National Park, California
https://www.nps.gov/deva/learn/nature/lightscape.htm#onthisPage-3

Canada

Mont-Mégantic International Dark Sky Reserve, Canada
Garibaldi Provincial Park, British Columbia
Jasper National Park, Alberta
White shell Provincial Park, Manitoba
Mont-Mégantic International Dark-Sky Reserve, Quebec
Charleston Lake Provincial Park, Ontario
Hopewell Rocks Provincial Park, New Brunswick
Prince Edward Island National Park (incl. Cavendish Beach)
Kejimkujik National Park, Nova Scotia
Iqaluit, Nunavut
Wood Buffalo National Park, Northwest Territories
Watson Lake, Yukon
https://www.asc-csa.gc.ca/eng/blog/2018/06/29/13-amazing-stargazing-locations-in-canada.asp
Grasslands National Park, Saskatchewan
https://darksitefinder.com/placemarks/grasslands-national-park-saskatchewan-canada/

United Kingdom

Bodmin Moor Dark Sky Landscape
https://www.darksky.org/our-work/conservation/idsp/parks/bodminmoor/
Galloway Forest Park
https://forestryandland.gov.scot/visit/forest-parks/galloway-forest-park/dark-skies
Elan Valley Estate (Wales)
https://www.darksky.org/our-work/conservation/idsp/parks/elanvalley/
Snowdonia International Dark Sky Reserve
https://www.eryri-npa.gov.uk/looking-after/dark-skies
Exmoor National Park
https://www.exmoor-nationalpark.gov.uk/enjoying/stargazing

Northumberland Dark Sky Park
https://www.northumberlandnationalpark.org.uk/things-to-do/discover-dark-skies/
Brecon Beacons National Park, Plas y Ffynnon, Cambrian Way
Kerry International Dark Sky Reserve, Ireland
https://www.kerrydarkskytourism.com/
Northumberland National Park and Kielder Water & Forest Park
https://www.darksky.org/our-work/conservation/idsp/parks/northumberland/
Ballycroy National Park and Wild Nephin Wilderness
https://www.darksky.org/our-work/conservation/idsp/parks/mayo/
Davagh Forest Park and Beaghmore Stone Circles
https://www.darksky.org/our-work/conservation/idsp/parks/davagh-forest/
Port Lewaigue Car Park – Isle of Man
https://www.visitisleofman.com/experience/see-and-do/great-outdoors/stargazing-sites
Bodmin Moor Dark Sky Landscape
https://www.darksky.org/our-work/conservation/idsp/parks/bodminmoor/
Isle of Sark Channel Islands
http://www.sark.co.uk/

France

International Dark Sky Reserve at Pic du Midi
https://picdumidi.com/en/discover-the-pic-du-midi/rice-en

Spain

Bassegoda Park, Albanyà
https://www.darksky.org/our-work/conservation/idsp/parks/albanya/

Germany

Westhavelland International Dark Sky Reserve
https://www.darksky.org/our-work/conservation/idsp/reserves/westhavelland/

Winklmoosalm
https://www.darksky.org/our-work/conservation/idsp/parks/winklmoosalm/

Iceland

Thingvellir National Park
https://darksitefinder.com/placemarks/thingvellir-national-park-iceland/

Road 54 Ocean Viewpoint
https://darksitefinder.com/placemarks/road-54-ocean-viewpoint-iceland/

Denmark

Møn and Nyord
https://www.darksky.org/our-work/conservation/idsp/parks/monandnyordpark/

Netherlands

De Boschplaat
https://www.darksky.org/our-work/conservation/idsp/parks/deboschplaat/

Hungary

Bükk National Park
https://www.darksky.org/our-work/conservation/idsp/parks/bukk/

Croatia

Petrova gora-Biljeg Croatia
https://www.darksky.org/our-work/conservation/idsp/parks/petrova-gora-biljeg/

Namibia

NamibRand Nature Reserve
http://www.namibrand.com/dark-sky.html

New Zealand

Aoraki Mackenzie International Dark Sky Reserve
https://mackenzienz.com/scenic-highlights/dark-sky-reserve/

Israel

Ramon Crater
https://www.darksky.org/our-work/conservation/idsp/parks/ramoncrater/

Chapter 4

Astrophotography Equipment

Telescopes

Depending on the objects that you are interested in Imaging, you might choose a long focal length lens or telephoto lens to magnify small objects, or a short focal length, wide-angle lens to cover a larger field of view. Many wide-angle images of the Milky Way or larger objects such as the Andromeda Galaxy can be successfully taken with no more than a camera lens.

However, if we want to take images of smaller and fainter objects, we need two things. The first is the ability to gather far more light, and the second is higher magnification. This is in a nutshell what a telescope does.

Naturally, choosing the optimal telescope and camera pairing for you depends on a balance of many factors. First, let's take a look at some of the basic specifications and terminology for a telescope, as they will affect the quality of your astrophotography.

Aperture

As in photography, the aperture is the diameter of the main lens or mirror used to gather the light. This is expressed in inches or millimeters. The larger the aperture, the more light the telescope is capable of gathering in a

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_4

given time. A larger aperture also has a greater resolving power, which means that it can distinguish finer detail. A larger aperture instrument is therefore capable of picking up finer detail and fainter objects. This might sound like the way to go, but it comes with a couple of caveats.

First, the cost per aperture size increases exponentially, which may limit your choice of instruments. And while a large instrument seems desirable, make sure that you will be able to handle setting it up and breaking it down easily. If it is too heavy or unwieldy to set up, it is less likely to be used regularly and may end up gathering dust. A larger telescope also requires a larger mount system, which will be more expensive. However, a good telescope and mount should last many years. These instruments are better sited on a permanent mount in a shed or observatory where you don't have to set it up every time you want to use it. You will therefore need to have a suitable location, power and preferably an internet connection.

Focal Length

The focal length of a telescope is the distance from the lens or mirror at which a focused image is formed. This directly relates to how large the object will be seen, and hence its magnification. A short focal length produces a low magnification image and wide field view. A long focal length produces a high magnification and narrow field of view. The focal length combined with the size of the imaging chip in a camera dictates the field of view that the camera will have. See the field of view description and calculation later in this chapter.

Barlow Lens

The focal length of the telescope may be fixed, but it is possible to effectively alter it using a *Barlow lens* to gain magnification. A Barlow lens fits into the eyepiece holder of your telescope, and the camera or eyepiece then fits into the other end of the Barlow lens.

The figure given on a Barlow lens is a multiplier. For instance, a 1000-mm telescope with a "2×" Barlow fitted changes the effective focal length of the telescope to 2000 mm, doubling the magnification. This does have a drawback however, as it also changes the effective focal ratio (to be discussed shortly) and makes for a slower instrument while the Barlow lens is in use.

Focal Reducer

A focal reducer may be supplied like a Barlow lens fitting in between camera and telescope, or it may screw into the camera nosepiece in the same way you would fit a filter to it.

If we fit a 0.5× focal reducer on the same 1000-mm focal length telescope, we reduce the focal length by half—hence the 0.5×—making it effectively a 500-mm focal length instrument. This reduces the focal ratio and effectively produces a faster instrument with half the magnification and twice the field of view.

Note that introducing more optical elements into the light path does also result in some light loss and can introduce chromatic aberrations, so it is sensible to purchase reputable parts that have first-class optical components and coatings.

Focal Ratio

The focal ratio is also known as the "speed" of the telescope. It is a measure of the telescope's light-collecting capabilities and is expressed by dividing the focal length by the aperture. This gives the f/number, which directly equates to that quoted on a camera lens. A 300-mm diameter reflecting telescope with a focal length of 1500 mm therefore has an f/number of F5. The smaller the f/number, the faster the instrument is at gathering light.

Telescopes for Deep-Sky Astrophotography

The following is a description of the popular telescope types commonly used by amateur astrophotographers today. The design of a telescope system as with most things is a compromise, and each configuration has its own advantages and disadvantages.

The Refracting Telescope

The refracting telescope is a very popular astrophotography instrument. Part of its popularity is due to its simplicity. Once it has been assembled and all the optics aligned[1] it is very robust and seldom needs the alignment to be

[1] The procedure of aligning the optical components is called collimation.

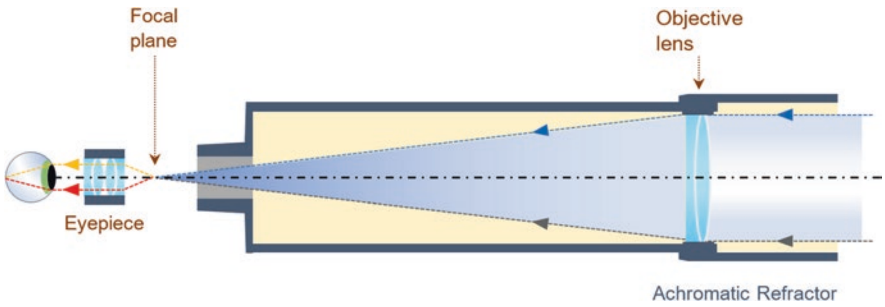

Fig. 4.1 Achromatic refracting telescope. (Image courtesy Peter Karboulonis and Opticstar)

redone. This makes it an ideal instrument for both observatory and portable use, where it is likely to take bangs and knocks while being transported and set up. Its main disadvantage is the cost, as it tends to be more expensive than its reflecting telescope counterpart (Fig. 4.1).

Disadvantages

- Comparatively more expensive than reflecting telescopes of equal aperture
- Suffer from chromatic aberrations

Advantages

- A robust portable option; holds its collimation very well and tolerates the rough treatment of being transported
- Has a sealed optical tube, meaning that the internal optical surfaces are protected from the surrounding environment. Consequently, only the external optical surfaces need cleaning in normal use
- A long back focus. Back focus is the amount of travel the eyepiece draw-tube is capable of which determines whether you can use a filter wheel or off-axis guider in the optical path. Manufacturers tend to improve this in instruments sold for astrophotography by fitting low-profile focusers. Some fit slightly larger secondary mirrors closer to the main mirror, which improves the back focus and reduces any vignetting.

Chromatic Aberration

Chromatic aberration is a problem inherent in refractor telescopes and optical assemblies that use lenses. It is due to the fact that light passing through the glass is refracted at slightly different angles dependent on its wavelength. This produces fringes of color, most easily seen around bright edges in the images produced.

Chromatic aberration is lessened to a large degree by using a sandwich of different types of glass. Their refractive properties help reduce the color fringing by recombining the different wavelengths of light. If you are using a refracting telescope for astrophotography, an apochromatic telescope is desirable. This has an objective lens made with two or three elements of different types of glass to correct the chromatic aberration, and is known as known as a doublet or triplet configuration respectively. Note that these extra layers add substantially to the production costs, and well-corrected refracting telescopes are more expensive than telescopes that have an objective lens made from one piece of glass. The triplet is of course the most expensive but generally offers the best color correction.

The Newtonian Reflecting Telescope

The Newtonian reflecting telescope is a great instrument for deep-sky astrophotography. For a given aperture, it tends to be much more affordable than a refractor. It uses a parabolic mirror, called the primary mirror, to gather and focus the light. The light gathered by the primary mirror is then directed sideways out of the telescope tube by a smaller mirror, called a flat or secondary mirror, which is set at 45 degrees. This is why the eyepiece on this type of telescope is situated on the side of the optical tube. The secondary mirror does block some of the light from getting to the main mirror, which has a slight effect on the contrast and brightness of the image produced (Fig. 4.2).

Reflecting telescopes do not suffer from chromatic aberration in the same way as a refracting telescope. In this design, the light is bounced from a silver coating on the front surface of the mirrors. Unlike standard domestic mirrors, which are silvered behind the glass, this front silvering stops the light from traveling through the glass and therefore prevents it from splitting into its component colors. Note that if any other optics are used later in the imaging train, such as a coma corrector (to be discussed) or a Barlow lens, they may introduce chromatic aberration.

Advantages

- Relatively inexpensive for a given aperture when compared to other types of telescopes
- Very large instruments are commonly available
- Lighter weight than other designs since it does not need a corrector plate
- Does not suffer from chromatic aberration
- Available in many different optical layouts, each with their own characteristics and applications

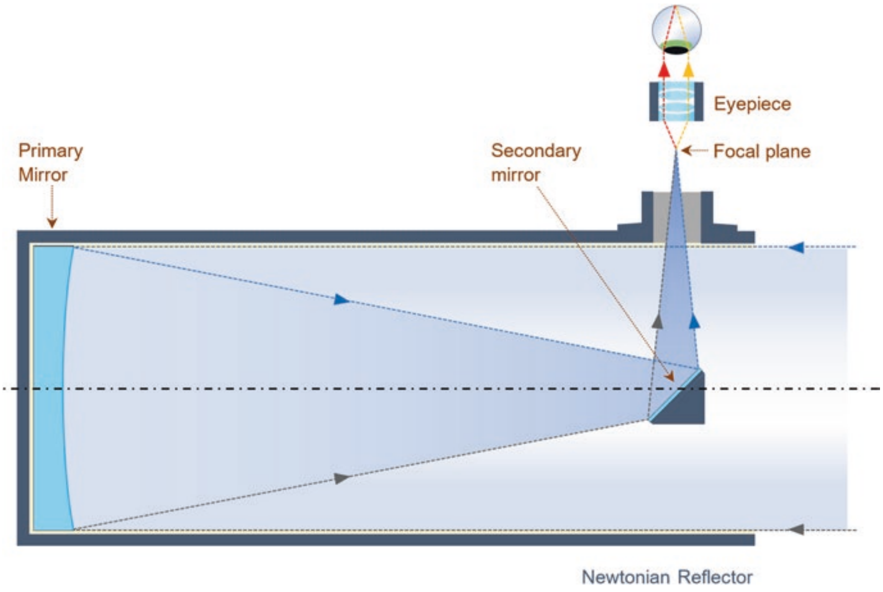

Fig. 4.2 Newtonian reflecting telescope. (Image courtesy Peter Karboulonis and Opticstar)

Disadvantages

- Easily loses collimation (optical alignment) while being moved or even over time, resulting in a degraded image. This requires that you learn how to re-collimate the telescope, which is not a difficult task but must be undertaken carefully and methodically.
- The mirrors require cleaning from time to time, which typically means taking them out of the optical tube. This also means that the instrument needs re-collimating when the mirrors have been reinstalled.
- Large-aperture instruments tend to get very big and may not be easy to handle
- Limited back focus
- Because the mirrors are open to the elements and the silvering is on the front surface, it will degrade over time. The mirrors will eventually require re-silvering, but if treated carefully they should last for many years before this is necessary.
- Tend to need a coma corrector to achieve a sharp focus and tight star shapes right to the edge of the FOV.

It is important to check that a Newtonian telescope that you are interested in purchasing for astrophotography has sufficient back focus to accommodate the equipment you will be using it with. Talk to astrophotographers from your local society and the supplier of the equipment so that you don't make an expensive mistake that may be difficult to correct later. Skywatcher Newtonian telescopes suitable for astrophotography have the designation PDS at the end of the name. This means it has a lower profile focuser and a shorter optical tube, necessitating a larger secondary mirror. The downside of a slightly larger secondary mirror is that it blocks some of the light from reaching the main mirror, which has a slight impact on contrast.

Cassegrain Reflecting Telescope

This optical system was designed by Laurent Cassegrain. It is part of the family of telescopes called Catadioptric instruments. It is similar to the Newtonian reflector design, except the secondary mirror reflects the light from the main mirror back down the optical tube and out of a hole in the center of the main mirror. This folded design results in a very compact telescope (Fig. 4.3).

Advantages

- General purpose telescope
- Great for deep-sky astrophotography
- Excellent for planetary and lunar photography
- Can be used at native long focal length or with a reducer for wider field work

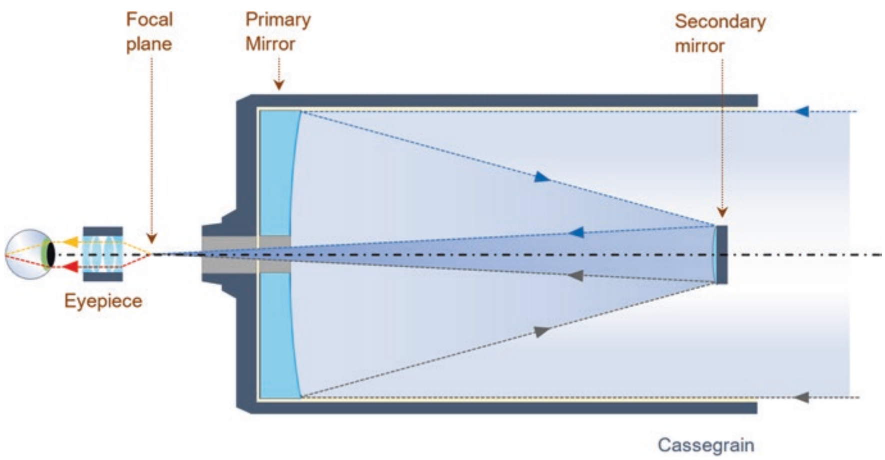

Fig. 4.3 Cassegrain telescope. (Image courtesy Peter Karboulonis and Opticstar)

- A great portable instrument with a compact tube, which is approximately 1/3 length of a similar focal length Newtonian
- Less expensive than a high quality refractor of the same aperture
- Don't require collimation as often as a Newtonian

Disadvantages

- Expensive compared to Newtonians
- Small field of view unless a reducer is fitted
- Due to longer focal length, it requires more accurate setup and tracking
- If it is fork mounted, there may be reduced clearance for cameras and equipment when the telescope is slewing or pointing in certain positions. Thus, there is a possibility that the camera and equipment will collide with the mount!

Schmidt Cassegrain Reflecting Telescope

The Schmidt Cassegrain is actually a development from the Schmidt camera, designed by Bernhard Schmidt in 1930 as a wide-field camera. This design combines the Cassegrain optical path with the addition of the Schmidt corrector plate. While the Schmidt configuration produces a wide field of view, when it is combined with a Cassegrain configuration, it produces a long focal length instrument with a small field of view (Fig. 4.4).

The Schmidt Cassegrain is similar to the Cassegrain with its folded optical path. However in this case, the main mirror is spherical instead of para-

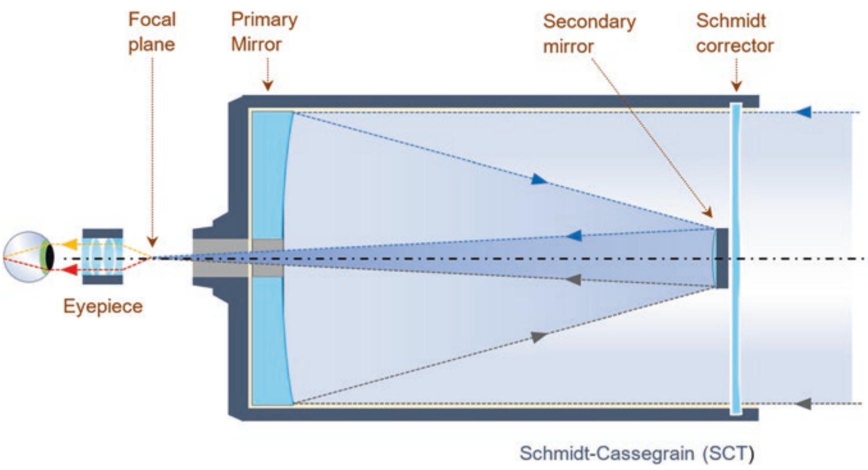

Fig. 4.4 Schmidt Cassegrain. (Image courtesy Peter Karboulonis and Opticstar)

bolic. Additionally, a Schmidt corrector plate is mounted at the top of the tube, resulting in a longer focal length design. The corrector plate allows the image to come to a sharp focus, which otherwise would not be possible with a spherical mirror.

Advantages

- General purpose telescope
- Great for deep-sky astrophotography
- Excellent for planetary and lunar photography
- Can be used at native long focal length or with a reducer for wider field work
- A great portable instrument with a compact tube, which is approximately 1/3 length of a similar focal length Newtonian
- Less expensive than a high quality refractor of the same aperture
- Don't require collimation as often as a Newtonian

Disadvantages

- Expensive compared to Newtonians
- Small field of view unless a reducer is fitted
- Slower instrument due to longer native focal length
- If it is fork mounted, there may be reduced clearance for cameras and equipment when the telescope is slewing or pointing in certain positions. Thus, there is a possibility that the camera and equipment will collide with the mount!

The Ritchey–Chrétien Telescope

The Ritchey Chretien telescope is a variation of a Cassegrain telescope design. It differs in that it has both a hyperbolic primary and secondary mirror. This more complex optical design eliminates the coma effect where stars particularly at the the edges of the field are seen as a smudged shape resembling a comet. This enables these telescopes to be built with a wider field of view. Many of the world's largest optical telescopes, including the famous Hubble Space Telescope, employ this configuration due to its superb optical qualities.

Advantages

- Low distortion, high quality images
- Compact and lightweight
- Faster instrument than a standard Cassegrain
- Flat field of view with no coma
- Quick cooling due to open tube design without a corrector plate

Disadvantages

- Cost. Tends to be more expensive due to the hyperbolic main mirror and convex hyperbolic secondary mirror
- Larger secondary mirror than a Newtonian

The Maksutov Telescope

The Maksutov telescope was patented by Dimitri Maksutov in 1941. It employs a spherical main mirror and a weak corrector plate with a silvered spot in the center that acts as a secondary mirror. This configuration is produced with a high f/number to reduce optical aberrations. Due to instrument's longer focal ratio and higher magnification, it is more suited to planetary, double star and lunar work (Fig. 4.5).

Advantages

- More expensive than a Newtonian of comparable aperture
- Very compact instrument due to folded optical design
- Very little chromatic aberration
- Good contrast
- No diffraction spikes which tend to be caused by the spider veins.[2]

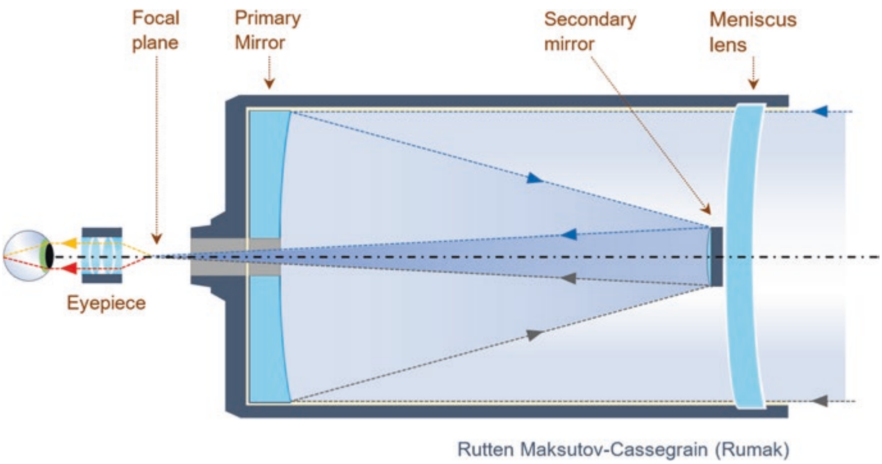

Fig. 4.5 Rutten Maksutov Cassegrain telescope. (Image courtesy Peter Karboulonis and Opticstar)

2 Spider veins are the common name used to describe the secondary mirror supports.

Disadvantages

- Heavy due to meniscus corrector lens
- Longer cool down required due to closed tube design
- Slower instrument due to longer native focal lengths of typically F13
- Large aperture models tend to be quite expensive to produce

Concluding Thoughts About Telescopes

In my observatory, I have a 12″ F5 Newtonian reflector mounted on a permanent pier. This is the ideal instrument for the faint and unusual galaxies that I like to image. For portable use when at dark sky sites, I have an 8″ F5 Newtonian but have also used an ED80, which is a 3 ¼″ F7.5 refractor. Being F7.5, it is a slower instrument and requires more imaging time than an F5, but it nevertheless rewards the user with spectacular images.

The answer to which telescope is right for you is simple:

> The telescope should be suited to the tasks that you require of it and should also be one that you can handle in terms of size and weight. If you intend to shoot larger and brighter gas clouds and objects, you will not need a focal length. If however your passion is to take images of very faint, small galaxies, then you will need to use an instrument with a longer focal length giving sufficient magnification and plenty of aperture to gather as much light as possible.

Cameras for Deep-Sky Astrophotography

The cameras used for amateur deep-sky astrophotography fall into two main types: DSLR (digital single-lens reflex) and CCD (charge-coupled device) or CMOS (complementary metal-oxide semiconductor). Each of these cameras are capable of producing very high quality astronomical images.

Digital Single-Lens Reflex (DSLR) Cameras

Digital cameras have largely taken over from film cameras and offer many advantages, including much higher sensitivity and no reciprocity failure. It used to be that the longer the exposure time was the less sensitive the film became. Although the initial cost of a digital camera is quite high, the lack of film and processing costs makes it a worthwhile investment. Using a digital camera also speeds up the rate at which you can learn and experiment with settings and techniques because you can see the results of your efforts instantly and there isn't as much wasted imaging time, as you can very quickly assess if an object is worth imaging given your equipment, skies and FOV. This instant feedback also allows you to modify exposure times the best choice of filters and the number of exposures as you go.

Digital cameras produce an image using an imaging chip which is an electronic component that has a two-dimensional array of light-sensitive detectors. An easy way to visualize how the imaging chip is laid out is by thinking of a sheet of graph paper, where every square is a light-sensitive detector or pixel. The more pixels we have, the better the resolution and clarity of the final image. However, the smaller the pixels are the less sensitive they are to light due to the reduced surface area. Manufacturers are constantly improving these imaging chips to provide higher resolution greater sensitivity and lower noise levels. As these improved imaging chips find their way into the next generations of cameras we can look forward to even better dedicated cameras than we have available today.

DSLRs have tended to have larger chip sizes, a higher pixel count and lower associated costs. But this gap is now closing, and there are almost weekly new CCD or CMOS cameras coming onto the market (Fig. 4.6).

Fig. 4.6 DSLR camera

DSLR cameras are typically standard consumer color cameras that can be used for daytime as well as astrophotography. As such, they are a good introduction to the hobby, especially as many people already possess them for normal photography purposes. There are many excellent images that have been taken with DSLRs and many deep-sky astrophotographers continue using them as their main camera, while others start off using a DSLR and then move onto a specialized CCD or CMOS cooled astrophotography camera.

One of the big advantages of a DSLR is that it is very inexpensive for the imaging chip size and has high resolution sensors. It is also available on the secondhand market at very little cost. But one thing to consider when using a DSLR is the limited battery life. It will be holding the flip mirror and shutter open for extended periods of time, which requires a lot of power. During the night it can get very cold, which can cause the batteries to drain even quicker. This can be accommodated by either having a supply of fully charged batteries available or getting a battery eliminator.

DSLRs do not need to be connected to a computer to work, as they natively store the images on a memory card, which makes them ideal for a grab-and-go system of the casual imager. Nevertheless, most DSLR models can be controlled by a computer, which makes their operation much easier and more convenient for astrophotography, as you do not need to touch the camera or the telescope to set up and direct the exposures. With less vibration from physical contact with the telescope system, there will be less blurring in the resulting images.

There is also a growing trend to modify DSLR cameras by totally removing the manufacturer's IR-blocking filter or replacing it with one more suited to astrophotography. This type of modification results in a much higher sensitivity at the red end of the visible spectrum and in particular allows the camera to pick up much more Ha, which is one of the particular wavelengths that we are looking to record. It is usually preferable to replace the filter with one of the replacement filters that have been designed for astrophotography, as the camera retains its autofocus function and can also be used for daytime photography by making a custom color balance profile to compensate for the change.

There are other modifications that can be done to a DSLR, including cooling the sensor to help reduce the noise from the camera and its electronics. This feature is fairly standard on dedicated deep-sky CCD and CMOS astrophotography cameras (Fig. 4.7).

To see how dramatic the difference is: if you have a cooled camera, try taking some long exposure images with the cooler off. Then, take the same images with the cooler on after giving it time to cool the imaging chip and compare the two images (Fig. 4.8).

Fig. 4.7 Cooled DSLR cameras

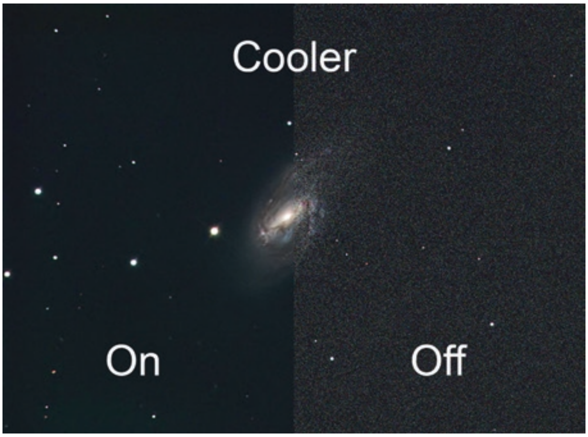

Fig. 4.8 Exposures with and without cooler on

For standard deep-sky imaging, the camera is typically placed where the eyepiece normally is in a position that is called prime focus. This uses the telescope at its native focal length (Fig. 4.9).

When using a DSLR or camera with a large chip size, it is quite common for a telescope to need some form of optical correction so that stars are

Fig. 4.9 Camera mounted at prime focus

Fig. 4.10 Coma corrector

pinpoints right across the image field. We can usually do this through a correction lens system, called a field flattener or coma corrector depending on the type of telescope being used. A coma corrector is usually used with a short focal length Newtonian reflector telescope, and a field flattener is used with a short focus refractor. Both coma correctors and field flatteners are designed for instruments with particular focal lengths (Fig. 4.10).

DSLR Camera Mirror Shake

As the name suggests, camera mirror shakes are vibrations that will result in image blurring. They are caused by the flip mirror in a DSLR camera moving out of the light path when an exposure is taken. The problem is usually cured by using one of the settings in the camera that enables you to move the mirror out of the way and lock it up, allowing time for the vibrations to subside before opening the camera shutter to take the exposure.

If not using computer control, the best way to do this is to use a cable release, which is basically a short cable with a shutter button that allows an image to be taken without touching the camera. It may also have an interval meter built in that allows you to set up both the exposure length and number of exposures to be taken. A cable release of this type is inexpensive and easy to use and it may also have an interval meter built in which will allow you to set up both the exposure length and the number of exposures to be taken automatically.

CCD and CMOS Cameras

Dedicated astronomy CCD or CMOS cameras need to be connected to a computer running control software in order to operate. These cameras are more expensive than DSLRs but do offer significant advantages.

In particular, the imaging chip is cooled to a set temperature. This is useful for two reasons. Firstly it keeps the imaging chip and resulting image noise to a minimum. Secondly, the calibration frames can be taken at the same temp as the images, so they work much better at reducing noise and removing hot pixels.

Additionally, the filters fitted to these cameras do not usually block out the hydrogen alpha region of the spectrum, as the filters in DSLRs tend to do. While some high-end dedicated astronomy cameras have a mechanical shutter assembly, there is no flip mirror as in a DSLR to produce vibration and add weight.

It used to be the case that CCD cameras were the best choice for astronomical imaging, but that is rapidly changing with the latest generations of CMOS cameras, due in part to the architecture of the imaging chips. Let’s take a look at both kinds.

CCD Imaging Cameras

In a CCD camera, the signal to be read is cascaded through the chip and turned into a voltage, which is then read by an analogue-to-digital converter (ADC). As the name implies, this converts the analogue signal from the pixels to a digital signal that can be read by a computer. It is a slower process than that in a CMOS camera, but since the signal passes through the same electronics, pattern noise is reduced. However, the noise generated when reading an image is higher.

Advantages

- Lower pattern noise
- Lower or no existent amp glow
- Consistent signal and high accuracy of pixel measurement

Disadvantages

- Slower read time
- Higher read noise
- More expensive to produce
- Older technology that is being phased out in favor of CMOS

CMOS Imaging Camera

In a CMOS camera, the signal from each pixel doesn't need to be cascaded and is turned into a voltage by its own transistor. This signal is then fed to one or two ADCs for each column of pixels. So, the process is much faster than in a CCD imaging chip. The use of all this extra circuitry has caused problems in the past, such as *amp glow*, which appears as a glow across part of the image, and also higher pattern noise. These problems are still present but have been drastically reduced. The noise generated by the process of reading an image is lower than in a CCD, due to each pixel being read by its own electronics and not cascading as in a CCD.

Advantages

- Camera design and construction is simpler
- CMOS imaging chips are cheaper to produce
- Faster read time
- Lower read noise
- Developing technology

Disadvantages

- Higher pattern noise
- More susceptible to introducing amp glow in images that needs to be processed out
- Pixel measurement not as accurate or consistent as CCD cameras (Fig. 4.11)

Camera Cooling

Most commercial cameras designed for deep-sky astrophotography have a form of cooling built in using an electronic component called a Peltier device. This device cools the camera sensor and in doing so reduces the unwanted electrical noise that it naturally produces. The temperature of the camera sensor is usually selectable using your imaging software and is then held at that temperature. Most cooled CCD and CMOS cameras have a method of reducing condensation that gathers in the imaging chamber as a result of the cooling. This can be achieved by either sealing the chamber

Fig. 4.11 Dedicated astronomy camera

with a dried inert gas or by having a desiccant (a drying agent) in the form of beads or a tablet that absorbs any moisture present and can be easily changed when it gets saturated. The old desiccant is then dried out for reuse or replaced with a fresh one.

There exist uncooled cameras such as the GPCam. These small, sensitive cameras are very inexpensive and can be used for deep-sky imaging when paired with the right software. Coupling one of these cameras with the SharpCap software and using it in its live stacking mode can produce some great results with short exposures, even on an Alt-AZ mount.

Cooling Considerations

If your camera supports cooling or if you have fitted a cooler such as the one in the projects of this book, remember to turn it on and set the cooling temperature. The effect of the cooling on noise is quite dramatic and should be used if available. Don't be tempted to set it to its maximum cooling setting, as this can cause condensation or even icing problems. The effectiveness of cooling does have a diminishing return—that is to say the maximum noise-reducing effect takes place in the first few degrees of cooling and falls off as the temperature reduces further.

To give you a starting point the temperature settings I tend to use are as follows.

Summer

−10 °C in summer. Note that during this time, the camera may struggle to reach lower temperatures due to the higher ambient temperature depending on the cameras cooling capability which is known as its temperature Delta.

If the camera has a cooling Delta of 30 °C it means that with an outside temperature of 16 °C and the temperature set to −10 °C, the camera needs to cool its chip by 26 °C and only has a leeway of 4 °C to cope with small variations in temperature and still manage to hold the temperature setting. This is sometimes confused with thinking that the camera can cool to −30 °C which is only the case if the ambient temperature is 0 °C. If the ambient temperature is +30 °C it will only cool the camera chip to 0 °C.

In this case the camera cooling Delta means the difference between the ambient temperature and the maximum amount that the camera can cool its chip by in degrees centigrade.

Winter

The camera cooler doesn't have to work quite as hard during the winter due to the lower ambient temperature. I usually set the cooling to about −20 °C, which gives me good noise reduction and doesn't cause icing or condensation problems.

A Couple of Final Points on Cooling

If your camera is equipped with some form of desiccant to keep the imaging chamber dry and free of condensation and icing, remember to replace it or dry it out regularly according to the manufacturer's instructions.

If you suffer from condensation or icing on the optical window or camera imaging chip either don't cool it quite as much or consider fitting a heated optical window on the camera, or you can put a dew heater around the camera nosepiece on a very low setting.

Monochrome Cameras

Mono cameras are naturally more sensitive and versatile than OSC cameras due to the fact that they do not have color filters on the imaging chip. When imaging with a mono camera, the value of each pixel is directly converted into the shades of grey for that pixel, and hence we use the full resolution of the imaging chip with no loss of light through color filters.

Purchasing a monochrome camera doesn't mean you can't produce full-color images with it. It just takes a little bit more work, as you need to image the object with a red filter, then a green filter and finally a blue filter, and then combine the images in order to produce a full-color RGB image.

For narrowband color images, the only difference is the filters used and the way the images are combined when processing them. You can use a Ha, OIII and SII set of filters, which are very effective at cutting out light pollution under suburban skies and during periods of bright moonlight. You can then produce your own false-color images like they do with the Hubble Space Telescope. The objective of these false color images is to show as much structure and detail as possible.

Figure 4.12 illustrates what a small section of a mono imaging chip looks like. The telescope or lens system being used produces an image on the face of the chip. Each of the squares shown is a pixel capable of receiving light

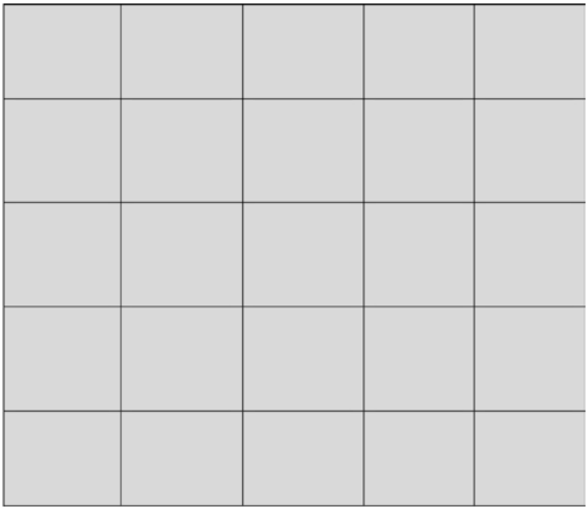

Fig. 4.12 Pixels on a mono camera chip

and turning it into an electrical charge. The charge builds up as more and more light falls on the pixels. When the exposure time has finished the electrical charge is read from the imaging chip, amplified, and sent through an ADC. The resulting digital representation of the light that has fallen on all the pixels of the imaging chip is packaged to become our image file.

Calibration frames are much easier to produce for a mono camera. Additionally, light pollution gradients in images are not as much of a problem as they can be with a OSC camera, and they are easier to deal with when they do occur.

One-Shot Color (OSC) Cameras

To produce an ordinary color image, we need to take a mono or grey scale image using a red filter, a blue filter and a green filter, and then combine them. To avoid taking three different pictures, a one-shot color (OSC) CCD camera uses an imaging chip with what is called a *Bayer matrix* of color filters over the individual pixels, as shown in Fig. 4.13. As you see with the filters, some pixels are sensitive to red light, some to blue light and some to green light. You can therefore extract the red pixels to produce a red filtered image, and the same for green and blue. Then, through the use of sophisticated algorithms, these can be recombined to produce a full-color image.

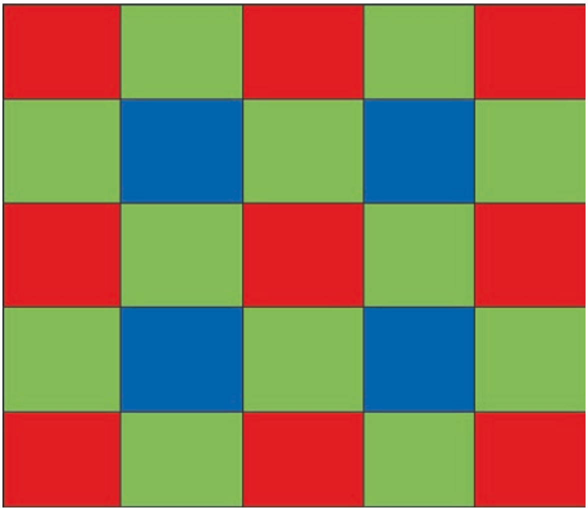

Fig. 4.13 Bayer filter matrix, as found in DSLRs and OSC CCD cameras

Simply put, the information from a group of pixels is used to calculate the real color of each pixel in the final image. This is a compromise, as the final image has a slightly reduced resolution due to the fact that each color doesn't have the full complement of pixels to gather light, so the image is to a degree interpolated.

Contrary to popular belief, you can use narrowband filters very successfully with a OSC camera. However, they are less effective, as the light is also travelling through the Bayer RGB filters on the imaging chip (Fig. 4.14).

When using a Ha filter with a OSC camera, only the pixels with the red Bayer filters will receive much light. The green and blue Bayer filters pass very little or no light that the Ha filter allows through. This means that you are effectively only using a quarter of the pixels on the imaging chip. You are therefore imaging with greatly reduced resolution and sensitivity. The same goes for OIII filters, except here you have two green-filtered pixels, so the resolution is not as badly affected. As you can see, this is not an ideal situation.

Despite this, I and many others have imaged very successfully in Ha, OIII and SII. It just requires you to extract the strongest of the RGB channels for each filter from the image and use it as a mono image. For example, if you are using a Ha filter, the color channel that shows the strongest image will be the red one, so it makes sense to use that. If you do that for the images with each filter, you will be able to combine the individual mono

Fig. 4.14 Ha Image of NGC7635, taken with OSC camera at 6 × 10 min exposures

channels together to create a full narrowband image. This may sound complicated but is very straightforward and easy in practice. It is also possible to extract the luminance channel from an RGB image and use that information, but it can result in a noisy image.

Under- and Oversampling

In order to select the right camera for you, you need to know what you are going to use it for and if the image and pixel scale are suitable for your setup so that you don't suffer from under or oversampling. In short, this refers to whether a camera system is capable of recording the level of detail that a telescope can resolve. In the case of under sampling the camera doesn't have enough pixels covering an area sufficient enough to pick up all the detail from the telescope. In the case of oversampling, the camera has more pixels over a given area than the telescope is capable of showing in detail.

It therefore follows that for every telescope, there is an optimum pixel size and hence camera combination. There is a useful calculator on the Astronomy Tools website to help you check this:

http://www.astronomy.tools/calculators/ccd_suitability

To use this calculator, simply enter your telescope details and the camera being checked to determine their suitability.

The type of camera that you choose in most cases will come down to budget, availability and preference. Be assured that whichever one you choose will be capable of excellent results if you take the time to understand your imaging system and setup and use it effectively.

Gain, Offset and Binning

With a DSLR camera, you use the ISO setting to set the sensitivity of the camera. The settings used are usually in the range of ISO 400 to 1600. This has the drawback that at higher sensitivities, the images become noisy, which is undesirable as it results in a loss of detail and images that are difficult to process.

With a CMOS or CCD camera, the settings that are used are called gain and offset. The *gain* is another form of sensitivity control and can be thought of like a volume control on an audio system. This is usually set by following either a suggested setting by the manufacturer or following a procedure given by the manufacturer that helps determine the correct setting for your camera.

The *offset*, sometimes called *bias*, is a small value given to every pixel in the imaging chip to set the *black point*, ensuring that no pixels have a level of zero. This means that all the pixels will record a light level and hence are used. The value of the offset can be set by the user for some cameras and the procedure for doing this will be specified by the manufacturer.

Another important camera setting is called binning. *Binning* is a way of clumping more than one pixel together in the camera to make larger pixels. These are naturally more sensitive due to the larger surface area. The downside is that binning directly impacts the resolution of the image. Looking at Fig. 4.15 on the left, where we can see the native pixels on the imaging chip on the right. Figure 4.16 illustrates binning 2 × 2, meaning every two pixels vertically and horizontally are added together to make one larger, more sensitive pixel. If we count the total number of pixels in the native resolution, we have 64 pixels. After binning 2 × 2, we now have 16 pixels but an increase in sensitivity of approximately 4. As can be seen, the resulting image has a quarter of the resolution of the native pixels.

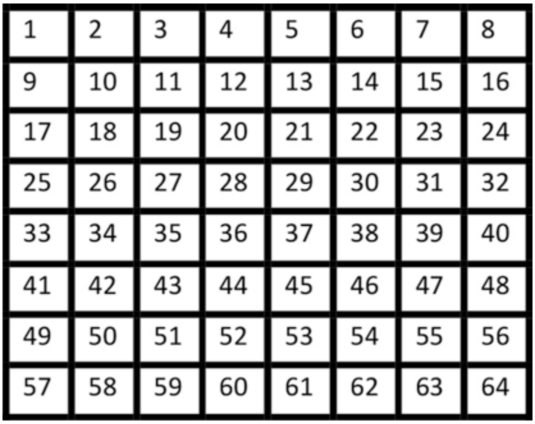

Fig. 4.15 Pixels on imaging chip, 1 × 1. Showing an 8 × 8 array of pixels

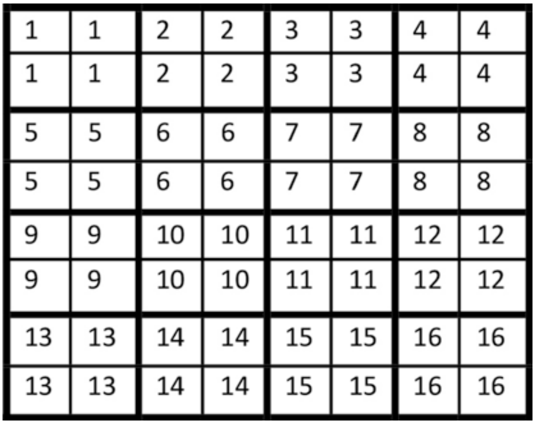

Fig. 4.16 Pixels binned to make larger pixels 2 × 2 Array in bold now shows 4 × 4 pixels

Common Binning Levels

1 × 1	Native resolution of imaging chip	1
2 × 2	Sensitivity increased by approximately	4
4 × 4	Sensitivity increased by approximately	16
8 × 8	Sensitivity increased by approximately	64

This tradeoff can be very useful if we are taking a quick image to check framing. Secondly, it can help us if we are taking a color image and using a luminance channel in the image. This is because a full resolution image will be needed in the luminance channel to ensure all the detail is retained, while the color channels can be binned in order to reduce the total imaging time needed.

Field of View

This is how large an area of the sky your telescope and eyepiece or telescope and camera combination can see. The FOV of your imaging system determines what size objects it can image. It is determined by the focal length and the camera imaging chip size. Put very simply, the lens or mirror focal length determines the magnification of the image that it projects onto the camera imaging chip. A long focal length provides more magnification and a shorter focal length less magnification.

The imaging chip sizes used in cameras vary, as you can see from the following Fig. 4.17.

The FOV can be calculated using the following formula:

$$\text{FOV in arc minutes} = \left(\text{width of chip in mm} \times 3460\right) / \text{telescope focal length}$$

We have to do this for both the height and width of the FOV. As an example, we will calculate the FOV size for a camera with a 2/3″ chip on a telescope of 1500 mm focal length.

For height,

$$6.6\,\text{mm} \times 3460 = 22836$$

Divide this by the focal length

22836/1500 mm

This gives the field height of 15.224 in arcmins.

Type	1/3"	½"	2/3"	4/3"	APS-C	DX	APS-H	35mm
W x H In mm	4.8x3.6	6.4x4.8	8.8x6.6	17.8x10	22.2x14.8	23.6x15.5	28.7x19.1	36x24
Diagonal In mm	6	8	11	20.4	26.7	28.4	34.5	43.3

Fig. 4.17 Field of view chart for a selection of imaging chips

For width,
8.8 mm × 3460 = 30448
Divide this by the focal length
30448/1500 mm
This gives the field width of 20.298 arcmins.

This is all very simple; however, in practice it is even easier to enter these figures in a planetarium program that can display a FOV indicator. You may also use an app or online field of view calculator that allows you to enter the details of your telescope and camera and choose an object from a database to actually see what size it will be in the images you take. This way, you can easily see if an object is a suitable target or if you will need to take multiple images of it and stitch them together.

Here is a FOV calculator: http://www.blackwaterskies.co.uk/imaging-toolbox/

Blackwater Skies imaging calculator is a superb calculator that allows you to choose your camera and telescope from dropdown boxes and shows you the field of view for many objects. Figure 4.18 is an example using my imaging equipment, where everything inside the green rectangle is what will be visible in the image.

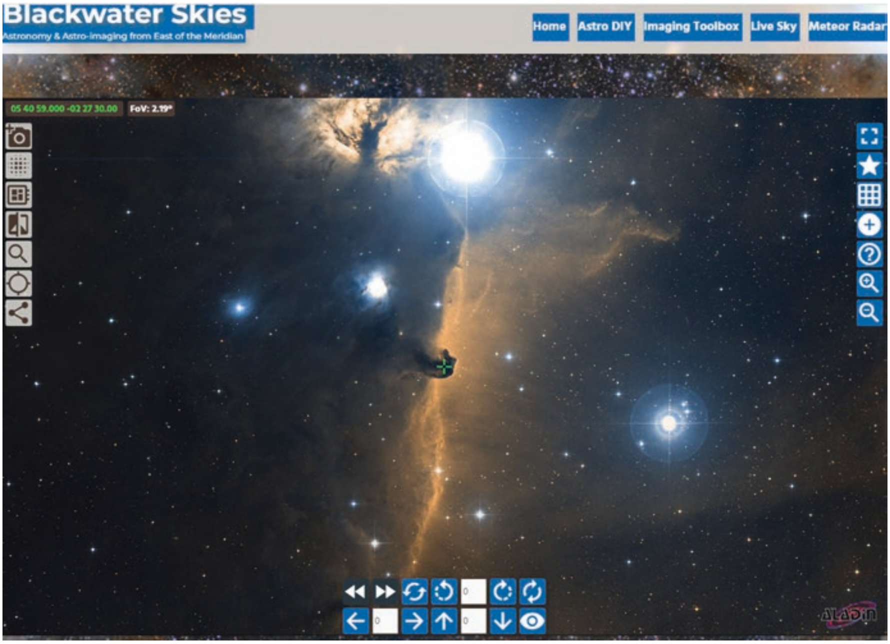

Fig. 4.18 FOV. (Screenshot permission of Blackwater Skies)

Exposure Times

How long should your exposures be? Generally, if you are trying to take a magazine-quality, noise-free deep-sky image, you need as much exposure time on an object as is reasonably possible. This may run into hours. Of course for many reasons, taking one expose of such a long length isn't practical and may not be the best way of achieving a high quality image. It would be disastrous to have an hours-long exposure spoiled because a small cloud or airplane crossed the field of view or even a small gust of wind cased the tracking to deviate.

Deep-sky astrophotography images are therefore usually made up of many shorter exposures that are added together in a process called *stacking*. This achieves a low-noise image with a good signal-to-noise ratio. Unfortunately, it is impossible to give a definitive answer for how long an exposure should be, since there are so many factors that affect it.

Factors to Consider

- How bright is the object?
- How bright is your sky?
- The sensitivity and type of camera being used
- The size and f-number of your telescope
- How accurately your telescope mount tracks
- How well you are polar aligned
- Are you autoguiding?
- Are you using any filters?

As a very rough starting point, most of my astrophotography is done using 300-second exposures for brighter objects and 600-second exposures for fainter objects and when using narrowband filters. This is using a 12″ f/5 reflecting telescope with a mono astronomy camera.

To determine exposure times more accurately, software can again come to the rescue. The old-school way of determining exposure times is to use a histogram, checking for under- and overexposure, which shows up as clipping on the image histogram. Using the Smart histogram function in Sharpcap, you can measure the brightness of your sky background and do an analysis of your camera, which will help you, decide on the best settings to use. NINA imaging software also has an optimal exposure time tool that can import the sensor analysis from Sharpcap to improve its accuracy. NINA also has a tool to help you set the camera bias correctly.

Light pollution is also quite often a determining factor in how long you can expose a single image for. As discussed previously, the LEDs used in modern fittings emit light across the visible spectrum—including at the same frequencies as the objects that we are imaging—and in particular the blue end of the spectrum. When we try to cut them out, we reduce the already scarce light coming from the objects.

Nevertheless, modern cameras are sensitive enough to image deep-sky objects despite the deterioration in our skies. This and certain filters can help, but the background sky glow should still be taken into consideration.

It is worth mentioning here that as deep-sky astronomical images are usually of very faint objects, the images typically look very dark when first viewed and require calibrating and stretching in order to see all the tones and detail that lie hidden within them.

Focusing Your Camera with a Bahtinov Mask

- This is done by putting a Bahtinov mask over the end of your telescope and pointing it at a bright star.
- Next place your camera into live view if using a DSLR or loop mode with an astronomical camera.
- Set a brief exposure time of about a second so that the screen is updated rapidly and you can see the effect as your focus changes.
- The star image will now have diffraction spikes through it but one set of spikes will move as you alter the focus see the star images at the bottom of Fig. 4.19 showing these spikes.
- The telescope will be accurately focused when all the spikes intersect the center of the star as seen in the lower center star image (Fig. 4.19)

Stacking

Stacking is the process of taking lots of short exposure images and combines them together. This means that if any individual images are ruined for any reason, they can be discarded, while only the best images are used to produce the final image. A final stacked image may have a total exposure time running into hours, but this may in reality be broken up into many five or ten minute exposures that have been added together by stacking.

Another reason to stack multiple images has to do with the signal-to-noise ratio. The digital noise from image to image varies, but if we stack

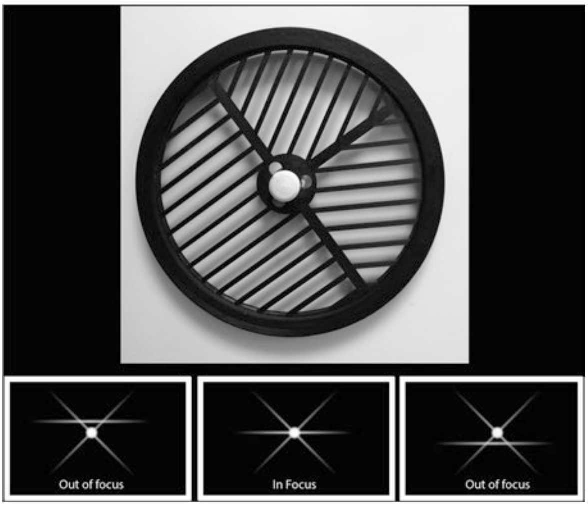

Fig. 4.19 Bahtinov Mask center top
Lower left star out of focus. Lower center Star in focus. Lower right star out of focus.

images together, we smooth out that noise and end up with a much cleaner image capable of being processed to show more detail. This is a vast over-simplification but at the moment will suffice.

Histogram

The *histogram* as seen directly on a DSLR or via software on an astronomy camera is a vital tool in assessing the correct exposure times for your images. It may be displayed slightly differently for mono or color cameras but the information it contains is basically the same.

Along the bottom of the histogram graph from right to left is the value of the pixels in the image, usually expressed in analogue-to-digital units (ADUs). Just think of them as brightness levels in the image. The brightest pixels, or whites, in the image are shown on the righthand side of the graph. The dark areas, mostly blacks, in the image are shown on the left, and the midtones in the middle area.

The vertical scale on the left of the graph represents the number of pixels with a particular value, going from zero at the bottom to just above the peak pixel value at the top. The pixel value is read by an ADC. The ADC is what detects the number of electrons the pixel has collected as a result of the intensity of the light falling upon it and assigns a number to it depending on

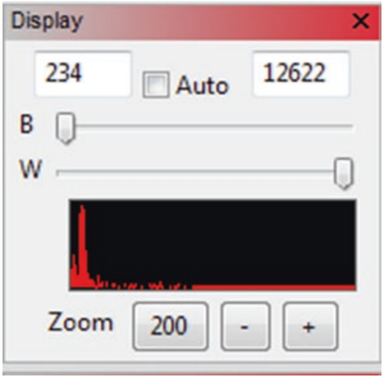

Fig. 4.20 Histogram screenshot. (Courtesy Stark-Labs)

its bit depth. The *bit depth* is a measure of how many brightness levels the ADC is capable of resolving.

In an astronomical camera, the analogue-to-digital bit depth is usually 12–16 bit. In the case of a 12-bit camera, the camera can differentiate between 0 and 16384 brightness levels. In the case of a 16-bit camera, the bit depth is from 0 to 65535. This means that the 16-bit camera is capable of discerning twice as many levels of brightness in the image.

From the typical histogram in Fig. 4.20, we can see that it starts off low, quickly rises to a steep peak and drops off steeply but then tails off very slowly. From the left of the bottom scale, what you are seeing is the sky background, which accounts for most of the peak and up to where it starts to fall off very gradually. The next section, which extends about 1/3 of the way across the image, is the greys or midtones in the image. The rest of the graph shows the whites or highlight areas of the image.

From this, we can infer that if the peak is cut off by the left edge of the histogram, we are underexposing the image. If the main peak is too far to the righthand edge, we are overexposing the image. To fully utilise the capabilities of our camera regardless of its type, it is important to understand the histogram and be able to modify the exposure length of the camera so that we get the maximum range of pixels capable of being recorded.

It is therefore a very useful exercise to try different exposure lengths and look at the histogram to work out an optimum exposure time for your equipment and skies. This usually occurs when the peak of the graph is approximately one third of the way across from the left of the graph.

Stretching

Images straight from the camera are usually very dark and show very little detail. This is because they need stretching to enable all the detail to be seen. *Stretching* is the process of rescaling the pixels in an image in order to make all its detail visible. Most image-capture software supports screen stretching which only stretches the image to enable the images you are taking to be seen without effecting the saved data. This gives us apreview that we can use to assess the images more easily whilst they are coming in from the camera. The effect of Image stretching permanently changes the actual image files and this can can be seen on the image histogram which enables processing to be done without loosing valuable information from the image. Stretching images is covered in the section on image processing in Chap. 9.

Telescope Mounts

The mount is the part of the telescope system that carries the optical components and moves it to point at the right area of the sky that is of interest for imaging. Once it has arrived at the correct position it needs to track or follow the apparent motion of the object across the sky for extended periods of time.

To carry out successful deep sky astrophotography the mount is vitally important as most of the objects to be imaged will be very faint and even using very sensitive cameras require long exposure times to capture them in detail. So it is important to understand the function of the mount and what we will be asking of it.

The mount therefore needs to be a very solid and stable base with enough power to enable it to accurately move the telescope optical assembly with the fine precision needed to take high resolution images.

This also means that it must also be aligned very accurately with the earth's axis as this is the movement we are trying to counteract and it must have the necessary fine adjustments available to achieve this.

The tracking needs to be done to an accuracy of around 1 arc second that means it has to track consistently to an accuracy of 1/3600th of a degree. The software in the telescope handset and in many of the computer programs used to control telescopes have tools to assist with the polar alignment and star alignment as will be discussed later.

The telescope mounts available for amateur astrophotography fall into 2 main types AltAz and Equatorial. The following is a description of each type.

It should now be apparent that the telescope mount is much more than a fancy camera tripod and has much greater and finer requirements to achieve its intended purpose.

Types of Mount

I will now describe which of the commonly available mounts are suitable for astrophotography and why others are not.

AltAz Mount

Telescope mounts come in two main types the first and simplest is the AltAz mount which comes from altitude meaning up and down and azimuth which means left and right. So this mount simply moves using an up down axis and a left right axis. This type of mount isn't the most suitable for astrophotography unless additional equipment such as a field rotator is fitted, or you are using software that can do live stacking of brief exposures such as Sharpcap. This is needed to eliminate something called field rotation in which the stars seem to rotate around the center of the field of view. The reason this happens is explained by Fig 6.2 (Fig. 4.21).

Fig. 4.21 An Alt AZ telescope. (Picture courtesy of Meade)

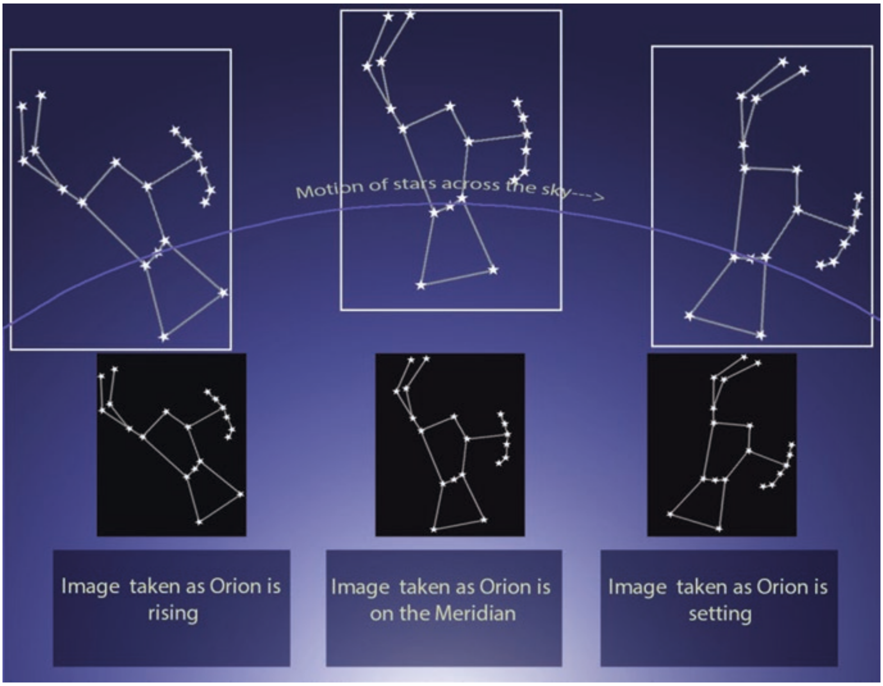

Fig. 4.22 Field rotation when using an Alt AZ mount

This diagram shows how an image appears to rotate in the field of the camera as it travels across the sky using an AltAz mount. The white rectangle is the camera view at each location in the sky keeping the same location in the center of the field of view. Underneath is the picture it would take at each of the three positions (Fig. 4.22).

If these images are stacked straight on top of each other the result will be an image similar to this in Fig. 4.23 which clearly demonstrates the field rotation from the camera's point of view.

Also, unless you take short exposures there will be evidence of some field rotation in each image. The stars will show as arcs which are longer the further away from the center of the field of view they are and as the exposure time increases.

It is possible to use stacking software to combine these images with the stars in register with each other but the extremities of the image may be lost; this is because the edges of the image will be cropped off in the stacking process leaving the smaller central area where all the images have a common overlap.

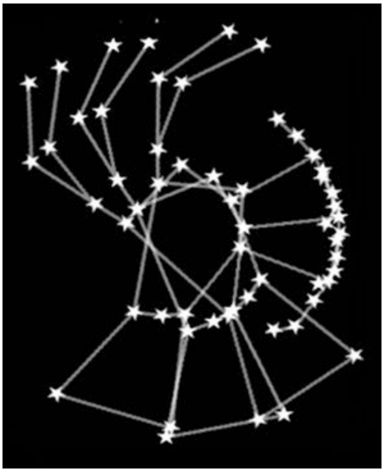

Fig. 4.23 AltAz Stacked images

This tends to work for the brighter deep sky objects as they don't need as long time exposure times but becomes more demanding the fainter the objects are. It is possible to take a lot of very short exposures and stack them but this needs a lot of storage space and memory so that the computer and stacking software can deal with the large amount of data required. It can be made to work but is not an ideal solution.

Despite the above mentioned issues, it is surprising that almost all large modern professional telescopes are on AltAz mounts. This is because the engineering is greatly simplified and with the size and weight of these telescopes the engineering costs are a very important factor.

The problem of field rotation is solved by employing a device appropriately called a field rotator which rotates the camera or equipment being used to image, hence eliminating the problem.

Whilst field rotators are available for amateurs they are still expensive and add another layer of complexity to the system.

Many commercial fork mounted telescopes are natively of an Alt AZ construction but with the option of adding an equatorial wedge which is capable of being adjusted to the angle of the latitude that the instrument is being used at, which turns it into an equatorial mount.

The Dobsonian Mount

The Dobsonian mount is probably the most common large amateur telescope mount today; it was designed with simplicity and home construction in mind. It is basically the same mount that cannons used but with the addition of the ability to also be turned horizontally. The design uses low cost materials such as plywood or MDF for the frame and Teflon pads as the bearings and only requires basic woodworking skills and tools (Fig. 4.24).

The designer of this type of mount was John Dobson, hence the name, who was an American amateur telescope maker who rose to fame in the 1960s as his simple but effective mount design really made it possible for people to design and build their own telescopes at home very inexpensively.

Home built optical tubes for a Dobsonian telescope can be made using Sonotube which is a construction item used as a former or mold when pouring concrete columns and comes in many diameters and lengths. The availability of different sizes and lengths means that there is always a suitable size for the aperture of the telescope to be built.

To keep costs down the original Dobsonian design also used surplus glass portholes from ships which were ground by hand to produce the main mirror. The design was a mix of ideas that were very cleverly brought together to enable an amateur to easily build a large and inexpensive telescope at

Fig. 4.24 Dobsonian mounted Telescope. (Picture courtesy Meade)

home that was also easy to use, robust and easily transportable depending on its size. One of the big advantages of a Dobsonian mount is that it is totally scalable so that it can be made as a small telescope or a very large one with only small changes to the basic design.

The Dobsonian mount can be fitted with an encoder system to tell the user where it is pointing in the sky or even to guide the user to an object from one of the built in catalogues.

Dobsonian telescopes are also available fitted with Goto computer systems which will slew to an object and track it across the sky, but as the geometry of the mount remains AltAz it will still suffer from field rotation.

Another option for a Dobsonian telescope is that it can be mounted on an equatorially mount platform which will allow it to track the sky without field rotation. Due to their geometry these tracking platforms usually have a set time limit over which they are capable of tracking, after which, the platform has to be moved back to a start point and the object reacquired in the telescope.

Equatorial Mount

An Equatorial mount is ideal for astrophotography as it tracks the objects of interest for imaging across the sky using one axis; it does however require more setting up which does have to be done very accurately to get the best results. Additional steps are still needed to do high resolution work (Fig. 4.25).

As can be seen from Fig. 6.5 the telescope RA axis is lined up with the celestial pole (the axis of rotation of the earth). By rotating the telescope in the opposite direction of the earth's rotation using this axis, the earth's movement is counteracted and it is possible to track the apparent movement of the stars across the night sky (Fig. 4.26).

There are two main types of equatorial mount commercially available to the amateur which are fork mounted which requires an equatorial wedge and the German equatorial mount GEM which is the type used for description in this book (Fig. 4.27).

All these mounts are available as Goto mounts which means they have a handset or a mobile phone app that is capable of instructing the mount to point at your chosen object automatically.

The ideal choice for system for astrophotography therefore, is a Goto which can be a fork mounted telescope on an equatorial wedge or a German Equatorial mount as long as it has the capability of being accurately aligned

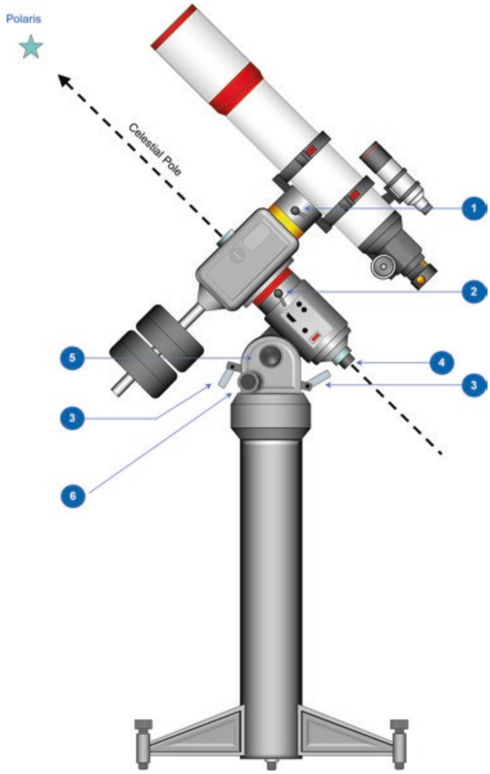

Fig. 4.25 By virtue of its design an equatorial mount tracks the stars across the sky. (Illustration courtesy of Peter Karboulonis' and Opticstar)

Fig. 4.26 The authors GEM mounted telescope

Fig. 4.27 Fork mounted telescope. (Picture courtesy of Meade)

with the earth's polar axis. In the case of a fork mount, this may require the separate purchase of an equatorial wedge as many fork mounted telescopes only come equipped as AltAz mounts (Fig. 4.28).

The equatorial mount has one of its movement axes parallel to the axis about which the earth rotates. It is the earth's rotation about this axis that makes the stars to appear to move across the night sky. So what the equatorial mount is doing is rotating the telescope in the opposite direction to the earth which enables it to image the night sky as if it was on a stationary platform in space. This axis is called right ascension. The other axis is called declination. The reason that this type of mount is mainly used by amateur astrophotographers is that it doesn't suffer from field rotation (Fig. 4.29).

If the images taken with the equatorial mount are now stacked, the image lines all line up so that they can be correctly stacked and each individual image shows pinpoint stars irrespective of its duration see Fig. 6.9. This means that the information from each image is successfully combined with all the others in the stack producing a stacked image which has reduced noise and can be processed to show fainter detail.

Types of Equatorial Mount

There are many types of equatorial mount but they all share one common factor and that is that the right ascension axis of the mount always needs to be aligned with the rotational axis of the earth.

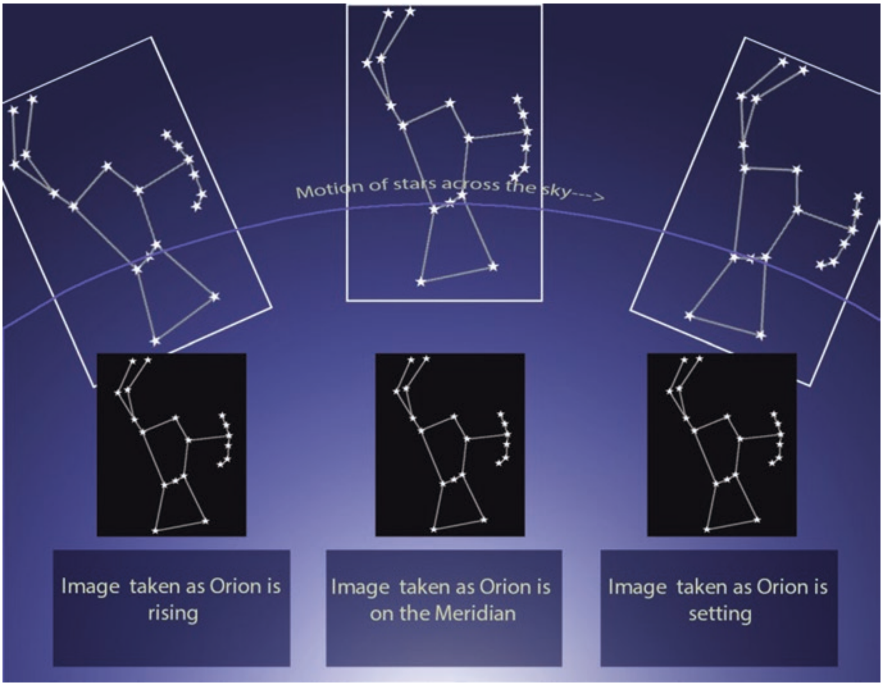

Fig. 4.28 Field of view movement using an Equatorial mount

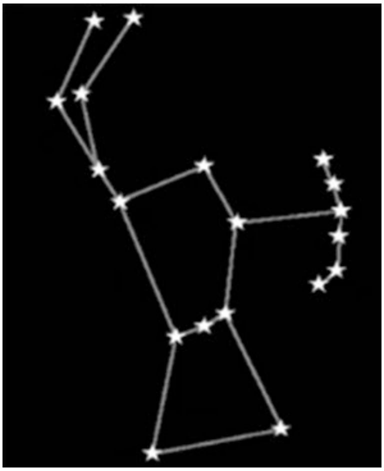

Fig. 4.29 Resulting Equatorial mount Stacked images

German Equatorial Mount GEM

This is sometimes call a "GEM" which is short for German Equatorial Mount, it consists of two axis one which is aligned with the earth's axis of rotation which is called the Right ascension axis. The other axis allows north south movement and is called the Declination axis. These names are usually shortened to RA and Dec for convenience (Fig. 4.30).

As can be seen in the picture one of its characteristics is the necessity to have counter weights to balance the weight of the telescope.

One disadvantage of the German mount is that as the telescope is tracking it passes through the meridian which is an imaginary line drawn from the North Pole through the southern horizon to the South Pole it must perform a procedure called a meridian flip.

A meridian flip is when the telescope and weights swap sides on the mount by the telescope rotating 180 degrees around the right ascension axis such that the telescope and weights swap positions. This is done to keep the weights in a lower more stable position and to reduce the chance of the telescope colliding with the telescope mount. If a meridian flip is carried out during an imaging run the target object will need to be re centered before continuing to image.

Fig. 4.30 A typical German EQ mount with telescope in the home position

Equatorial Fork Mount

The fork mount, as it is commonly called, is widely used by the major manufacturers of Catadioptric telescopes as discussed earlier in this chapter. This type of mount removes the necessity for a large counterbalance as the telescope tube is enclosed in the mount as opposed to the end of a swinging arm like the German equatorial mount. The balance still has to be corrected for any equipment such as guide scopes, cameras, filter wheels OAG that are attached to the telescope. Clearance between cameras and the bottom of the fork mount can be a problem and has to be taken into account when adding equipment. The fork mount design does tend to be more compact which is great for transporting and if space is tight in an observatory (Fig. 4.31).

Star Trackers for Portable Astrophotography

Whilst not the main focus of this book I feel that I should mention wide field camera star trackers, as these are becoming increasingly popular with the advent of more affordable models. These are great to use when travelling as they tend to be very small and much lighter than a full size telescope mount. Most of these star trackers can be mounted on a sturdy camera tripod for ease of use.

Fig. 4.31 Equatorial fork mount. (Picture courtesy Meade)

The following mounts are currently available and seem to produce good results, and at the same time offer portability and fast setup that make them a great grab and go option.

Sky-Watcher Star Adventurer Mount

The Sky-Watcher Star Adventurer is at the larger end of this type of mount having a payload capacity of 5 kg. It is driven using a servo motor and is powered by the use of 4 X AA batteries making it self-contained. The weight capacity means that it is capable of handling a DSLR and some Telephoto lenses.

The Sky watcher Adventurer Mount is sold in various packages from just the mount itself to the Pro pack that contains the Mount and Equatorial Wedge plus the Dovetail bar and 1 Kg counter weight (which is needed if you will be using it loaded to its maximum weight capacity), the ball head polar scope and illuminator. A shutter release cable for cameras is not supplied.

This mount has the following features:

1. Tracking is selectable between Sidereal, Solar and Lunar.
2. Preprogrammed speeds for Time lapse photography.
3. Built in polar scope with illuminator.
4. DSLR Interface for automatic camera shutter control.
5. External power may be used via a Mini USB port.
6. Free Firmware upgrades.

Vixen Polarie Star Tracker

The Vixen Polarie Star Tracker is a smaller tracker with a capacity of 2 Kg making it unsuitable for heavy cameras and lenses being designed for wide field astrophotography. Bearing this in mind it does a superb job and features sidereal tracking, half sidereal tracking and both solar and lunar rates. It is suitable for use in both northern and southern hemispheres.

Tis mount has the following features:

1. The Vixen Polarie uses a stepping motor to mount the precision gear movement.
2. It uses a sight hole to carry out polar alignment but there is a Polarie Axis Scope available as an optional extra, along with a Quick Polarie locator compass.
3. The Polarie is capable of running for up to two hours using 2X AA batteries or using a USB Mini-B Connection (4.4–5.25 V).

IOptron SkyGuider Pro EQ Camera Mount

The IOptron SkyGuider Pro EQ Camera mount functions as a versatile equatorial mount that can be configured with or without weights depending on the payload in use; it also has accessories allowing it to be used as a dual camera rig as long as the weight does not exceed the payload capacity. The SkyGuider is available as a tracking head and AltAz base or as a full Pro package.

This mount has the following features:

1. Sidereal, half sidereal, solar and lunar built in.
2. A payload capacity of just less than 5 Kg when properly balanced.
3. A notable feature is the factory installed LiPo battery that they claim will give up to 20 h runtime.
4. The SkyGuider boasts a built in illuminated polar scope to make polar alignment easier.
5. A camera shutter release port to operate compatible cameras.
6. An ST4 Autoguider port is supported.
7. The IOptron SkyGuider also has a 144X fast slew speed to help find and frame shots.
8. A counter weight system is available if you are using it fully loaded in a double camera configuration.
9. There is a port for a Go2Nova hand controller but this port functions with limited capabilities.

Explore Scientific iEXOS-100 PMC-Eight Equatorial Mount

This is new telescope mount and is a very affordable, fully featured Goto mount that has dispensed with a handset and requires you to use a tablet or mobile phone to control it via an app. This has two main benefits; it reduces the cost of the mount, as they are not manufacturing and supplying a handset, and it also means that the app used is easily updated and new features added. This will likely be the start of a new trend particularly at the budget end of the market, but probably becoming more common in time.

Go-to Handset Control

Most telescope mounts sold today are natively controlled by using a handset that comes with the mount, and is programmed to both fully control and set up the mount. In addition they also contain lists of stars, planets and deep sky objects (Fig. 4.32).

Fig. 4.32 Sky watcher Synscan Handset

The handset is designed to make it easy to setup and align the telescope system, synchronizing it with the user's sky once it has been given the time, location of the mount and the elevation above sea level.

The following description assumes that the telescope mount is level and the finder telescope has been lined up with the view through the main telescope.

When the handset is connected to the mount and the mount is powered on, the handset goes straight into a setup mode which requires the time and date to be entered, if daylight saving time is in effect and the latitude and longitude of the site where it is being used. This might not be required if the mount has built in GPS; in this case this information is retrieved automatically.

Information will then be provided regarding the position of Polaris in order for the mount to be adjusted for a polar alignment so that the rotation of the right ascension axis of the mount follows the movement of the stars across the night sky. It might be easier to simply download a polar alignment app and use that looking through the polar scope to match the reticule with the app display. This is sufficient accuracy for the beginner using a short focal length telescope and wide field setups. If you are using a long focal length telescope for imaging then there are more accurate methods.

Once the mount has been polar aligned you will be asked if you want to carry out an alignment procedure. This is commonly known as a star alignment and is the process of synchronizing the real sky to the telescope handset computer. This alignment also compensates for polar alignment and mount errors.

It is important that the handset prompts are read and followed as it will easily guide you through the whole process.

The alignment usually takes the form of a one, two or three star alignment. This process is very simple and involves the telescope slewing to where it thinks an alignment star is in the sky.

If the alignment star is not in the main telescope field of view it should be in the field of view of the finder telescope which has a much wider field of view. Simply center it again using the arrow keys on the handset and then when it is visible in the main telescope.

Once the alignment star is in the field of view of a low power eyepiece through the main telescope, simply use the arrow buttons on the handset to center that star, then press the sync button. This is done either once, twice or three times depending on which star alignment routine you choose. The three star alignment routine is the best choice for imaging as it takes care of some mechanical errors that may be present in the mount and also possible errors regarding the mount be being completely level. This should not, however, be relied on and the mount should be set up as accurately as possible.

When this has all been done, the handset can be used to point the telescope at the objects to be observed or imaged.

The accuracy of the pointing can be further refined by centering the objects, if necessary, and again synchronizing them with a button press. In this way the pointing accuracy can be continuously improved all night.

Some mounts have a built in GPS system which does most of this for you, and there are even mounts that will do everything including polar aligning themselves; these come at a premium price and may be considered too expensive for many amateurs.

There is also a new type of telescope mount becoming available which do not come with a handset but instead require you to use a tablet or mobile telephone with an app supplied by the mount manufacturer which is used to control the system. One benefit of this is that the mounts can be produced and sold at a cheaper price and the features and updates are more easily implemented. Another benefit is that if the mount is equipped with Wi-Fi it reduces the amount of wiring which can be a problem.

The Advantages of Using a Handset

1. The main advantage of using a handset is that it is compact and ready to use with the mount once it is plugged in.
2. The supplied handset has the main features that you need to control a telescope for basic operation.

3. Takes very little power which is usually taken from the mount so no additional power cables.

The Disadvantages of Using a Handset

1. Functions are limited to those that the manufacturer has programmed into the handset. It means that that there is no access to plate solving and automatic locating and centering of objects and no access to a multitude of other pieces of software to control the telescope, such as planetariums, Image planning software and auto guiding software just to mention a few.
2. In order to guide the telescope you have to use a standalone Autoguider which is expensive and not easy to use.
3. Limited to the lists of objects that the manufacturer has entered and most mounts only allow a few custom objects to be entered, whereas by using a planetarium, there is access to all the catalogues of objects that it contains. This includes transient objects like asteroids and comets that cannot be included in the standard handsets.
4. The time and date are lost at power down and need to be entered every time.
5. Updates are infrequent and seldom add new features.
6. A handset failure means the telescope is out of action until a repair or replacement can be effected. However, if a computer is being used, a spare or borrowed laptop can be pressed into service to keep you running.

Using a Smartphone or Tablet to Control a Full Size Telescope Mount

As previously mentioned some modern mounts are appearing that use a smartphone or tablet computer to replace the previously supplied handsets. This is the way forward for this technology and has many advantages given the fact that the manufacturers do not need to develop, support and supply the handset computers. Mounts should cost less to produce and sell and any updates will simply be an app update that can be carried out automatically.

Controlling Older Mounts by a Smartphone or Tablet Computer

Many older mounts are capable of being controlled by a smartphone or tablet using Wi-Fi or Bluetooth adapters. The correct adaptor should be used both for your telescope and the app as some are app specific.

When set up this gives access to a wealth of tools to control the telescope system such as the planetarium software Skysafari 6 Pro which whilst expensive, for the full featured version, has so many features and access to vast catalogues of objects.

Advantages of Using a Mobile Telephone or Tablet Computer to Control a Full Size Mount

- Almost everybody has a mobile phone
- Compact and lightweight
- High resolution screen on modern phones and tablet computers
- Does not require external power and long battery life
- Using a wireless connection keeps the cabling down which reduces spoilt images due to cables dragging or getting snagged.
- Keeps the cost down as a handset is not supplied with the mount and most people have a smartphone or tablet.
- Allows the use of many third party apps to control the telescope system adding flexibility and rapid implementation of new features.

Disadvantages of Using a Mobile Telephone or Tablet Computer to Control a Full Size Mount

- Ties up your mobile phone/tablet computer.
- Wi-Fi connection can be subject to interference from other devices.
- Screens can be too small to easily see details; more of a problem with phones.
- Can be difficult to enter details due to the small size; less of a problem with tablet computers.
- Screen may be too bright even on the lowest setting.

Portable Tracking Mounts Controlled by the Use of an App

There are also some small portable tracking mounts which use a smartphone or tablet to control them through the use of an app. One example of this is the Sky watcher Star Adventurer mini; this generates its own Wi-Fi hotspot to connect to using an app to set the number and duration of camera exposures, tracking speed and mode and turn the mount on and off. With this mount you can disconnect from it when it has been set and let it carry on itself with no further intervention.

Chapter 5

Computer Control of a Telescope

Using a computer to control an amateur telescope adds functionality that wasn't possible previously and turns a hobby telescope into one capable of taking fantastic images as well as doing serious work. Previously the main option was to connect a handset, desktop or laptop computer this has now changed with the advent of compact but very capable single board computers such as the Raspberry PI. At the end of this chapter I have included an over view of using these type of devices to control an imaging setup as I feel the impact they will make has only just started to be seen and may result in the whole device being built into the telescope mount so that it is one completely self-contained unit requiring only a tablet or mobile phone to act as an input and display device.

Basic Computer Control

At its most basic this involves the use of a computer connected to the telescope running a planetarium or other control software such as a planner to select the object to be imaged and using its functions to tell the telescope to slew to the object. Once the telescope has slewed to the object and you have confirmed it is in the field of view visually, you can fit a camera and start taking images which is a good way to start. As you gain experience and confidence, it is then worth looking at what other software and techniques and equipment that you can use to improve your images.

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_5

Advanced Computer Control

An advanced imaging session can consist of telling the telescope to slew to an object by clicking on it in a planetarium program. The telescope then automatically slews to the object. It will then automatically take a picture and check the star field against its installed star catalogue. It is then able to check if it is pointing at the intended area or object. If it isn't pointing in exactly the right area it will then move automatically to where it should be and take another picture to confirm it is now on target. This is a very powerful technique called plate solving and is usually completed in a couple of minutes leaving the telescope tracking with the field of view exactly where you wanted it to be. This technique is excellent for imaging runs that take more than one night or for returning to the same object later in the same night. The focus can also be automatically checked by taking very brief images and noting the characteristics of the stars that it can detect. This is usually plotted as a graph that is then analysed to determine the correct focus and move the focuser to that position. Another image is then taken to confirm that the focus is correct. The next step is for the auto guiding software to look at the field of view through a guide telescope or off axis guider (OAG) and choose a star to guide the telescope. Once the guide star has been chosen the auto guiding software will start to send corrections to the telescope to keep it tracking exactly on target. A short time is usually allowed to let the guiding settle down and then the system is ready to start the actual imaging run. The imaging run will comprise of instructions detailing the number of images to be taken, the sensitivity settings for the camera, the exposure length and filters to be used. The camera cooling temperature is usually set in the imaging software settings at the beginning giving the camera time to both cool and stabilize at the required temperature. The imaging software will automatically take the images and save them to the computer in a folder that is dated and in a sub-folder of the objects name. During this imaging run it will take many individual images that will be stacked together later to produce the final image. A full system like this is incredible to watch and is a marvel of optics, mechanical engineering, electronics and computing all working together in perfect harmony.

One of the beauties of a fully automated system is that it frees up your time and can also be operated and monitored remotely; this is a big advantage when it's very cold outside and you are spending a long time on one particular object. Some systems also employ safety features such as rain detection which can abort the images, park the telescope and shut the roof or dome.

This is basically how my system operates although I don't have the luxury of an automatic roof. However not everyone will want that degree of automation. It is up to you to decide how much automation you use; it's entirely up to you. The level of automation that you choose may also be influenced by the type of imaging work you intend to carry out.

Advantages

- It is possible to control the telescope by using a planetarium program which gives a visual representation of the night sky and usually features an indicator to show you where your telescope is pointing.
- The telescope may be controlled using database type software such as Astro Planner or Deepsky Planner which have very powerful database search facilities and enable you to create observing lists that are sorted on the basis of the many filters that they have.
- A field of view indicator on your planetarium software can be set to show exactly what will be visible in the field of view and if the object is of a suitable size for imaging in one shot or if a mosaic will be necessary.
- The telescope may be controlled using a multitude of programs, some free and some commercial, these can be specialized for your particular interest.
- The option is available to control the telescope as you take images or you can automate it to do everything for you. I tend to do a mixture depending on my mood and the imaging project that I am involved in at the time.
- Using plate solving software enables you to be sure that the object that you are interested in is positioned in your picture exactly where you want it. This is especially useful when imaging very faint objects that might need long exposure times to see them. It is also useful when imaging asteroids and comets which move rapidly and may not be easy to identify in a crowded star field.
- The user is able to use planetarium programs for very easy navigation to objects such as asteroids or comets which may only be temporary visitors to our skies.
- Plate solving which is a software tool that takes an image and uses star catalogues to work out where the telescope is pointing and can then synchronize it with control software and move it to the target object if it isn't pointing to the correct area of sky.
- Autofocus: you can have a focuser that automatically finds the best focus and then uses temperature probes to track focus changes due to changing temperatures.
- Automatic imaging runs can be set up leaving you free to get your binoculars out or make a coffee, whilst your telescope is doing things like searching for supernova in distant galaxies.

Disadvantages

- The initial cost of a computer controlled setup is high but with the advent of smartphone and tablet controlled mounts we are already seeing some good quality, less expensive equipment. However even a middle of the range setup should give you many years of good service.
- The imaging system can start to become quite complex and if there are problems it can be difficult to diagnose which can waste precious imaging time, however if you build it up in the steps that I suggest later, you will get to understand it properly which is essential to for successful running.
- It can take a considerable amount of time to set up all the different pieces of software and get them fine-tuned. That's what cloudy nights are for!
- It can take a considerable amount of time to setup your system for imaging each time you want to use it, unless you are lucky enough to have a permanent observatory.
- If you are using the telescope in your yard power shouldn't be a problem, however if you plan to take it to dark sites or star parties it needs to stay portable and be relatively quick to setup. A good source of stable power is required and it is essential to use the correct type of battery, preferably a large leisure battery or large enough capacity Li-ion. Beware using your car battery to run your telescope for long periods could flatten it.
- Wiring can become quite a tangle if not kept under control, which is why I prefer to fasten the wiring to the tube with cable ties and sticky pads.

P.C. Software Used to Control Your Telescope System

The following is a list of popular programs that are used to control a telescope for imaging and are suitable for a beginner to use. There are other programs such as Maxim DL and Sequence Generator Pro just to name two but they are beyond the scope of this book.

Planetariums

The Sky X

http://www.bisque.com/sc/pages/TheSkyX-Professional-Edition.aspx

This is a paid for program which has a very capable planetarium and also aims to have a full workflow for the astrophotographer. It includes plate solving software an auto guider and the ability to control many other devices such as filter wheels. It also has features such as screen stretching to get a better visualization of the data from your camera. One feature that it supports is live stacking, where it combines all the images from the main camera as they are taken.

Cartes du Ciel

https://www.ap-i.net/skychart/en/start

This is a free and open source planetarium program that many astrophotographers choose to use to control their telescopes using Ascom. It is expandable by downloading extra catalogues of both stars and deep sky objects and you can also easily download updates for comets and minor planets (Fig. 5.1).

Stellarium

Stellarium is a free to use planetarium program which has great charting capabilities capable of displaying 177 million stars and with added cata-

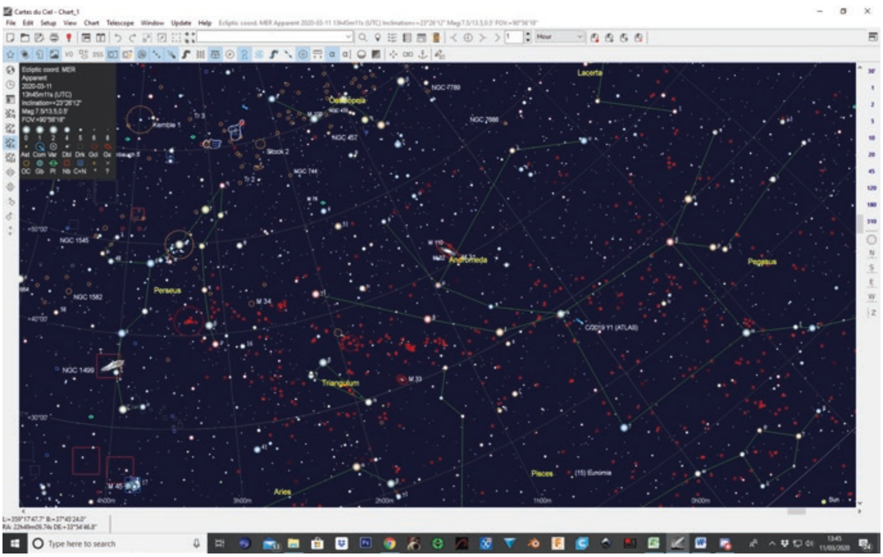

Fig. 5.1 Cartes du Ciel. (Screenshot by permission of Cartes du Ciel)

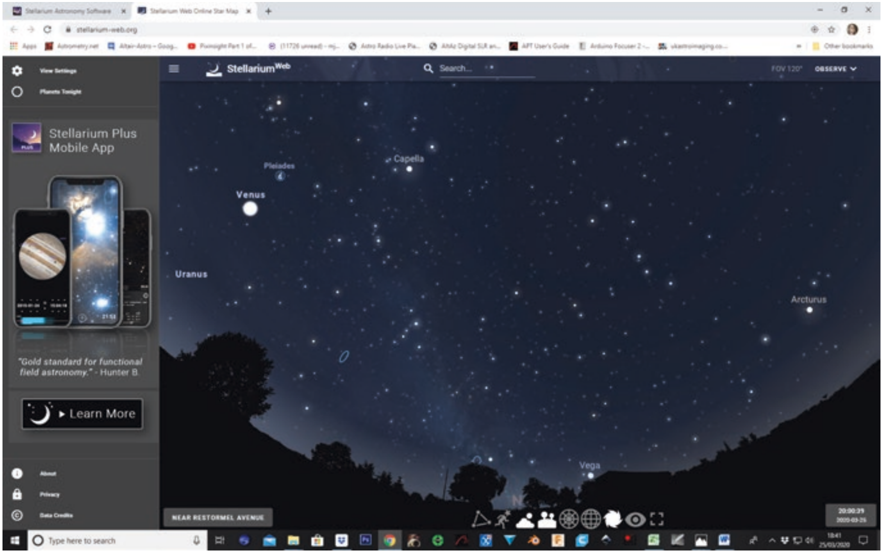

Fig. 5.2 Stellarium (screenshot from online version). (Screenshot by permission of Stellarium)

logues of over 1 million deep sky objects. Stellarium can also control your telescope. It has a realistic display of the Milky Way, and contains images of the Messier objects. It is also available for Windows, Linux/ UNIX and Mac OS (Fig. 5.2).

HNSKY, Hallo Northern Sky Planetarium

http://www.hnsky.org/software.htm

HNSKY is a freeware planetarium which can control your telescope system using Ascom for a windows computer or INDI for a Linux computer. It has huge databases that can be downloaded and supports updating comet and minor planet elements. It also boasts a very clear and uncluttered display which is very configurable.

C2A

http://www.astrosurf.com/c2a/english/

C2A is a free planetarium program with facilities to control a telescope through Ascom. It has expandable catalogues and easily updated comet and minor planet elements. It has a very clear display and is very configurable.

Database Programs

These are programs which have a more dialogue based interface which is deigned to do very powerful searches through huge catalogues of objects and reduce it to a list of objects that you are interested in. This is achieved by very flexible search criteria that you setup to suit your interests, equipment and sky conditions.

Astroplanner

http://www.astroplanner.net/index.html

This is a paid for program which is used to plan imaging or observing sessions using filters to interrogate the installed catalogues and produce a suitable list of objects to image or observe it can also control a telescope to slew it to the required objects.

Deep-Sky Planner 8

https://knightware.biz/dsp/index.php

This is a paid for program which is used, as the name implies, to plan either observing or imaging sessions and this is achieved through the use of powerful dialogue boxes to filter suitable objects into a spreadsheet plan view from a huge range of catalogues. From here, you can use it to control your telescope and slew it to the objects required. Deepsky Planner also has visibility information for the objects that you are interested in and it can also link into planetarium programs so that you can have the best of both worlds. The planner also has the ability to show images of the objects in your plan downloaded from the internet. You can also use Deep Sky Planner to export observing plans in the correct format required by APT, ACP and Sequence Generator pro. Deep Sky Planner also shows the diversity of software available and that it doesn't need to be graphically based in order to plan and operate a telescope imaging system effectively (Fig. 5.3).

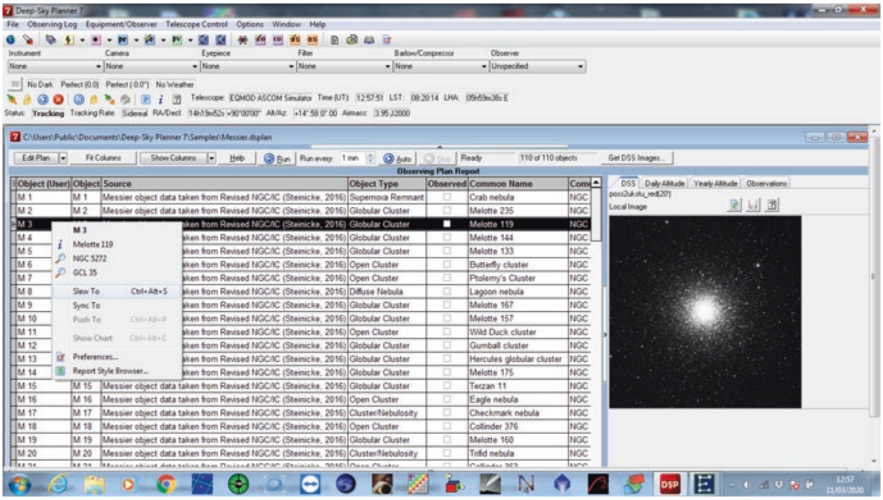

Fig. 5.3 deep Sky Planner. (Screenshot by permission of Deep Sky Planner)

Imaging Software

Astro Photography Tools (APT)

https://ideiki.com/astro/Default.aspx

Astro Photography Tools is a paid for program which is designed to control your telescope and is also capable of automating your imaging runs. APT links to Autoguiding software such as PHD2 and to Astrotortilla, which is plate solving software it also has integrated support for two others. It allows you to easily setup an imaging run on an object swapping filters as required and has its own focusing routines one of which is automatic. It has a basic list of objects and you can download a larger catalogue or even add your own. It supports live view and live view stacking for dealing with fainter objects (Fig. 5.4).

Nighttime Imaging 'N' Astrophotography (NINA)

https://nighttime-imaging.eu/

NINA developer Stefan Berg has a donation page to help the support the project.

https://nighttime-imaging.eu/donate/

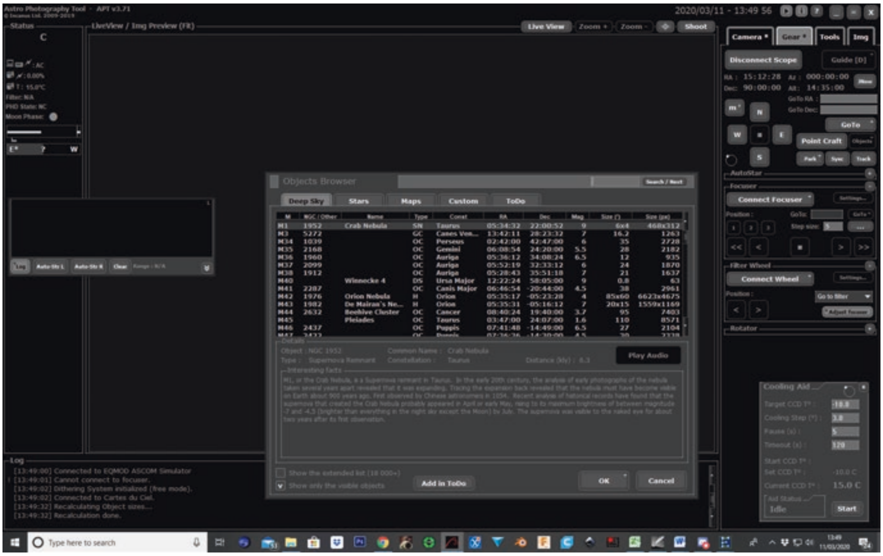

Fig. 5.4 APT Astro Photography tools. (Screenshot by permission of Astro Photography Tools)

NINA is a very powerful open source piece of software designed to allow you to automate your imaging sessions. It has a Searchable sky atlas with images, a framing wizard which is great for composing images showing a field of view (FOV) frame for your camera and telescope. It is also used when building the panels to produce a mosaic of objects that are too big for your FOV. It has a flat wizard for the easy creation of accurate flats to calibrate your images. The most powerful aspect of NINA has to be its sequencer where you define the objects that you require images to be taken of along with exposure, filters to be used. It also supports the automatic operation of many focusers and filter wheels. NINA links to plate solvers and autoguiding software. NINA can literally be setup to take a full night of images with no intervention by the operator if wished. It is being very actively developed and has a growing community on its discord server (Fig. 5.5).

Sharpcap

https://www.sharpcap.co.uk/sharpcap/support-and-troubleshooting/217-2

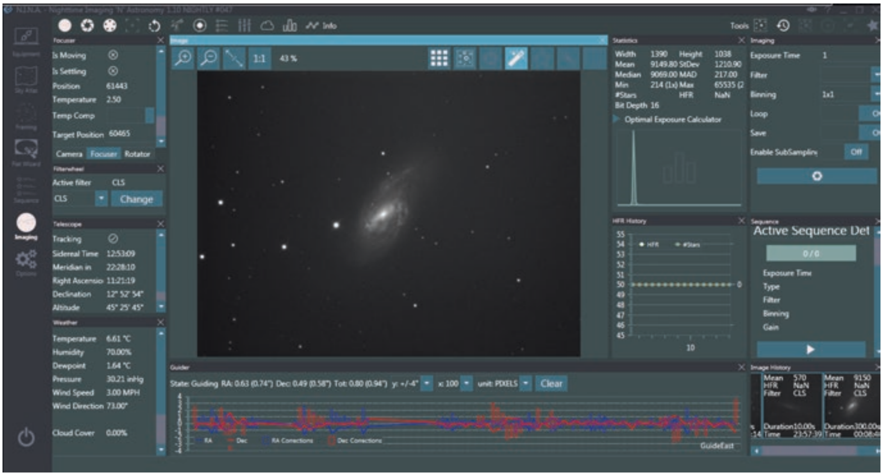

Fig. 5.5 NINA Image capture. (Screen shot by permission of Stefan Berg)

Sharpcap is an image capture program that is breaking new ground with some of its' tools and features; it has a fantastic live stack mode that enables you to see your images being added together as they come in from the camera. The live stack mode takes care of alignment and even rotational errors which means that it has the potential to take images using an Alt AZ mount which wouldn't normally be suitable. It also has a fantastic sensor analysis tool and really quick and easy to use polar alignment routine. It can be used with Web cams and USB frame grabbers. It is also capable of controlling the following ASCOM devices: focuser, filter wheel and telescope mount. Another interesting feature is the seeing monitor, which can be used to automatically save the frames that are above a selected quality threshold.

Auxiliary Software

PHD2 Push Here Dummy 2

https://openphdguiding.org/

PHD2 or Push here dummy! Is a free autoguiding software package that enables your telescope to lock onto a guide star and then send corrections to the telescope mount system. It does this in order to keep the telescope precisely on target eliminating stars looking egg shaped or even trailing. It

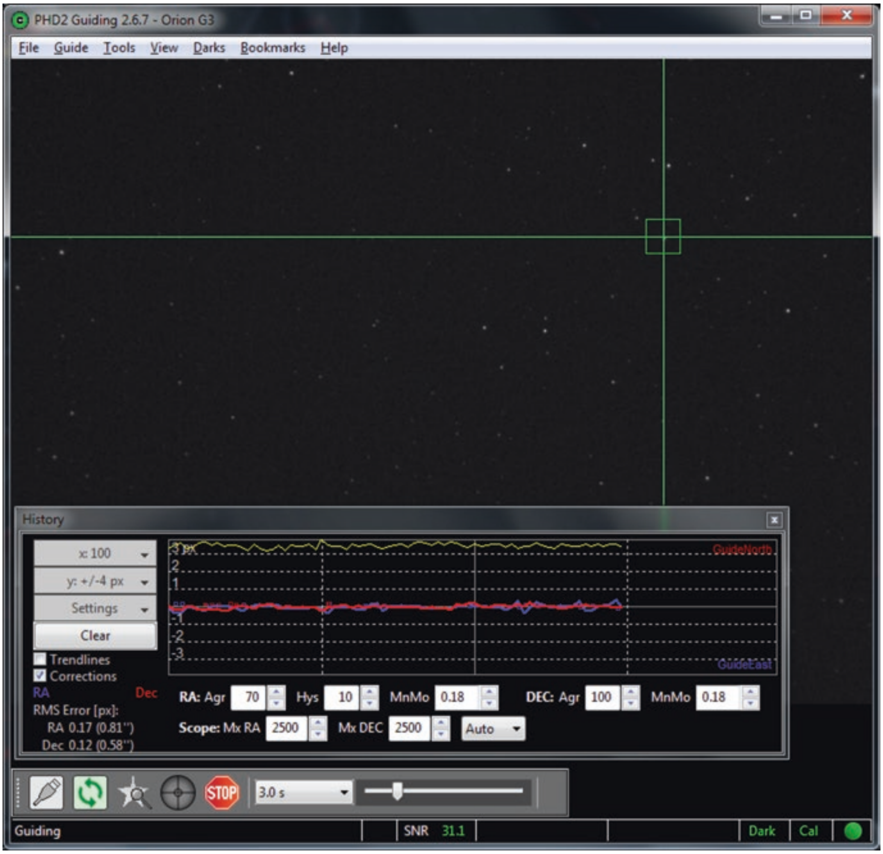

Fig. 5.6 PHD2. (Screenshot by permission of PHD 2 Open guiding project)

must be said, however, that you should still aim to align your telescope as accurately as possible in order to get the best images that you can (Fig. 5.6).

Astrotortilla

https://sourceforge.net/projects/astrotortilla/

Astrotortilla is a free plate solving package. Its' main job is to take an image automatically and then identify the stars in the image and compare them to its catalogue of stars and determine exactly where the telescope is pointing. When it has done this you have the option to automatically slew the telescope to the target object if it isn't in the field of view (Fig. 5.7).

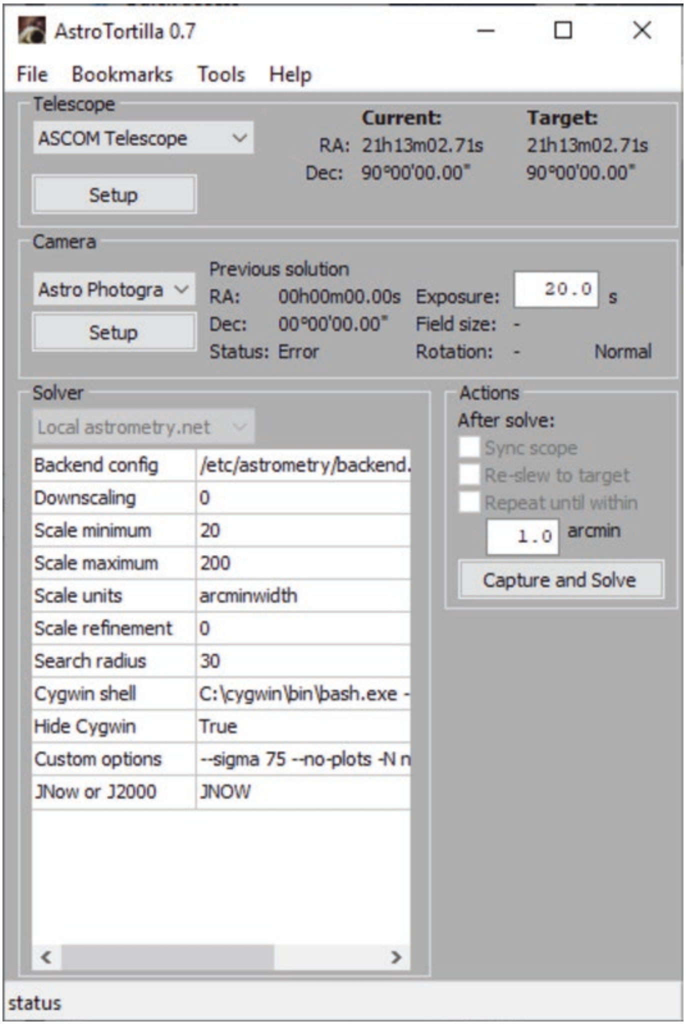

Fig. 5.7 Astrotortilla. (Screenshot by permission of Astrotortilla)

All in One Packages

Astroart by MSB Software

http://www.msb-astroart.com/

Astroart is paid for software and is a fully integrated package, which includes: full telescope control via continuously updated plugin. A very robust autogu-

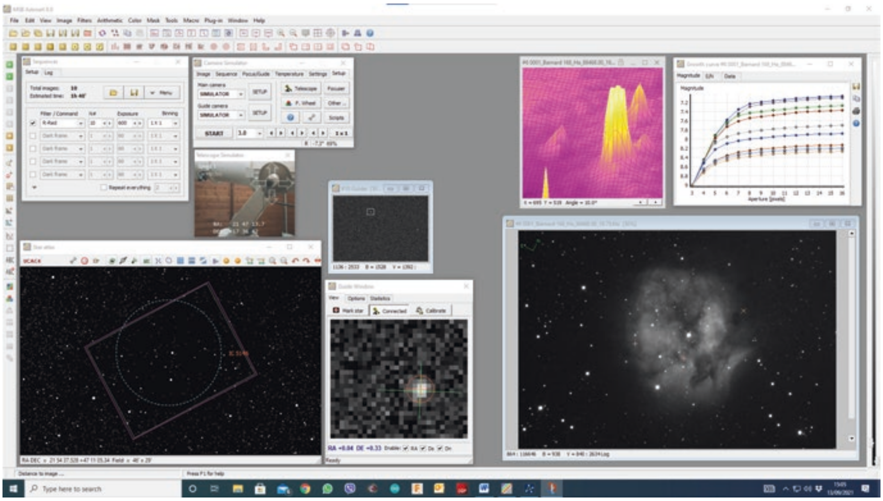

Fig. 5.8 Astroart. (Screenshot by permission of Fabio Cavicchio)

iding module, plate solving, filter wheel control, focuser control. It can be setup to carry out full imaging runs and even write scripted runs for things such as supernova searches. In addition to this it also has a star atlas and will allow you to process and stack your images. It also includes astrometry and photometry measuring tools which include batch processing functions. Astroart is also capable of full image processing including stacking stretching and has some very powerful filters such as Maximum Entropy Deconvolution, adaptive denoise and gradient removal. The built in autoguider software in Astroart does a solid job of guiding even in slightly blustery conditions which would usually stop me from imaging. It also incorporates sophisticated Astrometry and photometry functions that can generate a correctly formatted MPC (Minor Planets Centre) reports (Fig. 5.8).

At the time of writing Version 8 is about to be released incorporating the following improvements and additions.

Image Processing

New DDP (Digital Development Process), Deconvolution, gradient removal with mask, multiscale denoise filter, Low pass filter, processing history and improved scripts and Macros

Image Analysis

Seven views (Stars, histogram, statistics, history, zoom, 3d, header)

Color processing
New LRGB, trichromy, demosaic, white balance, attenuate channel, saturation, and align planes

Pre-processing
New Image preview, new normalization and rejection methods, reports with graphs and faster sigma stacking function

Batch photometry
User defined reports and graphs

Blink and animations
Full screen blink and animations with live annotations

Image browser
Optimized for astronomical images with single and grid layout

Instrumentation
Support for Ascom switches and weather stations, temperature ramps and multicore processor plate solve support

User Interface
Navigation panel, customizable image border, four color themes to help preserve night vision and improve visibility

Raspberry Pi Based Telescope and Imaging Control Devices

This is one of the new upcoming areas in astrophotography as it is capable of giving us fully featured portable imaging systems that are light and have lower power requirements than previously required.

What Is a Raspberry Pi Computer?

A Raspberry Pi is a single board computer that is about the size of a deck of cards running a Linux operating system. It has 4 USB 2 ports and an Ethernet port along with and HDMI socket. The current Raspberry Pi model is the Pi 4 but lower models are still available such as the Pi3+ which is perfectly capable of running the required software for an astro imaging system. The standard Raspberry Pi computers have built in Wi-Fi, Bluetooth a, HDMI output, Ethernet port and 4 USB ports. The operating system is loaded onto an SD card that is inserted into a card holder on the device and is loaded at power up.

Currently there are four Raspberry Pi based devices available. Three commercial offers: Stellarmate, ASIAIR, AstroPiBox and a free to download option: Astroberry Server that is based on open source software that has been developed and improved by astronomers.

A common feature of these devices is that they can be controlled by either a mobile phone, tablet computer or connection to a computer using either a Wi-Fi, a web based interface or NoVNC. NoVNC is a graphical client application that enables you to share computer desktops using a web browser that supports html5 and Websocket.

Raspberry Pi Based Imaging Control Systems

• Astroberry Server	Open Source	Requires a Rasp Pi 3+/4+
• Stellarmate	Commercial product	Requires a Raspberry Pi 3/4+ if OS purchased on its own.
• ZWO ASIAIR Pro	Commercial Product	Supplied with Raspberry Pi
• AstroPiBox	Commercial Product	Requires a Raspberry Pi 4+

For those people who are happy to supply their own Raspberry Pi there is another option – Astroberry.

Astroberry

This is a ready to use operating system capable of controlling all your astro imaging equipment from the one device.

Astroberry Features

- Produces its own hotspot for wireless operation
- Web interface
- Capable of controlling all your astro imaging devices
- Kstars planetarium
- EKOS with all available mounts which is a cross platform observatory control and automation tool which is designed to carry out astrophotography tasks
- Indi framework
- CCDceil Image capture software
- Astrometric measurement

- ASTAP Plate solver, stacking and astrometric software
- PHD2 for autoguiding
- Gnome Predict for satellite tracking
- oaCapture for planetary imaging
- FireCapture for planetary imaging
- Astroberry DIY mounts for focuser and relay board
- Astroberry PiFace mounts for focuser and relay board
- Astroberry Motor Hat for a focuser based on the Adafruit Motor Hat
- Virtual GPS in case you don't have a GPS fitted
- Sky charts Hallo Northern Sky
- File server

Stellarmate by Ikarus Technologies

Stellarmate is very useful to those astro imagers who like to build their own devices as not only can it be purchased as a complete package as detailed below including the operating system on an SD card. Unusually though you can also purchase just the operating system and supply your own Raspberry Pi, I also fitted a real time clock to it which is how it is supplied in the package. This gave me the option of using my own Raspberry PI computer and 3d Printing a case to suit my specific purpose (Fig. 5.9).

Package Contents

- Stellarmate Unit
- 1.8 m HDMI Cable
- 3 3A 5v Power supply
- 2 meter 12v DC to 5v DC Micro USB cable
- Optional mount to USB cable

Stellarmate is supplied with a 32GB or more Micro SD card pre-loaded with the operating system.

Stellarmate Features

- Control of your telescope CCD CMOS and DSLR cameras, filter wheel, focuser, guider, adaptive optics
- Built in native autoguiding with dithering support

Fig. 5.9 Stellarmate Package. (Picture by permission of Stellarmate)

- Plate solving using both online and offline solvers
- Load an image and slew to its solved coordinates to continue an imaging run on another night
- Measurement and correction of polar alignment using astrometry.net solver
- Easy polar alignment assistant
- Automatic scheduler to control observatory equipment capable of selecting the best targets taking into account the conditions and constraints
- Smart Dark library
- Automatic management of Dark frames
- Define multiple profiles for different setups
- Autofocus and manual focus modes
- Image sequencer supporting time stamping filter selection etc
- Automatic flat field capture
- Integration with Kstars observation planner and Sky map
- Scriptable
- Integrates with all INDI native devices

Ekos

Ekos which is a cross platform observatory control and automation tool that focuses on astrophotography tasks.

Installation of Software

If you are buying it as a downloaded operating system only simply visit the link you are given to download it as a 2GB file that is then extracted and written to an SD, card using software called Etcher. When this has been done, it is inserted into the Raspberry Pi which is then connected to a power source. At this point it will start to boot up which may take a couple of minutes.

Connection Options

- Initially the primary method of connecting to the device is to connect it to a computer using the Ekos desktop application on a Mac, Linux or Windows computer.
- You may also connect to it using HMDI a keyboard and mouse accessing the on-board fully featured Ekos software.
- The final method for connecting to Stellarmate is to use the mobile app which is still in development at the time of writing. If you use this method you will need to enter the serial number under the unit. If you have only downloaded the OS then the serial number will be automatically generated for you.

Next Steps

- The next step is to create an account on Stellarium.com and activate it using the email that they will send.
- After filling in the usual login details it will create a Wi-Fi hotspot called "Stellarmate" which is the hotspot which is the initial way of communicating with it using a tablet or mobile phone using the free Stellarmate app.
- The app must be used to do the initial configuration and is required so that it can set the time zone and geographic settings.
- When using the app the first time you are required to sign into the stellarmate.com account that you created.

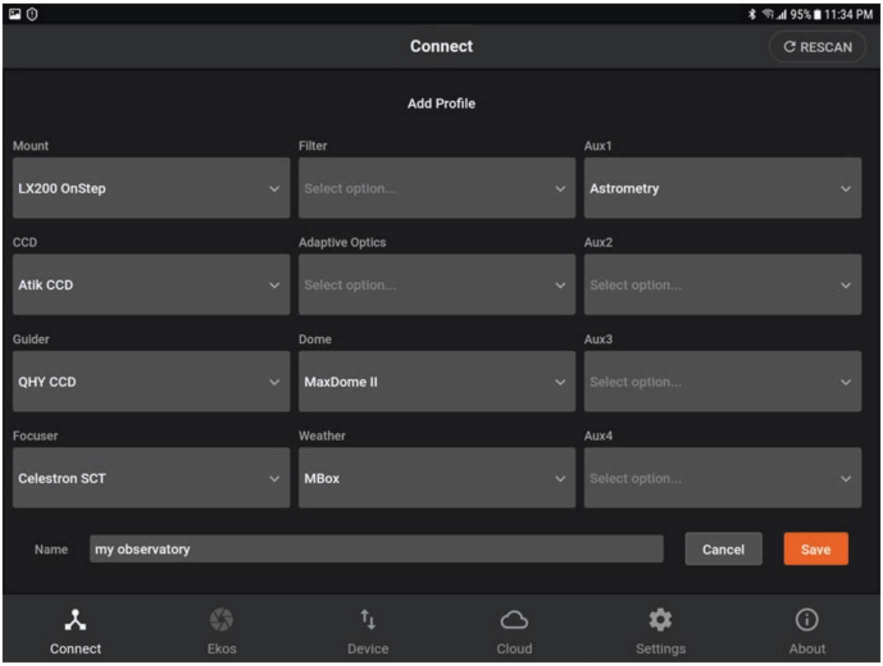

Fig. 5.10 Stellarmate Connect Screen. (Screenshot by permission of Stellarmate)

- Scanning for New devices should reveal your new device and you can click on it to connect.
- You will be required to register the app again at this point and once this has been carried out you are ready to configure your equipment.
- By default a simulator profile is selected and it now simply a matter of pressing ADD and entering the equipment that you wish Stellarmate to control.
- Change the profile to the one that you have created and then when you have connected to all your equipment press the Ekos tab which is now active.
- You will now be presented with an interface that offers many but not all of the fully fledged Ekos application features (Fig. 5.10).

Using Stellarmate

Once all the equipment is connected to Stellarmate it is controlled from one main screen from which you can access most of the functions needed to take images (Fig. 5.11).

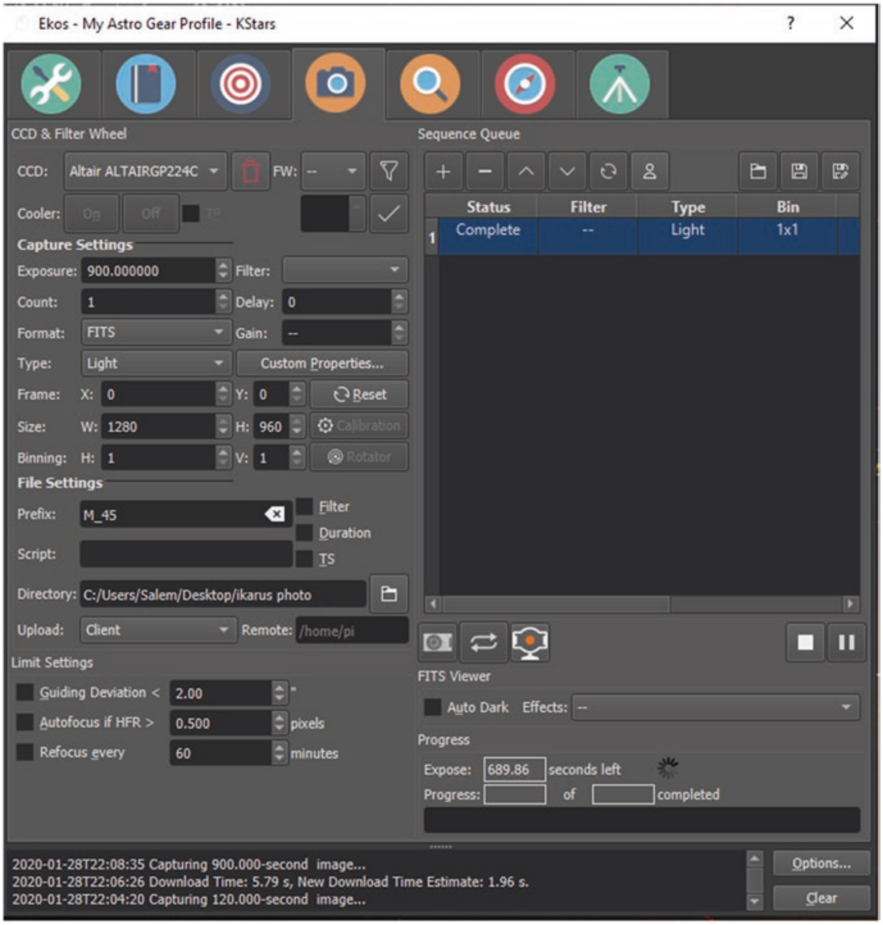

Fig. 5.11 Stellarmate Ekos Image Capture Module. (Screenshot by permission of Stellarmate)

Shown here are the image capture module and the Ekos Kstars Scheduler module which is very powerful (Fig. 5.12).

Despite being relatively newcomers these single board computer astrophotography controllers are no doubt set to make a big impact and I am sure this is just the beginning of a new era in astrophotography. This may result in a future generation of telescope mounts that are capable of running as a fully featured astrophotography system and only require a tablet or smartphone to act as a display and control input device.

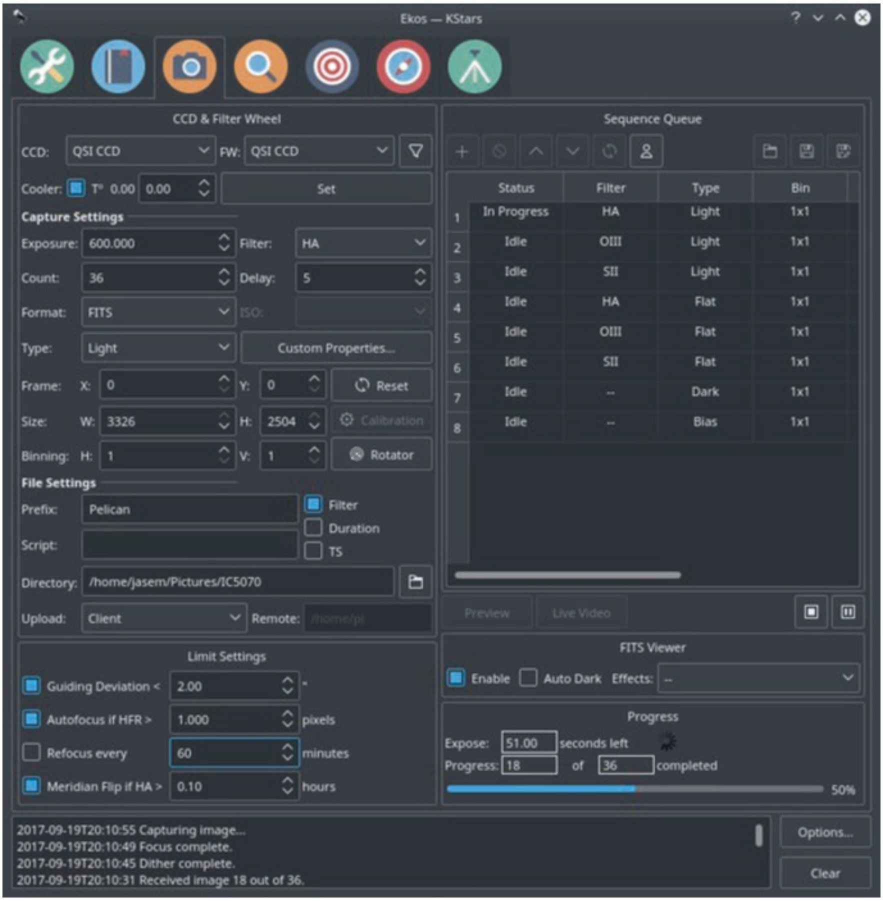

Fig. 5.12 Stellarmate Ekos Image capture schedule screen. (Screenshot by permission of Stellarmate)

ASIAIR Pro

This is a fully featured astro imaging hardware and software package contained in a very small rugged metal case but capable of fully featured operation. It comes complete with It sports a very slick user interface which makes it quick and easy to setup and use. Like all the other Pi based controllers it is based on the Linux operating system.

ZWO ASIAIR Pro features

- Wi-Fi control
- Custom interface for quick easy operation
- Mount control *check for compatibility
- Camera control *check for compatibility
- Shutter release port for DSLR
- Four 12v power output ports that are switchable using the app
- Focuser control with Autofocus capability
- Filter wheel control *check for compatibility
- Plate solving and mount sync
- Autoguiding
- Can link to Skysafari planetarium using Skysafari Bridge

AstroPiBox

https://astropibox.com/english/index.html

The last of the Pi based astro imaging controllers that I have found to be available is the AstroPiBox which is sold as an operating system only supplied on an SD card that you fit into your own Raspberry Pi 4.

- Supported Mounts: HEQ5, NEQ-6, AZ-EQ6, EQ8, Vixen GP-DX Sky-Sensor, Astrophysics, Avalon M-Zero, EQ3-2/EQ5 Goto, EQ3-2/EQ5 motors (with ST4 port), EM200
- Cameras: ZWO ASI, ATIK
- Linux (Raspberry Pi OS Buster)
- INDI Library (version 1.8.5)
- PHD2 Auto Guiding software (version 2.6.8)
- CCDceil Imaging Software (version 0.9.71)
- Cartes du Ciel Planetarium (version 4.3)
- Kstars Planetarium (version 3.4.2)
- A unique feature of the AstroPiBox is the user can specify a town postcode and it will produce a light pollution map centred on that area.
- Astrometry.net offline integration

I expect that very soon we will start to see telescope mounts that have a device similar to one of the Raspberry pi computers built in which would make the basis of a fantastic quick and easy astro imaging system when combined with a tablet or smartphone as its controller.

Chapter 6

Setting Up and Using Your Telescope

Practice Setting Up and Aligning the Telescope

Chapters 6, 7 and 8 give detailed instructions describing how to set up a Goto telescope for astrophotography as this is one of the many skills you will need to be well practiced in if you intend to take good quality images.

Without a telescope mount that is well situated and aligned with the earth's axis and synchronized with the sky you will have difficulty finding objects. It will also be impossible to track them accurately for the time needed to enable your camera to gather enough light to be able to capture great images.

Before starting your first imaging session you will need to be fully prepared and part of that preparation is making sure all your equipment is readily at hand. It will also help if you are already familiar with the necessary techniques that you will need to put into practice. The telescope setup techniques are described in the following chapters in this book and it is important to understand and practice them until they are second nature to you.

Setting Up the Mount

It would be really frustrating and difficult to take your telescope outside on a beautifully clear night and then spend most of that time reading the instructions and trying to work out what they are telling you to do. It is

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_6

much better to be prepared and already be familiar with the techniques of setting up a telescope system beforehand. That way you can simply use the instructions as a check list or memory jog to ensure that all the necessary steps are carried out correctly and in the correct order.

Choosing Where to Site the Telescope

First you need to choose the location where the telescope will be used; making sure that you can see Polaris from this location. It is of course possible to align the telescope mount without seeing Polaris but this is a slightly more advanced technique and not advisable to try on your first night.

If you are setting the telescope up in a suburban garden, try to pick a spot as sheltered from artificial lights as possible or try to shield them if necessary to avoid being dazzled as even very small amounts of light will affect your eyes' dark adaption. You will also need to be aware of potential obstructions that may restrict the free movement of the telescope as it is slewing and guiding. It is also much easier to setup your telescope where there is plenty of space for you to move around the telescope giving you easy access to all parts of it.

The legs on the tripods are designed to work will on hard surfaces such as a flagged patio or on grass as long as it isn't so soft that the legs will easily sink into it. If you are setting up the telescope on grass it can be worthwhile putting down 3 small stone or concrete flags, one for each tripod leg, this will spread the weight with less danger of sinking and give a more stable base. Using small flags as a base also gives you a quick reference when setting up the telescope on subsequent nights. It can be helpful to mark the flags with the position of the tripod legs to help further. Do not attempt to setup the telescope on decking as it is simply not stable enough and will flex and be susceptible to vibration as you move about on it.

Looking at the tripod you will find that most of them have an indication of which leg or position needs to be north facing and will need to orientate it facing the correct direction before attempting to level it.

It would be really frustrating and time consuming to get the telescope completely setup only to find out that you can't see Polaris through the polar telescope to easily align it.

To avoid this problem make sure that you can easily see Polaris if you are in the northern hemisphere or Sigma Octantis if you are in the southern hemisphere from the height and position of the polar alignment telescope. This will be considerably different to your viewpoint when standing up next to it.

Familiarize Yourself with the Telescope Controls

You will need to be able to operate the telescope in the dark with very little additional light so you should make sure that you are completely familiar with all of its component parts and controls.

Practice and Practice Again

The best way to do this is to repeatedly set the telescope up in daylight pretending as necessary that you can see Polaris and alignment stars. Going through the motions will make setting up the telescope so much easier when you are doing it for real as you will remember the positions of the controls and the steps that you need to take. Take it slowly and carefully, it will seem like there is a lot to do the first few times, but it will soon become much easier to do and the more you practice you will find yourself setting it up more efficiently and quickly. I have outlined the procedures to employ, but it is better to write your own brief checklist specific to your set up which will jog your memory and ensure that you don't forget any steps. The use of checklists is a very helpful strategy to adopt when operating an imaging system.

Tools and Accessories Needed

- A Low power eyepiece, preferably with cross wires. This is used to increase the accuracy of the alignment procedures.
- A spirit level, to correctly setup the mount tripod. This isn't absolutely necessary but is advisable when starting out. The spirit level will also be used to set an accurate home position for the telescope.
- A dim red torch preferably a head mounted one will be handy to find things in the dark and keep your hands free; using a red light will help preserve your dark adaption.
- A method of determining your longitude, latitude and altitude above sea level. You can use Google maps or a smartphone app for this. Most polar alignment apps for smartphones will give you this information.
- An accurate clock, watch or smartphone; remember to set a summer time correction if it is needed.
- A polar alignment app.

- Extension cable for your power supply or a 12volt battery, such as a leisure battery. Don't forget to use an earth leakage protection device such as an Residual Current Device (RCD)
- A small garden kneeling mat is very useful for use when you are kneeling down looking through the polar alignment telescope as it helps to avoid getting sore or dirty wet knees.

Setting Up a Telescope in Easy Steps

- Place the tripod on your chosen site orientated north according to the manufacturer's instructions as this varies from mount to mount. Fit the accessories tray or leg spreader plate depending on what is supplied with your mount.
- Use an accurate spirit level to make sure that it is level, some mounts have a built-in spirit level but these don't tend to be very accurate so it's best to use your own. The software will allow for errors in the mount not being level but it is better to get things right in the first place.
- Fit the mount head to the tripod securely on a Sky Watcher mount; this is done using the long threaded rod that also fastens the spreader plate.
- Fit the telescope itself to the mount making sure that the clutches are locked; this is so that it will not swing around and cause injury or damage itself. This is usually achieved by a dovetail fitted to the telescope tube and a matching saddle clamp on the mount. Again, make sure that this is secure and not able to move.
- If you are setting up a large heavy telescope, you may need to fit some or all counter weights incrementally so that the mount and tripod don't topple over through being unbalanced. When fitting weights to a telescope, make sure that you do fit the safety end stop button at the end of the counterweight bar which will stop the weights falling off the end should the retaining screw come undone.
- At this point you may attach your finder telescope if it's not already fitted and using the screws that hold it in place adjust it so that its field of view matches that of the main telescope.
- The position that the telescope is mounted onto the mount must ensure that it is balanced correctly or it will not be able to track and move accurately and in addition will put unnecessary strain on the mount system. This will need to be checked later when you fit cameras etc.
- The finder telescope will need to be aligned to the main telescope so that objects in the center of the finder telescope are in the center of the field of

view (FOV) of the main telescope. This will make your star alignment much quicker and easier.
- Aligning the finder telescope can be easily done before dark by pointing the main telescope so that you can see a television aerial or other distinct feature through the eye piece, then adjusting the finder telescope so that it is centered on the same aerial or feature.
- It may be necessary to fit any remaining counter weights if this has not already been done.
- Move the telescope to its home position; this can vary by manufacturer but will be detailed in the instructions supplied. On a German equatorial mount it is usually the case that the counterweights are pointing down and the telescope is pointing up.
- Plug in the hand controller.
- Fit a low power eyepiece as this will be required for the star alignment procedure.
- Power the system up.
- You then need to follow the handset instructions as it will guide you through setting the time and location remember to set any daylight saving time correctly.

Polar Alignment

Set the Altitude marker on the telescope mount to match your latitude.

If you have set it all up correctly the polar alignment telescope should be pointing towards Polaris which should be visible through the polar telescope as it has a wide field of view. If Polaris is not in the field of view of the polar telescope, look alongside the body of the polar telescope to determine which way to move the mount, to bring Polaris into the field of view. One technique that I use is to shine a laser up through the polar telescope eyepiece and you will then be able to see the beam and move the mount using the altitude and azimuth controls until it is pointing towards Polaris. Please don’t use the laser technique near airports or where there might be a chance of dazzling aircraft flying over (Fig. 6.1).

Now center Polaris in the polar alignment telescope using the altitude and azimuth screws on the mount (Fig. 6.2).

Next you need to rotate the right ascension axis of the telescope to match the position indicated by your polar alignment app (Fig. 6.3).

Polaris now needs to be moved to the position indicated by the small circle in the mount reticule using the Alt and AZ screws. Once this has been done, the polar alignment has been completed.

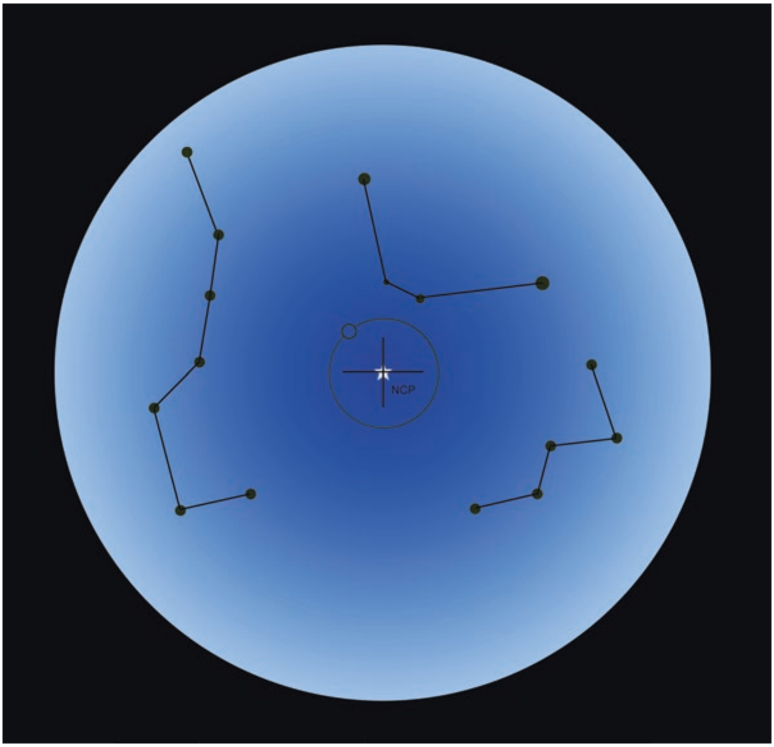

Fig. 6.1 Polaris centered in the Polar scope

Star Alignment

Star alignment is the method of aligning the telescope mount system's computer model of the sky to the visible stars so that the Goto function is able to operate correctly.

The handset will ask which type of alignment you wish to perform; possibly a one two or three star alignment. The best one to choose if you plan to take images is the three star alignment as this one is the most accurate and compensates for other issues. It comprises of choosing an alignment star suggested by the handset and the telescope slewing to the location, then centering that star in the field of view of the main telescope only using the direction buttons on the handset and then pressing a button to confirm that it is in the center of the field of view. This is where having the finder scope lined up accurately with the main telescopes view might help, as sometimes the alignment star might not be visible in the main telescope but with a much wider field of view, it should be visible in the finder telescope. The

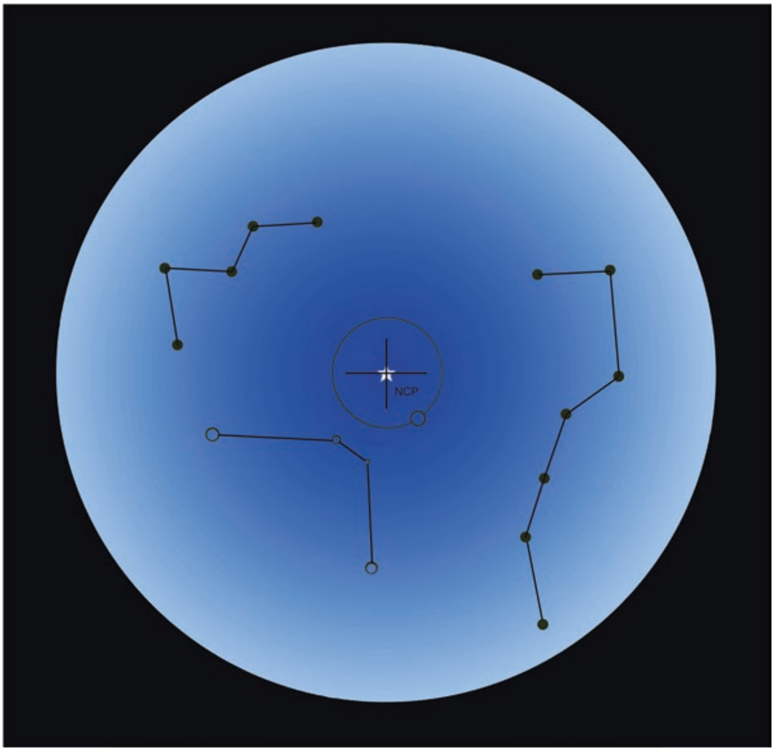

Fig. 6.2 mount rotated to match polar alignment app

finder telescope can then be used to bring it into the FOV of the main telescope so you can continue with the alignment.

The star finding and centering procedure will be repeated with three different stars if that's the alignment type you chose. If done correctly the stars to be aligned on will usually be closer to the center of the telescope field of view as each step is completed.

The star alignment is best done by closely following your handset instructions and when correctly completed it will report that the alignment is successful, along with any polar alignment error.

Fitting the Camera

Fit your camera using any necessary adapters making sure all lock screws are secure, but not over tightened. Connect all USB and power cables being careful to make sure that with the cables fitted the telescope still has free

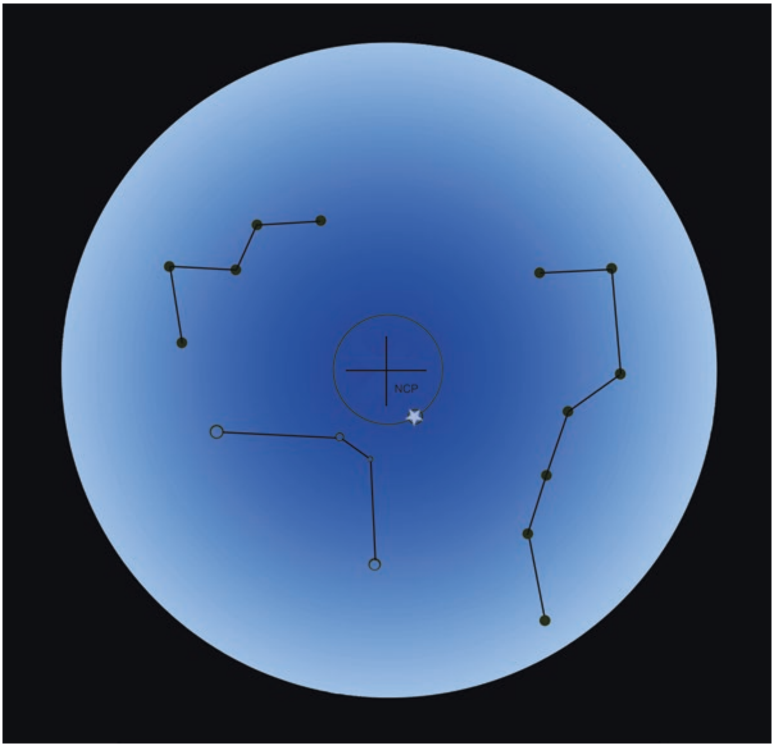

Fig. 6.3 Mount moved using altitude (Alt) and azimuth (AZ) screws to re-center Polaris

movement in both its axes and there isn't any danger of the cables becoming snagged or pulling on any handles levers or controls.

Balancing the Telescope

It is now necessary to balance the telescope in both its axes, to make sure that the mount isn't being strained by moving a poorly balanced telescope. Poor balance would result in poor tracking performance and excessive wear and tear on the mount train components.

Declination Balance

With the camera fitted, the telescope needs to have its balance checked again. This is easily done by moving the telescope so that the counterweight bar is horizontal. Use a spirit level to check and then slowly release the declination clutch. Be ready to catch the telescope and stop any movement while it is unbalanced. To balance it, you will need to slightly loosen the telescope retaining ring screws and slide the telescope backwards and forwards in the rings until it is balanced and will stay still in any declination position.

Right Ascension (RA) Balance

With the counterweight bar horizontal again, slowly release the right ascension clutch again being careful to stop any unwanted fast movement of the telescope due to it not yet being fully balanced. Rotate the telescope about the RA axis adding or removing counterweights as required and also moving the position of the weights along the counterweight bar to fine tune it until a good balance is achieved.

The following steps really need to be carried out under the stars but again you can pretend and just go through the steps, to ensure that you are becoming familiar with the whole process.

Focusing the Camera

The camera will need to be focused next and this is usually done on a bright star near the object to be imaged.

Moving or Slewing to the Object to Be Imaged

Once the camera is focused on a bright star, move or slew the telescope to the object to be imaged and take a brief test image to make sure that everything is working.

Once you are happy that you have carried out all the above steps do it again a few times to make sure that it sticks in your memory as this will make it much easier to do for real.

Packing the Telescope System Away After Use

Practice taking the telescope system apart and packing it away as well as setting it up and get in a routine of having a place for everything so that things don’t get lost in the dark.

A useful tip is to keep a note book and jot down any areas that you find difficult or are unsure about and next time you can specifically address those issues.

None of the steps described are difficult and with practice the whole thing can be completed quickly and efficiently. As mentioned you will find it very helpful to write a checklist which is unique to your setup so that you can use it until you are so familiar with it that you can carry everything out by memory without needing to use the list.

The key to setting up and putting away your telescope system quickly and efficiently is to practice.

Your First Clear Night

Before You Start

If you have followed the advice in the previous chapter, you will be familiar with the component parts and controls of your telescope. You will have worked through the steps required to assemble it correctly and will know the basics of polar alignment and use of the handset to do a star alignment.

The Polar alignment and star alignment are both required for the Goto function to work as without the polar alignment the telescope will not be able to track the stars movement across the sky accurately. Without the star alignment, the telescope Goto computer has no idea where it is actually pointing and so isn't able to slew to the objects that you wish to locate.

On the first clear night, you will be fired with enthusiasm and expectation and want to see your telescope working in all its glory using its Goto function to locate objects. However, unless you are used to setting up a Goto German equatorial mount, it is better to just carry out a rough polar alignment and then use the mount just for tracking and find a few objects by star hopping. This will allow you to get some real hands on experience using the telescope and looking through in addition to finding some easy objects by star hopping to them. This will enable you to learn how to use your telescope and be rewarded by seeing some beautiful sights.

This simple approach has another benefit as it will also help you understand the process when the Goto doesn't quite center the telescope on your target allowing you to correct it manually if it is necessary, so that valuable observing or imaging time is not lost.

Learning how to find objects with your telescope always brings about a great sense of achievement. It is an amazing feeling to actually find and take your own detailed pictures of the objects that you have only seen in books or online. This experience somehow makes them more real and adds to the feeling of awe and wonder as we explore the universe in which we live.

Cooling Time Required

Please note that your telescope especially if it's kept in a house, garage or shed will need time for the optics to reach the ambient temperature. If you use it before it has had sufficient time to acclimatize, the image quality will not be at its optimum. This isn't a fault and won't cause any damage to your telescope it just means that you won't get the best views until its temperature has equalized with its environment. The focus will require adjusting while the telescope temperature is equalizing.

Depending on the size of your telescope lens or mirror it might take from 30 min to a few hours for this to happen. Just give it plenty of time, if you can't allow it that time because the sky has suddenly cleared or due to other factors don't worry about it, just use it anyway and enjoy the experience.

Setting Up

Put your telescope on a firm and level surface orientating the tripod so that the polar axis is pointing to the north. If using a Sky Watcher telescope look for a tripod leg with an N marked on it this must be facing the north. Other manufacturers equipment and models may vary check the instructions that come with your telescope if in doubt.

Dark Adaption

When observing most astronomical objects, it is important to allow your eyes to adapt to the dark this process takes a while and can be ruined in a moment by stray light so once your eyes are adapted be careful not to spoil it. The time taken for eyes to become fully dark adapted is believed to be around 40 min during which time there are chemical changes in the eye that make it more efficient. Once you have this dark adaption it is wise to preserve it as much as possible. Using dim red lights and red or Rubylith film over screens and torches is a good idea.

Some observers use an eye patch if they have to briefly move into a more brightly lit area this is then removed at the telescope. This is of major importance to visual observers but not as important if you are taking images unless you like to use binoculars while the telescope is busy imaging.

Polar Alignment

You may just use a compass or locate Polaris (The Pole Star) as we are not going to be too accurate for the sake of this first night. Set the latitude adjustment on the telescope mount to your current latitude. Look through the polar telescope and using the altitude and azimuth adjusters, center Polaris in the field of view. This will suffice for the first night unless you are feeling confident enough to use the polar alignment method that is described in the previous chapter.

Finding Starter Objects by Star Hopping with Binoculars

This is one of the skills that are still necessary for an astronomer even using a Goto telescope, as due to the setup and telescope mount errors that could occur, it might not always arrive at exactly the correct location in the sky. It is a good exercise to try star hopping using a pair of binoculars at first and then when you are familiar with the techniques move on to using it with your telescope.

Things You Will Need

- A good star chart, which can be either a computer program of which there are many excellent free ones or printed charts.
- A low magnification eyepiece.
- A pair of Low magnification Binoculars.
- Star charts Printed or computer based.
- Red Torch.
- Plenty of patience.

In its most simple form star hopping is exactly as it sounds we start on an easy to locate star and move from that using stars and patterns of stars to get to our intended target. The following is an example to get you started.

Slewing the Telescope to Find Objects

Turn on the mount system and release the RA and DEC clutches slowly making sure that the telescope doesn't suddenly move due to being unbalanced. This will enable you to freely move the telescope around the sky.

Pick an object from the starter list and charts and try to locate it using the finder telescope, which you have aligned with the main telescope following the instructions in the previous chapter. Look at the charts and star hop to it using patterns of stars that you find noticeable on the charts. Just try to have fun and don't get discouraged if you find it hard to locate objects as it is a skill that needs to be developed by practice and you will soon be using the Goto function to find things for you, but at this stage it's important to have a go yourself.

Use the list of easy to find objects that are in this book or make your own, either using planning tools or just doing an internet search and practice your star hopping skills. Another good source of suggested objects is the monthly astronomy magazines that are widely available. You will no doubt find that you have a particular liking to some types of objects be it galaxies, planetary nebulae, globular clusters or the many other wonders that await you.

Most astronomers have very fond memories of the first night using a real telescope and the impact it makes on them so make the most of it.

Take your time and be patient with yourself and the equipment; the objective is to enjoy what you are doing while you learn new skills. During your first session it can be useful to make notes of any questions or difficulties that you have so that you can address them later.

When you have finished your first observing session, dismantle and pack your telescope away carefully taking your time as rushing can result in costly mistakes. Make sure to let any of the optics dry out if dew has formed on them before putting the covers back on. Wipe down non optical areas of the telescope and mount that may be coated in dew with an old towel. Have a good look around your observing site to make sure that nothing has been left outside before you lock up.

How to Find Messier 57 the Ring Nebula

The Ring Nebula M57 also known as NGC 6720 is in the constellation of Lyra, It was discovered by the French astronomer Charles Messier while he was searching for comets. The Ring Nebula is best seen in the summer and fall when it is high in the sky.

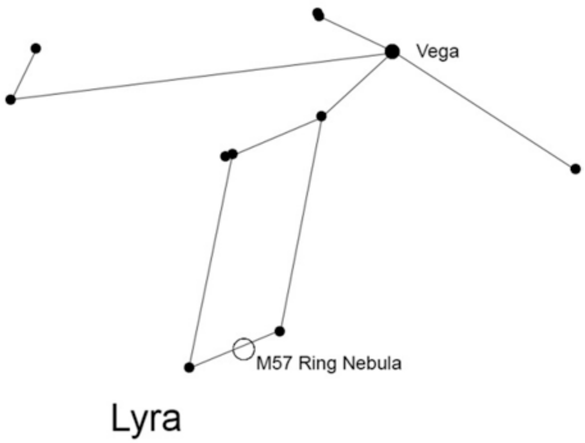

Fig. 6.4 M57 in Lyra

M57 is found by first using a planisphere (a graphical map showing what area of the sky will be visible at any time and date of the year; available on line to buy or downloadable from astronomical website such as https://in-the-sky.org/planisphere) to locate the bright star Vega and from there identify the constellation Lyra as seen below (Fig. 6.4).

Figure 6.5 below represents a closer map of the area of the Ring Nebula. In this example Vega is clear to see and then it is relatively easy to locate the bottom two stars of Lyra, Sulafat and Sheliak Our target M57 is approximately 2/3 of the way from Sulafat to Sheliak. Pointing the telescope at Sulafat will reveal the field of view as shown in this example by the black circle and demonstrates the stars that should be visible.

Moving the telescope to center on the two bright stars up and to the right, which is north and west of Sulafat M57 will come into view on the edge of the field of view (Fig. 6.6).

Now the telescope has moved to the brighter of the two stars to the west of Sulafat, the Ring Nebula is in the field of view and you should be able to center it.

The exercise above was a very simple example of star hopping and it may take many steps to arrive at a target but the principle is exactly the same. Start at an easy place to find using a bright star and move from star field to star field using easily recognizable star patterns along the way until you arrive at your target. It can also helpful to prepare star hopping charts in advance and then you know exactly what you are doing and don't waste valuable time.

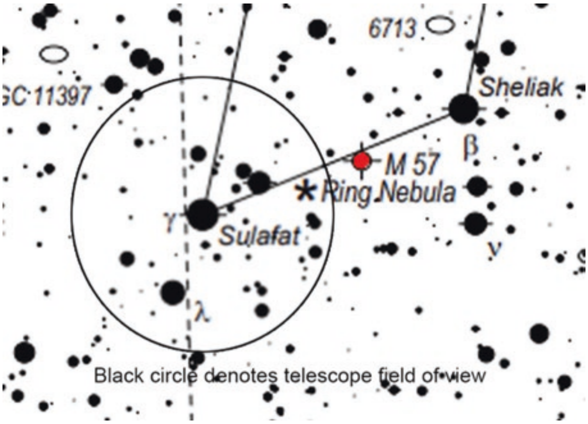

Fig. 6.5 Center on Sulafat

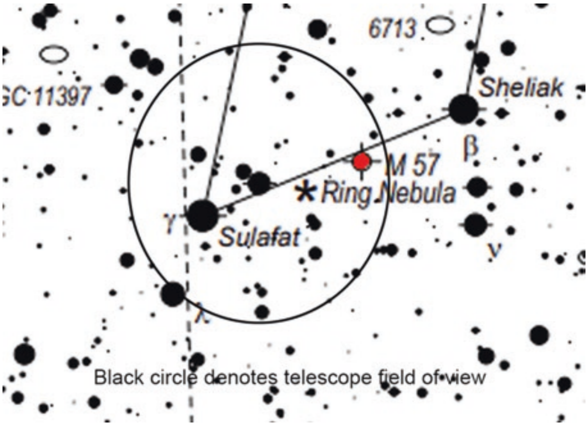

Fig. 6.6 Sulafat and M57 will appear in the field of view

You can even cut a round circle out of a piece of cardboard to emulate the field of view for your telescope which can be laid on the charts to give an accurate visualization of the fields of view that you can expect to see.

Eyepiece Selection

There is much discussion and lots of opinion on choosing the correct eyepieces for your telescope, but here it is assumed that you are just starting out with a new telescope and as such it probably came with at least one eyepiece. This is usually a low to medium power and will be a starting point for you to learn to how to use your telescope. It is recommended that you do some research and buy a few decent quality eyepieces of varying magnification.

Recommended Star Charts

The following are the star charts that are useful to have handy for planning imaging sessions.

Skysafari Pro 6

This has been mentioned in more detail earlier in Chap. 5 so won't be repeated, except to say that it is my electronic planetarium of choice.

Printable Charts

Deep Sky Hunter Star Atlas

http://www.deepskywatch.com/deep-sky-hunter-atlas.html

By Michael Vlasov

This is a superb star atlas that is designed to be printed in A3 but will print very successfully in A4 on a home printer. It is downloaded as a PDF file, which makes it super easy to print. It is available in two main versions: black stars on a white background or White stars on a black background described as the field edition as it is easier to use in the dark (Fig. 6.7).

I highly recommend this as Atlas and I would also like to acknowledge my thanks to Michal Vlasov for giving me kind permission to use screen-shots and extracts from his star atlas in this book.

Triatlas

https://allans-stuff.com/triatlas/

By José Ramón Torres and Casey Skelton

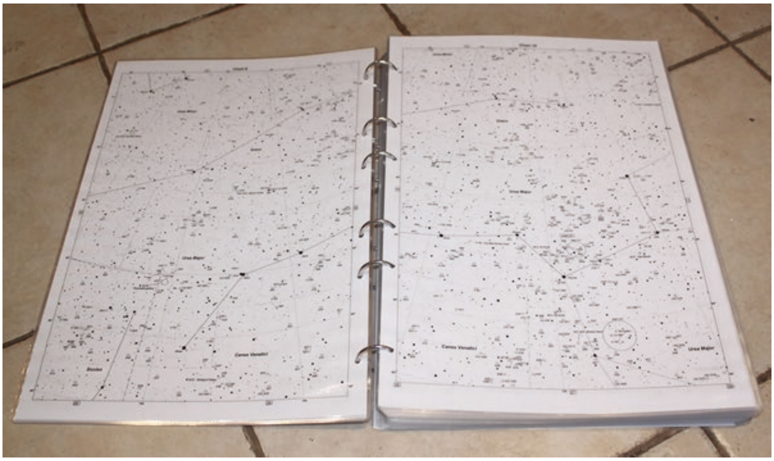

Fig. 6.7 Deep sky hunter atlas

This again is a very detailed, free to download and print star atlas. The full version comes as 571 charts and shows stars to magnitude 12.6, galaxies to mag 15.5 and 1200 planetary nebulae. It is a very comprehensive piece of work and as it is split into different versions, its best to take a look at the website and see which version suits you.

First Objects to Image

The objects in this list are among the brightest, easiest and most rewarding for a beginner to take images of in the northern night sky. The list includes galaxies, planetary nebulae, globular clusters and gas clouds. This list will enable beginners and those who live under badly light polluted skies to have easy targets to practice imaging.

There are also some objects that are not as bright and these have been added as they are wonderful targets to image and will help you learn astrophotography by pushing your skills a little bit further.

General Advice When Using a OSC Camera or DSLR

- If you have the older style sodium or mercury vapor streetlights, consider using a CLS or UHC filter to reduce sky glow and enable you to pick up fainter detail without it being lost in light pollution.

- If you have LED streetlights it would be worth considering purchasing a filter with a dual pass band that allows both Ha and OIII light through. This will deal with most of the light pollution while allowing the most light from many types of objects to pass through. This will have the effect of substantially reducing sky glow and increasing the contrast in the object beings imaged.

Using a Mono Camera

If you are using a mono imaging camera you have the following basic options.

- You can use the camera without filters, to obtain mono images.
- You can use one of the modern light pollution filters specifically designed to reduce the effects of LED light pollution.
- You may use Ha, OIII and SII filters to selectively choose the wavelength of light that you are interested in imaging. Any combination of the images taken with these filters can be combined later in software to produce a false color image.

Exposure Times

The exposure times given in the following examples are a very rough guide and you will need to experiment to find the best settings for your camera and telescope combination.

Open Clusters and Globular Clusters

These are some of the easier objects to attempt and produce spectacular images which do not need long time exposures to capture great images (Fig. 6.8).

As globular clusters are made up of great condensations of stars it is important to have a well-focused telescope so that they are resolved as clearly as your equipment will allow. Keep the exposure times short to avoid star bloating (an oversaturation of the pixels in the image) which results in an image with the center burned out.

Start with a short exposure of around 30 s and if you are using a DSLR try an initial ISO setting of around 800 increasing it to 1600 if required.

Fig. 6.8 M13 The globular cluster in hercules

Once you have taken a single exposure that looks like a good balance of capturing the globular cluster well and not burning its core out or bloating the stars too much, then try to take a series of pictures that can be stacked. One of the more advanced techniques is to take a series of both long and short exposures. The short exposures are to capture the detail in the core, while the longer exposures are to capture the fainter stars that would otherwise be missed. The exposures are then combined to produce an image that is capable of displaying all areas of the globular cluster successfully. This is a great technique, but does require a bit more effort in the processing stage.

Using an OSC Camera or DSLR

- If you have the older style sodium or mercury vapor streetlights consider using a CLS or UHC filter to reduce sky glow and enable you to pick up fainter stars without them being lost in light pollution.
- If you have LED streetlights it would be worth considering purchasing a filter specifically designed to reduce the sky glow produced by the blue component that these type of lights typically emit.

Using a Mono Camera

If you are using a mono imaging camera you have the following basic options.

- You can use one of the modern light pollution filters specifically designed to reduce the effects of LED lights.
- You may use red, green and blue filters to take images and then combine the images later in software to produce a standard color image.

Planetary Nebulae

Planetary nebulae vary in size and brightness some like M27 the Dumbbell are large and bright and others are small and faint and even star like in appearance, which can make them difficult to identify without filters. The filters they respond to depend on the particular object, but most emit light strongly in OIII and some in Ha and to a lesser degree SII. If you do try using narrowband filters such as Ha OIII or SII you will need to use longer exposures to compensate for the reduction in light passing through the filters but this will produce better images (Fig. 6.9).

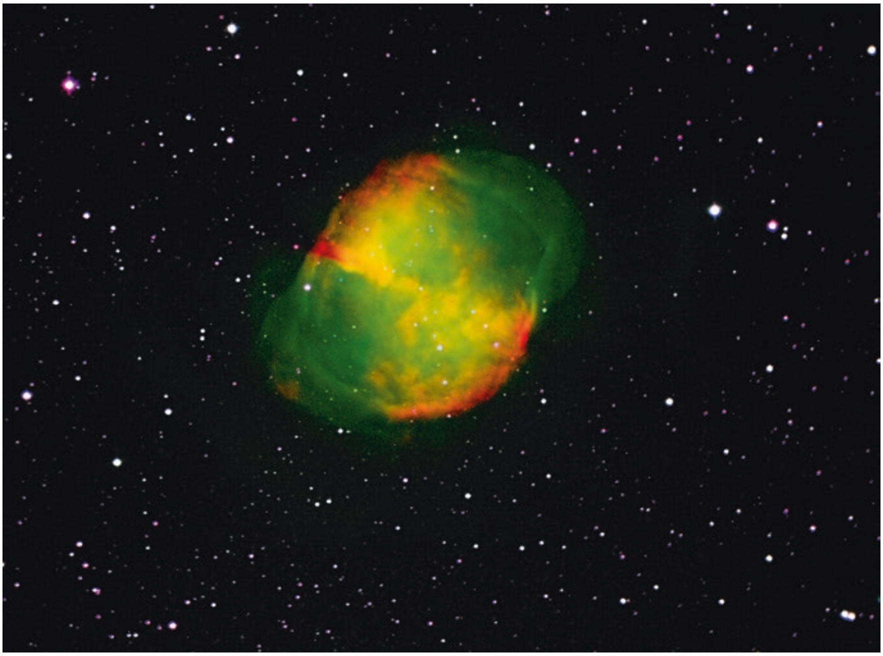

Fig. 6.9 M27 The dumbbell Nebula in lyra

The brighter objects in this list such as M27 chosen here should be relatively easy to image from most skies with both mono and color cameras.

Focus needs to be checked and adjusted to be set as accurately as possible using a Bahtinov mask (see Chap. 4, Fig. 4.19) on a star bright enough to see the focusing spikes clearly (refer to Chap. 4 Fig. 4.19 for explanation of the Bhatinov mask and focusing spikes). This will capture the finest detail possible given your equipment and skies.

Start with an exposure time of around 1 min, which should be achievable, even with an unguided but accurately polar aligned telescope. Look at the captured image and use the histogram to determine if the exposure needs to be longer or if you need to reduce it due to light pollution swamping the image or areas of the object getting burned out. Check the polar alignment and telescope balance if you are getting star trails, which will blur the detail that would otherwise be sharp and clear.

Using a OSC Camera or DSLR

- If you have the older style sodium or mercury vapor streetlights, consider using a CLS or UHC filter to reduce sky glow and enable you to pick up fainter detail without it being lost in light pollution.
- If you have LED streetlights, it would be worth considering purchasing a filter with a dual pass band that allows both Ha and OIII light through. This will deal with most of the light pollution while allowing the most light from the planetary nebula to pass through. This will have the effect of reducing sky glow and also increasing the contrast in the planetary nebula being imaged substantially.

Using a Mono Camera

- You may use one of the modern light pollution filters specifically designed to reduce the effects of LED lights.
- You may use Ha, OIII and SII filters to selectively choose the wavelength of light that you are interested in imaging. Any combination of the images taken with these filters can be combined later in software to produce a false color image.

Galaxies

Imaging galaxies well is incredibly rewarding and also highly challenging as they vary from the very bright ones like the large M31 Andromeda galaxy, to the tiny NGC and PGC galaxies that are abundant in the sky. Images taken of galaxies with Ha filters can also be added to standard color images to highlight areas of star formation (Fig. 6.10).

Galaxies are more challenging to image especially from poorer skies as they emit light across the whole visible spectrum which means they can't be as effectively separated from light pollution by the use of filters. This is not to say that they can't be imaged from poorer skies, it just needs more care reading the camera histogram and determining exposure times, along with careful processing.

Take care not to use exposure times that are so long that the core of the galaxy is burnt out. Burning the core of galaxies might be unavoidable, especially if you are only taking single images and not stacking multiple exposures as you will be trying to balance getting enough light from the fainter areas while not burning the central core out.

Fig. 6.10 M81 Galaxy in Ursa Major

Using a OSC Camera or DSLR

- If you have the older style sodium or mercury vapor streetlights consider using a CLS or UHC filter to reduce sky glow and enable you to pick up fainter detail without it being lost in light pollution.
- If you have LED streetlights it would be worth considering purchasing a filter specifically designed to reduce the sky glow produced by the blue component that these type of lights typically emit.

Using a Mono Camera

If you are using a mono imaging camera you have the following basic options.

- Using one of the modern light pollution filters specifically designed to reduce the effects of LED lights.
- Using red, green and blue filters to take images and then combine them later in software to produce a standard color image. Using this technique with galaxies can be challenging depending on the level of light pollution in the sky.

Emission Nebulae

Emission nebulae are good targets for imaging but tend to require lengthy exposure times and the use of filters in particular Ha for light polluted skies (Fig. 6.11).

Using a OSC Camera or DSLR

- If you have the older style sodium or mercury vapor streetlights, consider using a CLS or UHC filter to reduce sky glow and enable you to pick up fainter detail without it being lost in light pollution.
- If you have LED streetlights, it would be worth considering purchasing a filter with a dual pass band that allows both Ha and OIII light through. This will deal with most of the light pollution while allowing the most light from the planetary nebula to pass through. This will substantially reduce sky glow and also increase the contrast in the planetary nebula being imaged.

Fig. 6.11 M16 The eagle Nebula

Using a Mono Camera

- Try using one of the modern light pollution filters specifically designed to reduce the effects of LED lights.
- You may use Ha, OIII and SII filters to selectively choose the wavelength of light that you are interested in imaging. Any combination of the images taken with these filters can be combined later in software to produce a false color image.

Reflection Nebulae

Reflection nebulae are basically gas clouds that are illuminated by the reflected light from nearby stars and as such tend to be a bit more difficult to image, especially from light polluted skies. Bright ones that are worth imaging by an astrophotographer are the Iris Nebula NGC 7032 and M45 the Pleiades. These are good targets on which to gain experience when starting to capture these elusive objects. It is of little or no benefit to try narrow

Fig. 6.12 The Iris Nebula gas clouds

band filters on reflection nebulae due to the spectral composition of the light they emit. The broader band light pollution filters may be of some help here (Fig. 6.12).

Finder Charts

It is worth taking the skills and learning at a sustainable speed and not overloading with more than is necessary at this point. The images that you will take will be thrilling and friends and family will be amazed at what you can achieve from your own backyard. Be sure, however, that with practice and dedication even better images will be possible. It is a case of refining skills and tweaking equipment to get the very best.

I have listed a small selection from the previously mentioned Messier list which includes some spectacular objects for you to practice finding.

It is recommended that you locate the constellation first using either an app or planisphere and then use your charts to pinpoint the objects to be imaged. The charts are shown in appropriate scale for each object with each square being 5 degrees.

These finder charts have all been prepared by using Deep Sky Hunter Star Atlas by kind permission of its author Michael Vlasov.

Deep Sky Hunter can be downloaded from Michael's website here.

http://www.deepskywatch.com/deepsky-atlas.html

M42. The Orion Nebula

One of the first objects that most people want to try and image is M42, the Orion Nebula as it is very easy to locate and looking at it through even a very small telescope is awe inspiring and for a deep sky object, it is very bright.

The first images that you take of the Orion Nebula will be exciting regardless of your skills and experience.

This is one of the deep sky objects that is a great target for both beginners and advanced imagers as it is very easy to capture the bright areas. For more experienced imagers, capturing the fainter areas and the stars that make up the Trapezium requires both imaging and processing skills (Fig. 6.13).

The discovery of the Orion Nebula is attributed to Nicholas Peiresc in around 1610, it is a bright diffuse nebula and is situated in the sword of Orion, under the belt. It can be located with the naked eye by looking at the three stars that make up the belt and then looking for three stars hanging down from the center of the belt known as the sword. The Orion Nebula is what appears to be the middle star of the sword. However, in order to be seen in all its glory will require some form of optical aid such as a telescope or binoculars.

Magnitude	4.0
Constellation	Orion
Type	Diffuse Gas cloud
Distance	975 light years
Size	66′ × 60′

Imaging Advice

Filters

This is bright enough to use red green and blue color filters. It also responds well to narrowband filters such as Ha, OIII and SII.

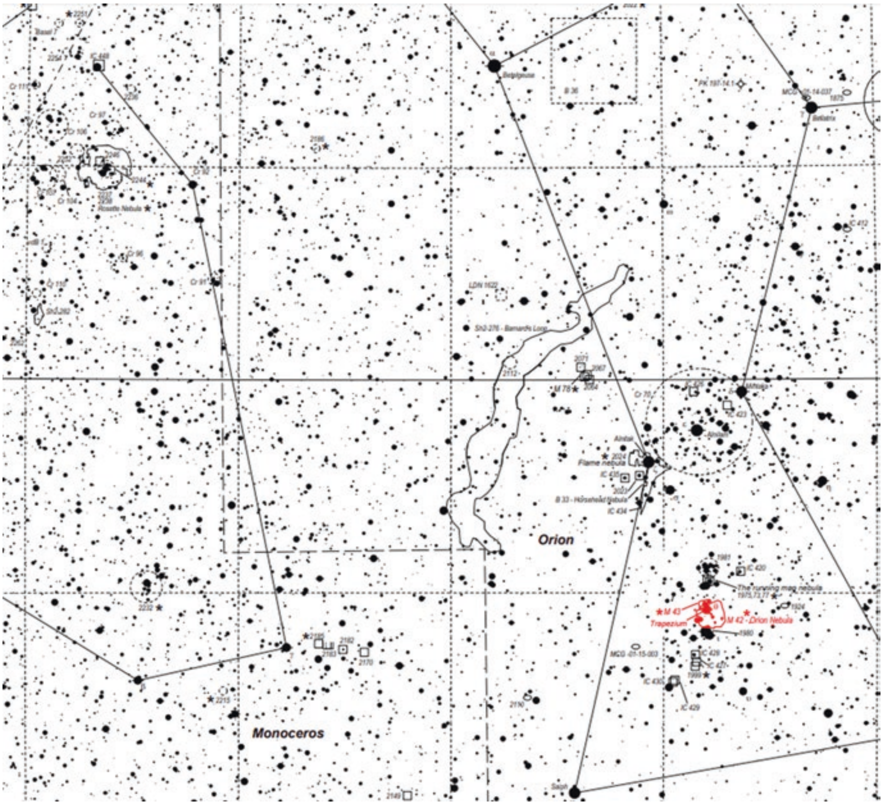

Fig. 6.13 Finder chart 1 messier 42 the Orion Nebula

Exposure Times

Very short exposures are required to pick up the brightest areas of the nebula and longer exposures to pick up the extremities. As a beginner don't worry about burning out the brighter areas in the center there is plenty of time to hone your skills later.

Try starting with exposures of around 15 s and adjust as required by your particular equipment when reviewing the images captured.

M27. The Dumbbell Nebula

The Dumbbell Nebula is a bright planetary nebula which was discovered by Charles Messier in 1764 whilst searching for comets. It is a great object to image as it is bright, quite big, has lots of detail and is very colorful (Fig. 6.14).

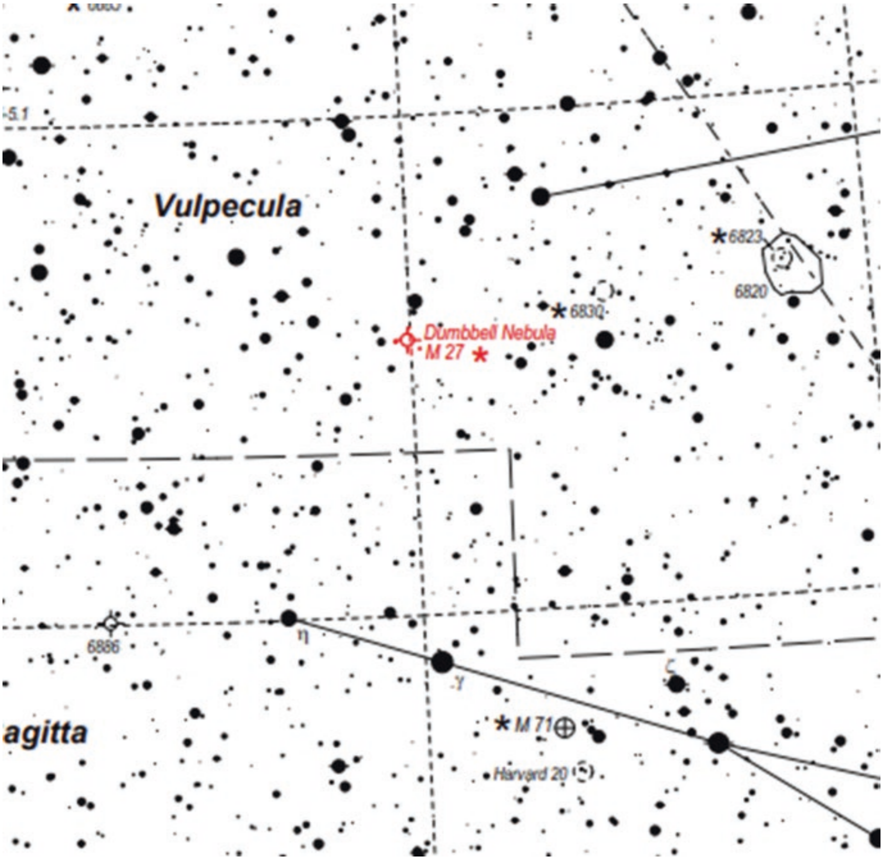

Fig. 6.14 Finder Chart 2 Messier 27 the Dumbbell nebula

Magnitude	7.6
Constellation	Vulpecula
Type	Planetary Nebula
Distance	975 light years
Size	8′ × 4′

Filters

This is bright enough to use red green and blue color filters. It also responds very well to narrowband filters such as Ha, OIII and SII.

Exposure Times

Short exposures are required to pick up the brightest areas of the nebula and longer exposures to pick up the extremities.

Try exposures starting with 2 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

M57 the Ring Nebula

The Ring Nebula is a small object to image but it is a thrill to capture it for the first time. It only needs a short exposure to catch this in all its glory. It appears as a small smoke ring suspended against the blackness of space (Fig. 6.15).

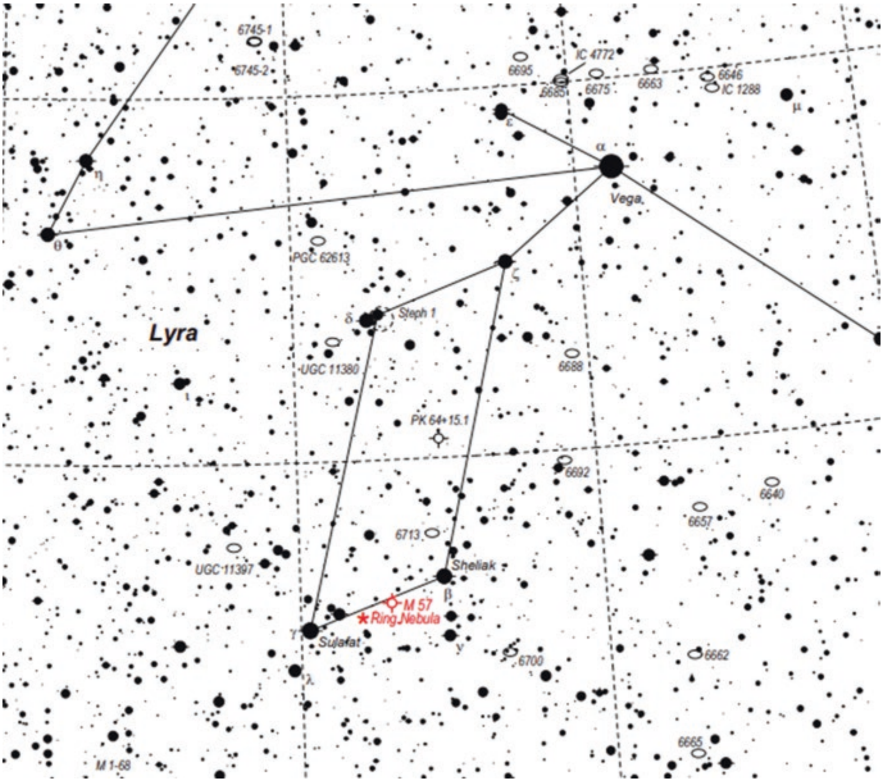

Fig. 6.15 Finder chart 3 messier 57 the Ring Nebula

Magnitude	9.3
Constellation	Lyra
Type	Planetary Nebula
Distance	1410 light years
Size	80″ × 6″

Filters

This is bright enough to use red green and blue color filters. It also responds very well to narrowband filters such as Ha, OIII and SII.

Exposure Times

Short exposures are required to pick up the brightest areas of the nebula and longer exposures to pick up the extremities.

Try exposures starting with 1 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

M51

M51 is a bright face on spiral galaxy with an interacting companion NGC5195. This galaxy was first discovered in 1773 by Charles Messier and its companion was discovered in 1781 by Pierre Méchain. Being the first galaxy in this list, it is only right to mention that galaxies tend to require longer exposure times due to them being fainter and they are not as easy to easy to filter out from the sky background so are best imaged on darker, moonless nights (Fig. 6.16).

Magnitude	8.1
Constellation	Canes Venatici
Type	Spiral Galaxy with interacting companion NGC5195
Distance	37 million light years
Size	12′ × 6′

Filters

Filters may be beneficial, as long as they match your light pollution.

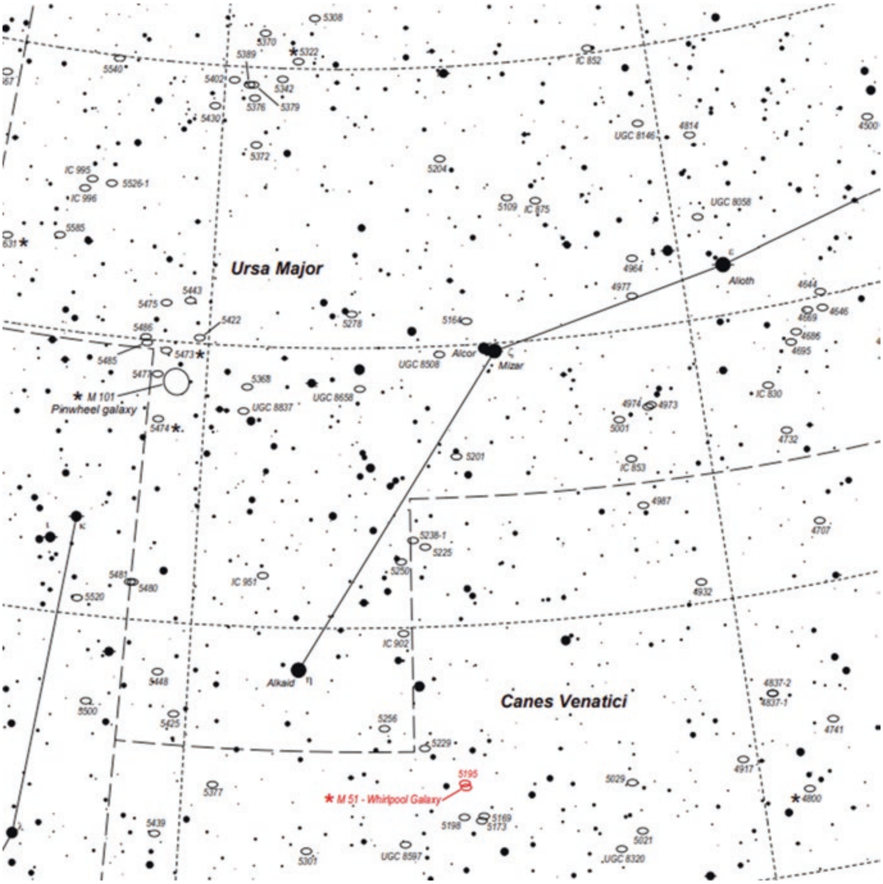

Fig. 6.16 Finder chart 4 messier 51 the Whirlpool Galaxy

Exposure Times

Longer exposures are required when imaging galaxies, due to the lower surface brightness that many of them exhibit.

Try exposures starting with 3 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

M3 Globular Cluster

Messier 3 is a bright globular cluster in the constellation of Canes Venatici. This is as the name suggests a vast cluster of typically older stars and these clusters are located in a halo around the outer regions of galaxies. They may

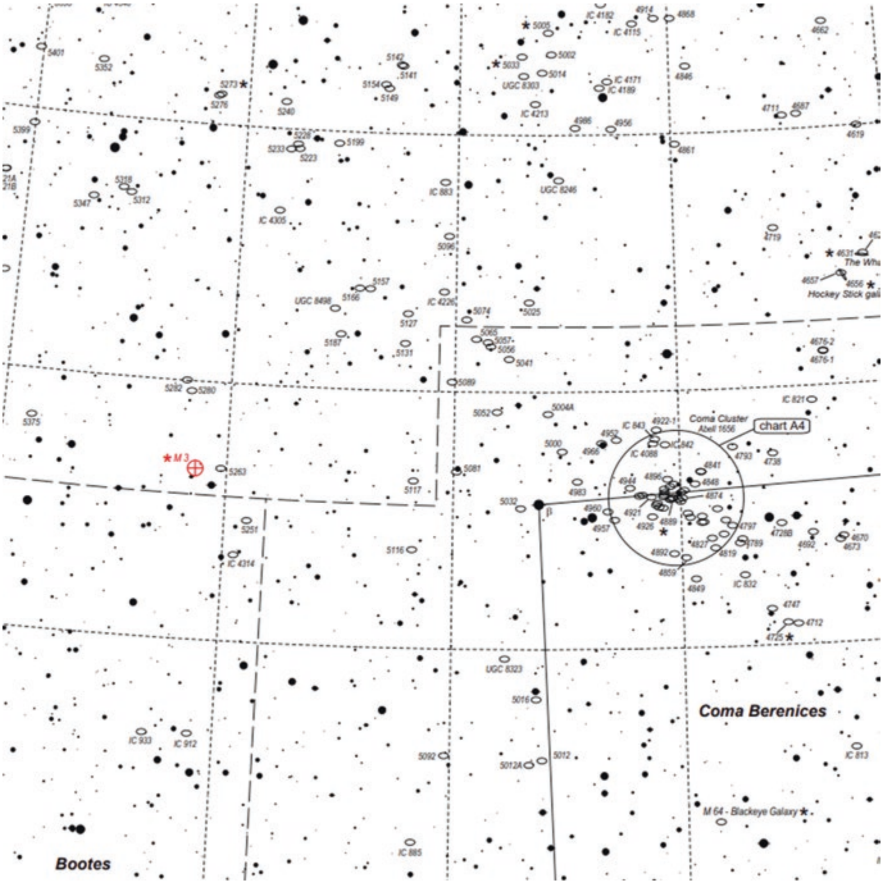

Fig. 6.17 Finder chart 5 messier 3 Globular Cluster

contain from hundreds of thousands, to millions of stars. There are around 150 of these surrounding our galaxy the Milky Way. In one area of the Virgo cluster of galaxies the Hubble space telescope has identified more than 11,000 globular clusters (Fig. 6.17).

Magnitude	6.4
Constellation	Canes Venatici
Type	Globular Cluster
Distance	34,000 light years
Size	18′ Diameter

Filters

M3 is bright enough to use red green and blue color filters.

Exposure Times

Short exposures are required to pick up the brightest stars of the cluster and longer exposures to pick up the fainter members.

Try exposures starting with 30 s increasing to 3 min and adjust as required for your equipment when reviewing the images captured.

M101 Also Known as the Pinwheel Galaxy

Messier 101 is a large spectacular face on spiral galaxy in Ursa Major; not as bright as some of the other objects but big with lots of detail in its spiral arms. It is a great object to practice on and is circumpolar so visible all year round barring local obstructions. Messier 101 was discovered in 1781 by Pierre Méchain (Fig. 6.18).

Magnitude	9.6
Constellation	Ursa Major
Type	face on Spiral Galaxy
Distance	23 million light years
Size	$10' \times 8'$

Filters

Filters may be beneficial as long as they actually match your light pollution.

Exposure Times

Longer exposures are required when imaging M101 due to its lower surface brightness and face on orientation.

Try exposures starting with 3 min increasing to 5 or 10 min and adjust as required for your equipment when reviewing the images captured.

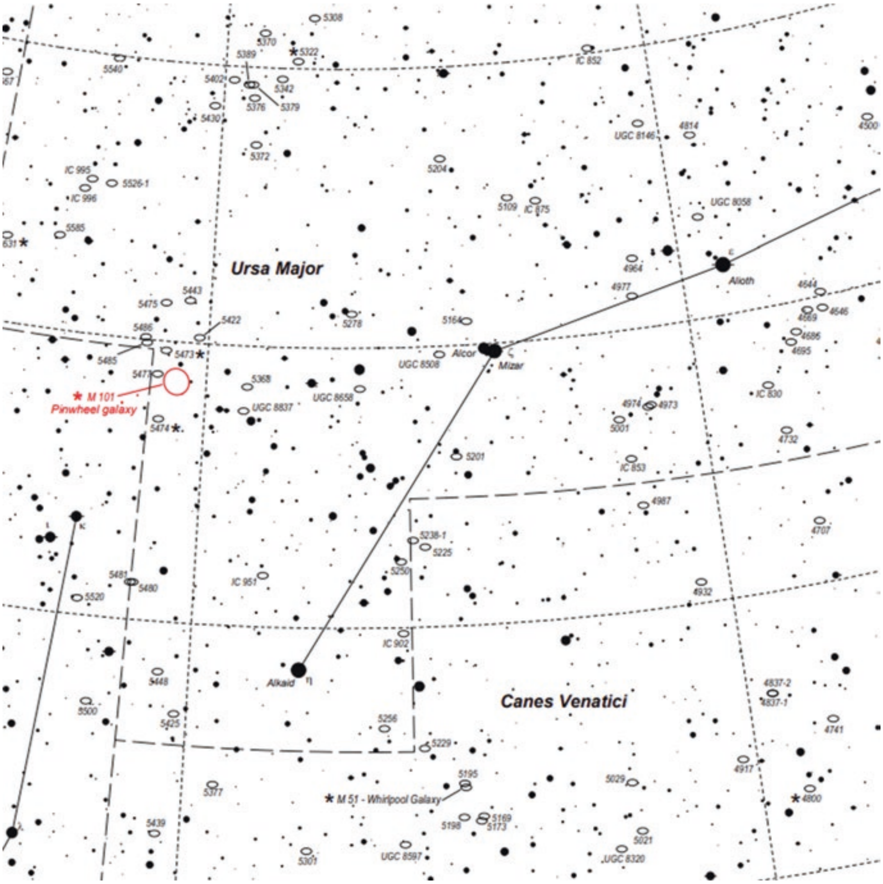

Fig. 6.18 Finder chart 6 messier 101 Galaxy

M81 Galaxy

Messier 81 also known as Bodes galaxy is a large bright beautiful spiral galaxy in Ursa Major. M81 and M82 were discovered in 1774 by Johanne Bode (Fig. 6.19).

Magnitude	6.9
Constellation	Ursa Major
Type	Spiral Galaxy
Distance	11.6 million light years
Size	16′ × 10′

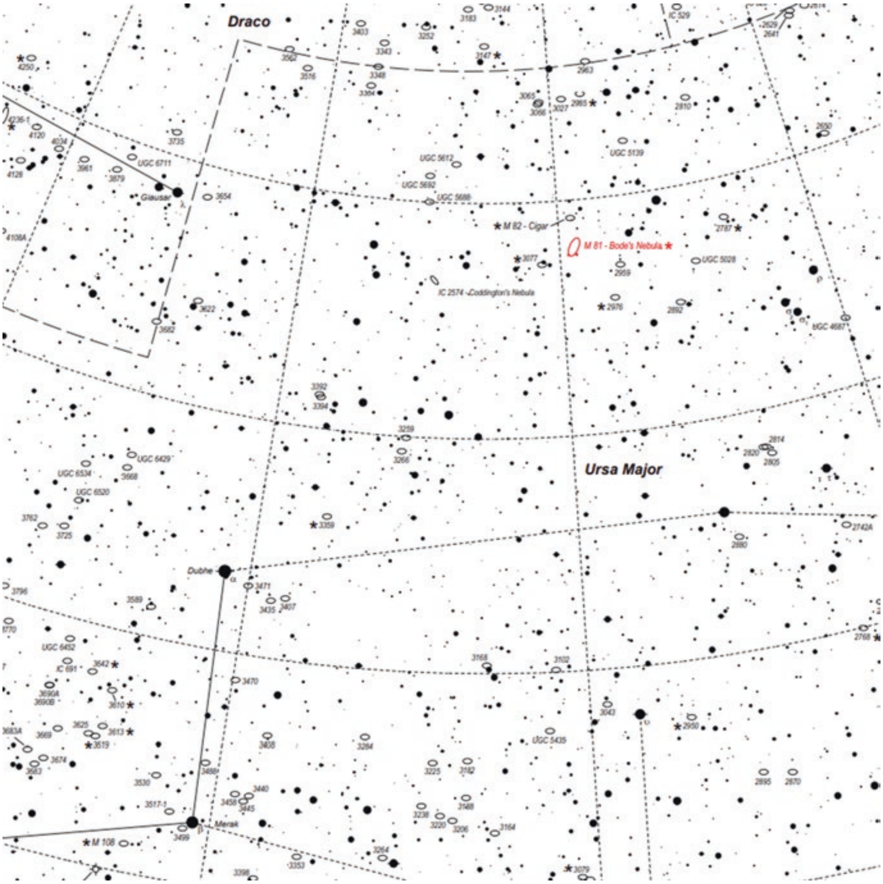

Fig. 6.19 Finder chart 7 messier 81 Galaxy

Filters

Filters may be beneficial as long as they match your light pollution.

Exposure Times

Longer exposures are required when imaging galaxies due to the lower surface brightness that many of them exhibit.

Try exposures starting with 3 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

M82 Starburst Galaxy

Messier 82 also known as the Cigar Galaxy is a starburst galaxy which means it is undergoing an exceptionally high rate of star formation when compared to an average galaxy. The reason for this is thought to be a result of interaction with its neighbor Messier 81. M81 and M82 were both discovered in 1774 by Johanne Bode. It was previously thought to be an irregular galaxy but two spiral arms were found that are visible in Infra-red (Fig. 6.20).

Magnitude	8.4
Constellation	Ursa Major
Type	Spiral Galaxy
Distance	12 million light years
Size	11′ × 4′

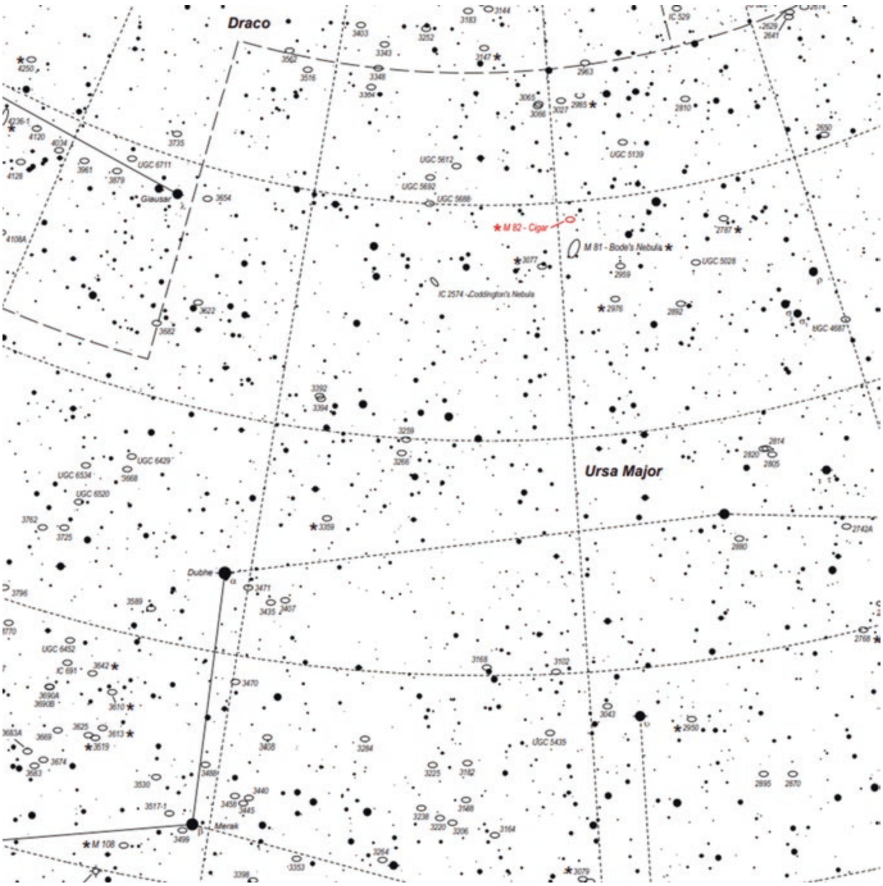

Fig. 6.20 Finder chart 8 messier 82 Galaxy

Filters

Filters may be beneficial as long as they match your light pollution.

Exposure Times

Longer exposures are required when imaging galaxies due to the lower surface brightness that many of them exhibit.

Try exposures starting with 3 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

M97 The Owl Nebula

Messier 97 the Owl Nebula is a planetary nebula in Ursa Major, it was discovered by the French astronomer Pierre Méchain in 1781. A planetary nebula is formed when a glowing shell of ionized gas is ejected from a giant red star that is near the end of its life. M97 is estimated to be around 8000 years old. Once you have started to become more proficient at finding objects M97 is a good test as it is not particularly bright (Fig. 6.21).

Magnitude	9.9
Constellation	Ursa Major
Type	Planetary Nebula.
Distance	2000 light years
Size	11′ × 4′

Filters

This responds very well to narrowband filters such as Ha, OIII and SII. Suitable light pollution filters may also help.

Exposure Times

Long exposures are required to pick up the uniform areas of the nebula and longer exposures to pick up the extremities.

Try exposures starting with 2 min increasing to 5 or 10 min and adjust as required for your equipment when reviewing the images captured.

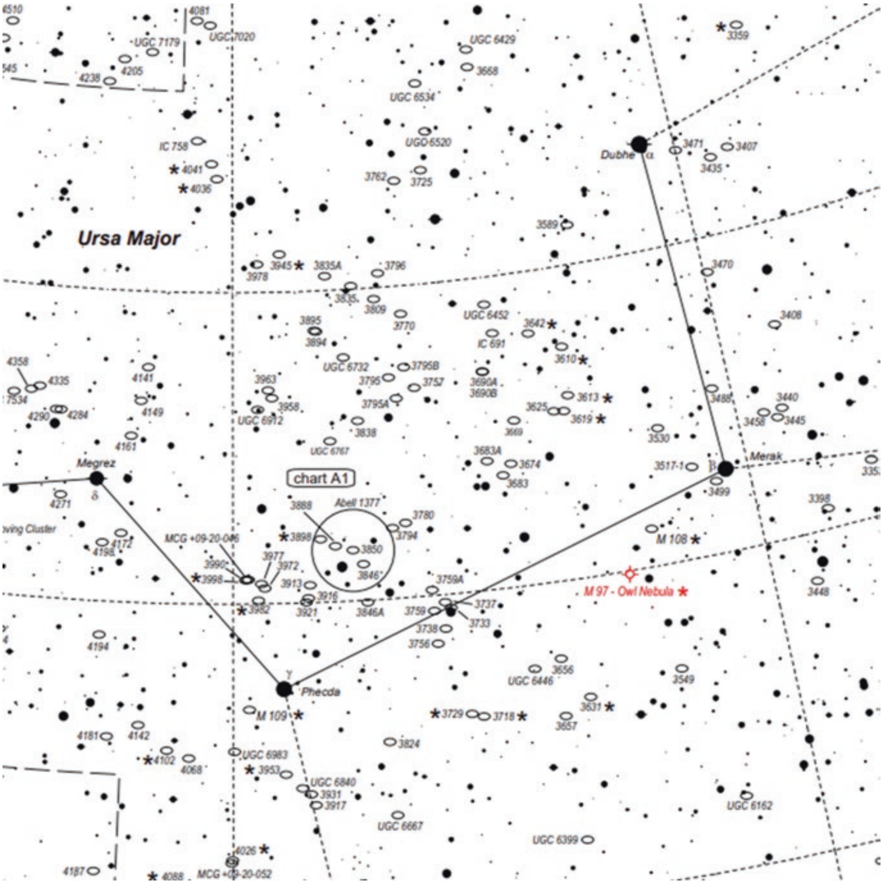

Fig. 6.21 Finder chart 9 messier 97 Planetary nebula

M13 the Great Hercules Globular Cluster

This is one of two bright globular clusters in the constellation of Hercules. It is a vast cluster of stars that was discovered in 1714 by Edmond Halley who described it as light patch as the instruments of the day were unable to resolve it. M13 is made up of approximately 750,000 stars. Globular clusters are home to some of the oldest stars and are thought to be remnants of galaxy formation they are older and much denser then open clusters (Fig. 6.22).

Magnitude	5.8
Constellation	Hercules
Type	Globular Cluster
Distance	22,000 light years
Size	20′ Diameter

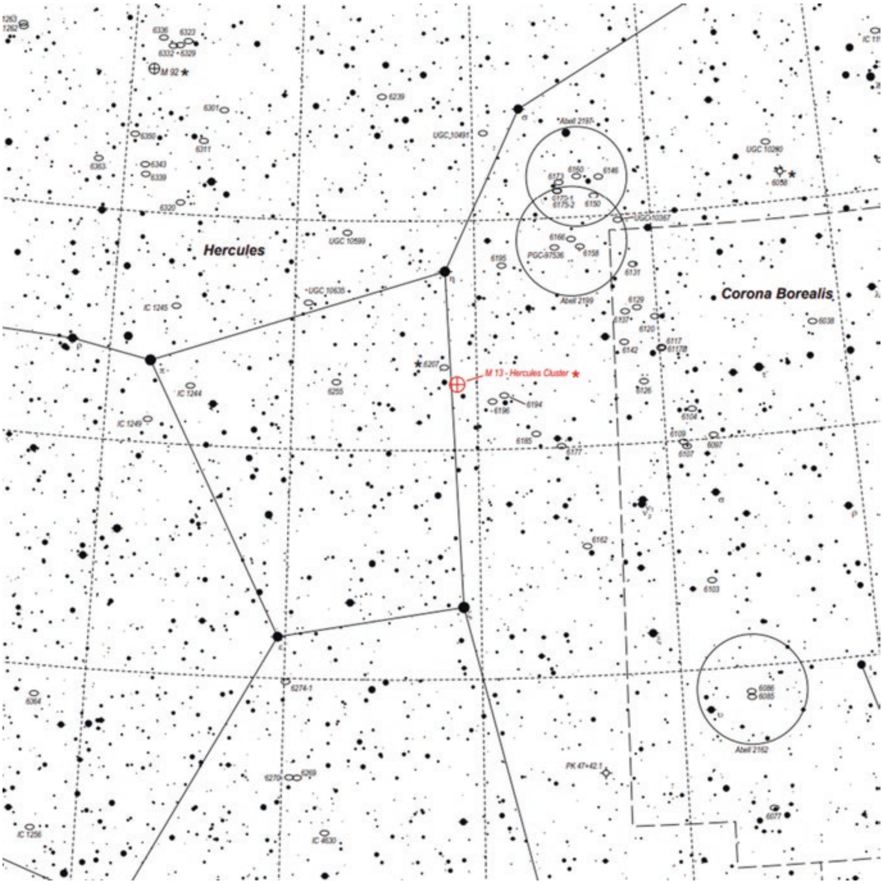

Fig. 6.22 Finder chart 10 messier 13 globular cluster

Filters

M13 is bright enough to use red green and blue color filters.

Exposure Times

Short exposures are required to pick up the brightest stars of the cluster and longer exposures to pick up the fainter members.

Try exposures starting with 30 s increasing to 3 min and adjust as required for your equipment when reviewing the images captured.

M92 Hercules Globular Cluster

This the second of two bright globular clusters in the constellation of Hercules, It is not quite as bright or large as M13 but is a jewel in its own right. M92 was discovered in 1774 by Johanne Bode It is thought to be one of the oldest clusters with an estimated age of 14.2 billion years which is almost the same as the age of the universe (Fig. 6.23).

Magnitude	6.3
Constellation	Hercules
Type	Globular Cluster
Distance	26,700 light years
Size	14′ Diameter

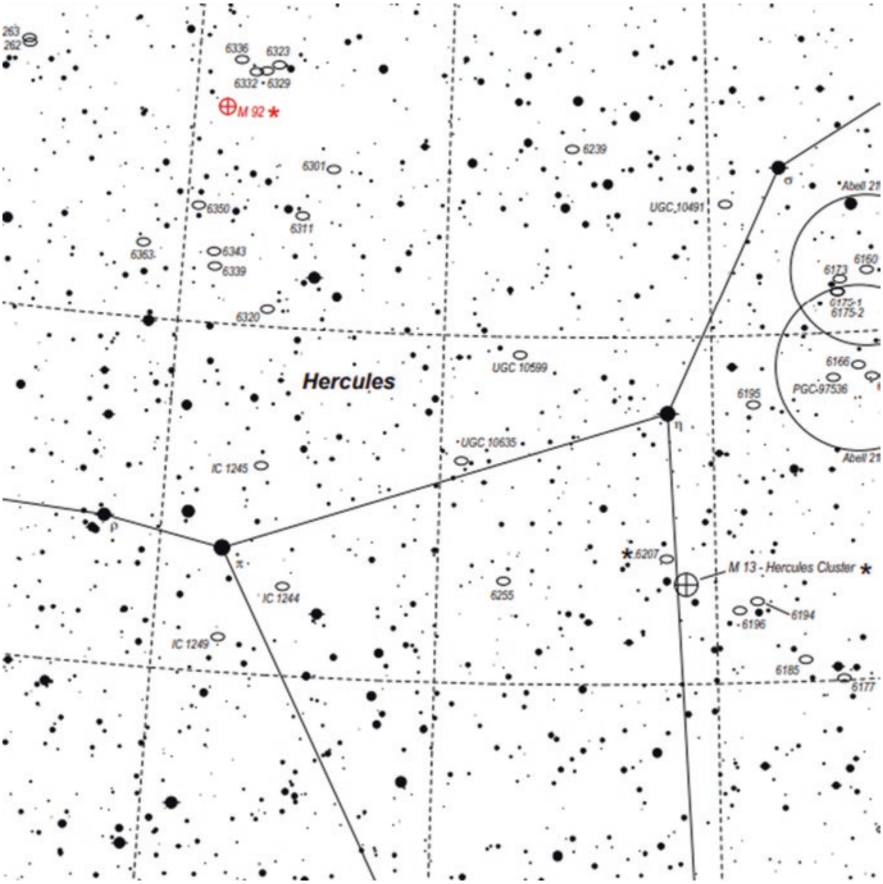

Fig. 6.23 Finder chart 11 messier 92 globular cluster

Filters

M13 is bright enough to use red green and blue color filters.

Exposure Times

Short exposures are required to pick up the brightest stars of the cluster and longer exposures to pick up the fainter members.

Try exposures starting with 30 s increasing to 3 min and adjust as required for your equipment when reviewing the images captured.

M31 the Andromeda Galaxy

The Great Andromeda Galaxy is a large and bright spiral galaxy, it is also the nearest major galaxy to our own the milky way. In 964 the Persian astronomer Abd al-Rahman al-Sufi described it in his book of fixed stars as a nebulous smear. It is clearly visible as a smear to the naked eye from a dark sky site. Messier 31 is a great object to image, with a wide field setup such as a DSLR on a tracking mount and is possible with even a modest telephoto lens. It is also easy to pick up its companion galaxies M32 and M110 (Fig. 6.24).

Magnitude	3.4
Constellation	Andromeda
Type	Spiral Galaxy
Distance	2.5 million light years
Size	3.16° × 1°

Filters

M31 is bright enough to enable the use of red, green and blue filters from most locations and sky conditions.

Exposure Times

Longer exposures are required when imaging galaxies but as M31 has a high surface brightness the exposures don't need to be as long.

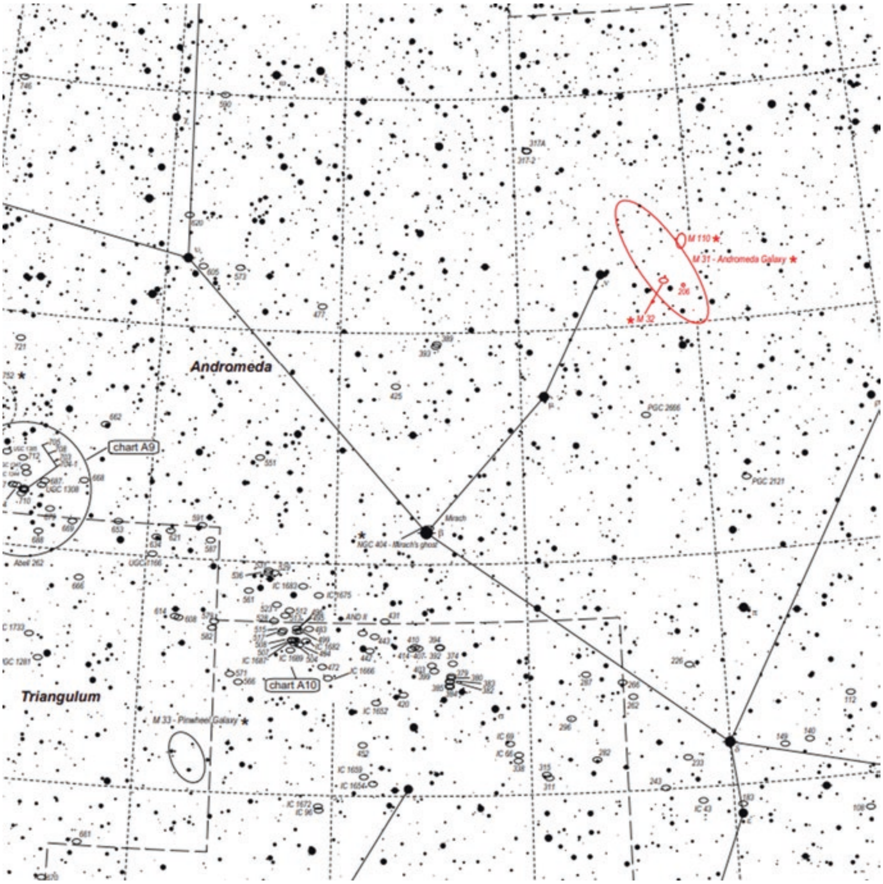

Fig. 6.24 Messier 31 Andromeda Galaxy

Try exposures starting with 2 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

This is another object with a very high dynamic range and will require careful processing to enable both the faint areas to be visible without burning out the core and losing all detail in that area.

M63 the Sunflower Galaxy

The Sunflower Galaxy, M63 is a tilted spiral galaxy and was one of the first to be recognized as such by Lord Rosse, when he observed the spiral structure within it. M63 lies in the constellation of Canes Venatici and was discovered in 1779 by Pierre Méchain (Fig. 6.25).

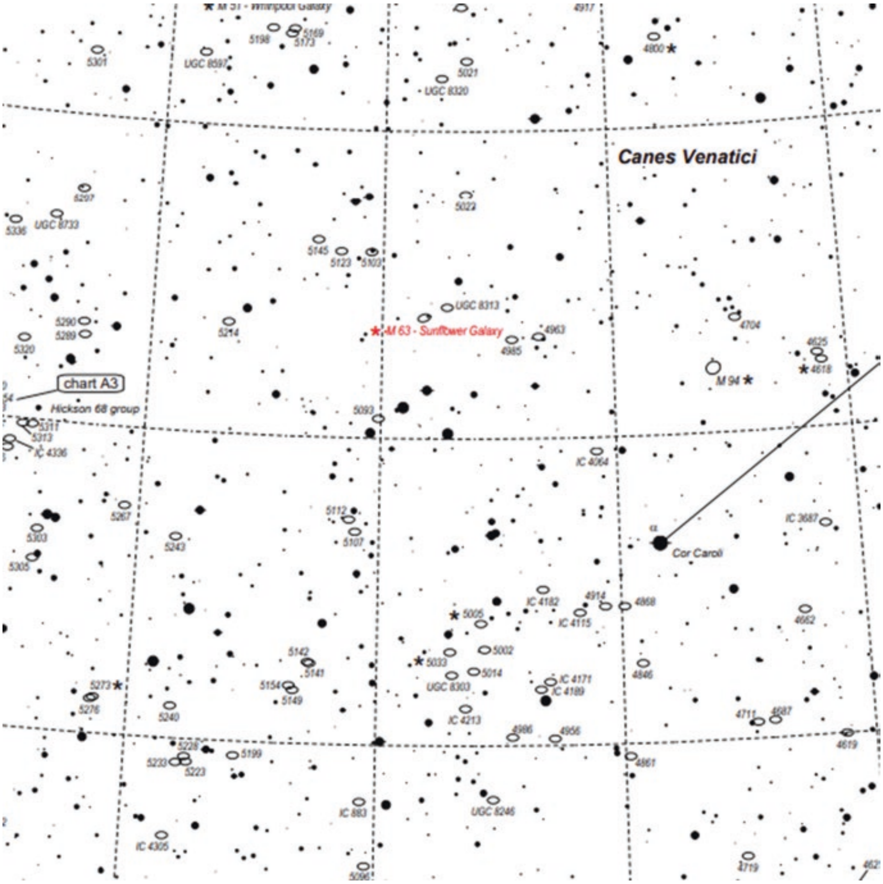

Fig. 6.25 Finder chart 13 messier 63 galaxy

Magnitude	9.3
Constellation	Canes Venatici
Type	Spiral Galaxy
Distance	29.3 million light years
Size	12.6′ × 7.2′

Filters

Filters may be beneficial as long as they match your light pollution.

Exposure Times

Longer exposures are required when imaging galaxies due to the lower surface brightness that many of them exhibit.

Try exposures starting with 3 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

M64 The Black Eye Galaxy

The Black Eye Galaxy is a tilted Spiral galaxy in the constellation of Coma Berenices. M64 was discovered by Edward Piggott in 1779 also by Johann Bode in the same year. Charles Messier discovered it in the following year 1780. Its name describes the large dark dust lane which obscures part of its nucleus and is very prominent in images even taken with modest equipment (Fig. 6.26).

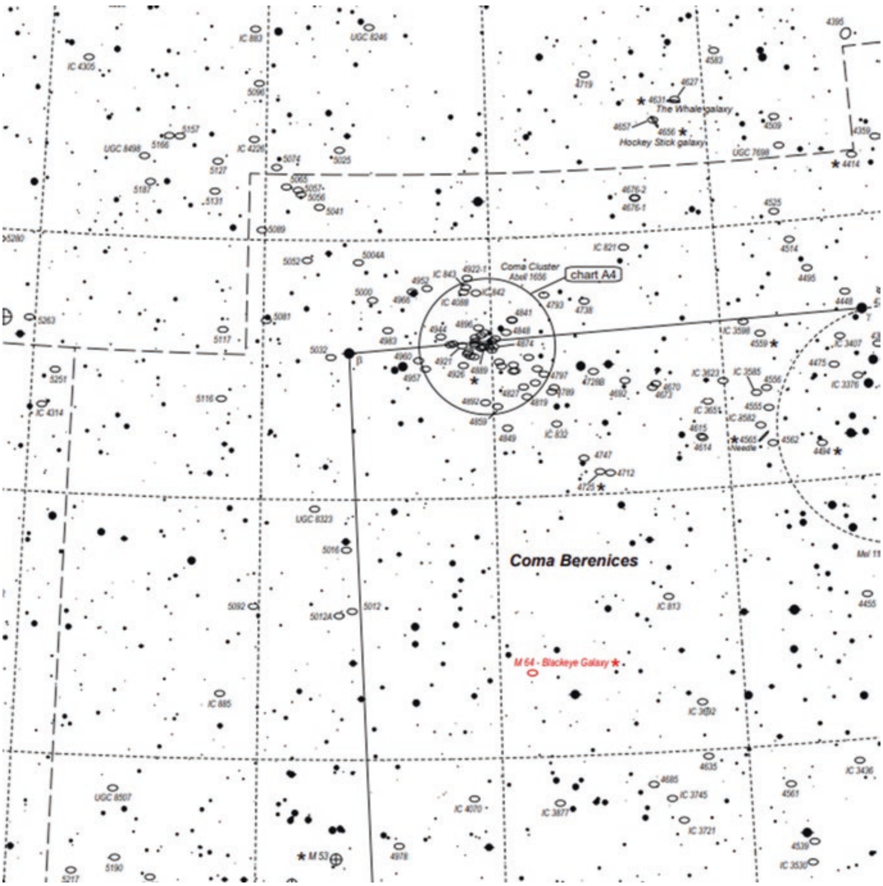

Fig. 6.26 Finder Chart 14 Messier 64 Galaxy

Magnitude	9.4
Constellation	Coma Berenices
Type	Spiral Galaxy
Distance	17.3 million light years
Size	10.7′ × 5.1′

Filters

Filters may be beneficial as long as they match your light pollution.

Exposure Times

Longer exposures are required when imaging galaxies due to the lower surface brightness that many of them exhibit.

Try exposures starting with 3 min increasing to 5 min and adjust as required for your equipment when reviewing the images captured.

I hope you try imaging some of these suggested objects and enjoyed star hopping in order to find them. There are thousands of other objects that are within the capabilities of a modest amateur astrophotography system. Sometimes, the hard part can be deciding which one to image!

These charts have been prepared **using Deep Sky Hunter star atlas** by kind permission of Michael Vlasov.

Deepskywatch Website

Deep Sky Hunter Star Atlas

Website http://www.deepskywatch.com

Deep Sky Hunter Star Atlas is a free and printable atlas of the sky. It is best printed on A3 sheets for desk use, but is also perfectly usable printed on A4 for use at the telescope. It is recommended that it is laminated for use at the telescope so that it is waterproof and you may use whiteboard marker pens for temporary notes or a permanent marker for notes you to keep.

This is an excellent star atlas to use for star hopping which is detailed in Chap. 12 and as with all home printable atlases you can print pages for use at the telescope which are easily replaceable if they become damaged.

Companion to the Atlas

http://www.deepskywatch.com/files/deepsky-atlas/Deep-Sky-Hunter-DSO-images.pdf

This is a companion list with images of deep sky objects for use after you have mastered the basics of astrophotography and you are ready for further challenge.

Allans-stuff.com

Triatlas Project Star Chart

Website https://allans-stuff.com/triatlas/

On this site you will find the full printable "Triatlas project star chart". The full chart is huge but if you are serious about the night sky it is a must. It has smaller versions so you can choose which one is the most suitable for you, your skies and equipment. This chart is downloaded in blocks of charts so you can choose the areas that are of interest to print or view. This is a superb star atlas and prints beautifully it can, however, take a bit of time to get used to the scale and to orientate yourself when using it.

Night Sky Planner

https://calgary.rasc.ca/darksky/nightplanner.htm

Another good resource to help find suitable objects to observe from your location is Larry McNish's Night Sky Planner which is to be found on the Royal Astronomical of Canada Calgary website.

First Night with a Goto Telescope and Handset

This section is designed for an aspiring astrophotographer who has never setup a Goto telescope. It will show you how to easily setup the mount and align it with the earth's polar axis and carry out a 3 star alignment.

This is an essential skill that is required to enable you to setup your telescope accurately enough that you will be able to attach a camera and take images of deep sky objects, which is our ultimate goal.

This setup routine needs to be second nature so that it can be carried out quickly and accurately; it can be easily achieved by practicing the following steps.

Mount Setup Home Position Polar Alignment 3 Star Alignment

By now, you will be familiar with assembling and leveling the mount, balancing the telescope, pointing the RA axis towards Polaris, hooking up the power and turning it on. You will know how to enter your site location details and using an accurate time source, set the handset time remembering to enter the daylight saving time correctly and practicing the rest of the setup and alignment. Once you have done this preparation, you will set an accurate home position which is the starting point for the polar and star alignment that you will do next.

Key to Fig. 6.27

1. RA lock.
2. Dec lock.
3. Azimuth Adjustment screws.
4. Latitude adjustment screw (behind mount).
5. Telescope Dovetail clamp.
6. Counter Weight.
7. Polar telescope cover.

Setting an Accurate Home Position

The telescope home position is a reference position that is used for the mechanical components and the electronics to synchronize with each other.

On the Sky Watcher German equatorial mounts (GEM) the home position is typically with the counter weights pointing down and the optical tube pointing toward the pole, as shown here. You may need to check the instructions if your mount is different (Fig. 6.28).

The suggested method that you use to achieve an accurate home position, is basically as described in an Astronomy Shed YouTube series of videos on mount setup and is carried out as follows:

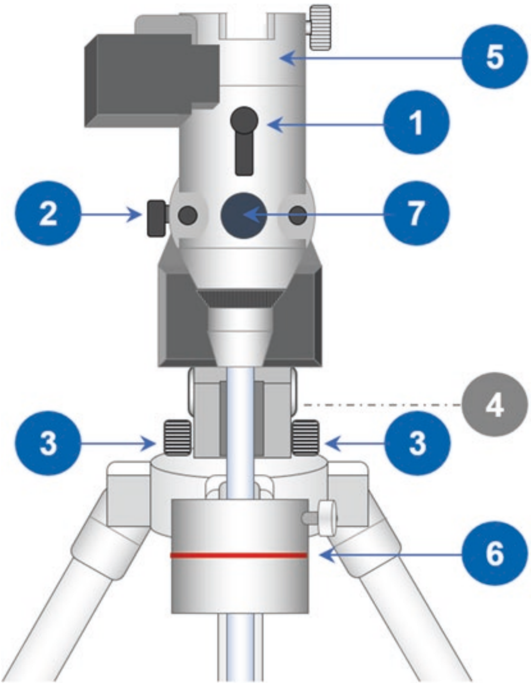

Fig. 6.27 GEM mount with the controls labeled for reference illustration by Peter Karboulonis' of Opticstar

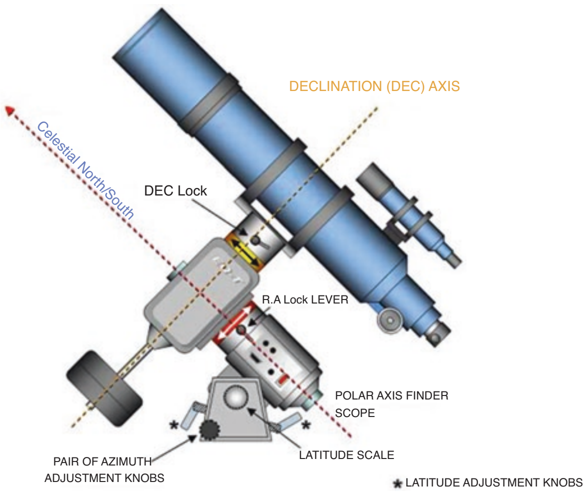

Fig. 6.28 Home position for a Sky watcher GEM mount illustration by Peter Karboulonis' of Opticstar

Please note you may need to refer a diagram of your mount to identify the necessary components and controls if you haven't familiarized yourself with them already. The starting point is the adjustments to be made to the RA axis.

Right Ascension Axis

- Unlock and turn the right ascension (RA) axis so that the counterweight bar is horizontal with the weights pointing to the west and lock its clutch. You can either use a spirit level or electronic level box to check this.
- Unlock and rotate the RA setting circle so its indicator points to 6 h and then lock the setting circle.
- Rotate the mount, having unlocked its RA clutch, until the RA index mark is aligned with 12 h on the RA setting circle and lock the RA axis. The telescope should now be pointing up towards the pole.

Declination Axis

- Unlock and rotate the declination axis until the optical tube is horizontal and check with your spirit level or electronic level box.
- Unlock and rotate the declination setting circle to show 0 degrees against the index mark and lock it.
- Finally unlock and rotate the declination axis so that the index mark is aligned with either 0 or 12 degrees on the declination setting circle and the telescope tube is pointing up.

The Mount Is Now Set in an Accurate Home Position

You may turn the power on to your mount now which will assume that the telescope and mount are in the home position and allow it to initialize in that position.

If you have a mount such as the AZEQ6gt or EQ. 8 which has dual encoders and its already been switched on you may now need to turn the power off and then back on again as it assumes the mount is in the home position when power is turned on.

My handset will ask if the telescope is being used as an equatorial mount or an AltAz mountif you have an NEQ6, HEQ5 or similar equatorial mount you can ignore this step otherwise set it to equatorial.

It will then ask for the time in 24 hr. clock format followed by the date which is in the American format of Month/Date/Year or MM/DD/YYYY.

Then, enter your latitude followed by longitude. You can find this from Google maps or many mobile phone apps.

Enter if daylight saving time is active, this is simply asking if summer-time is active and you are prompted with a toggled Yes, No.

Polar Alignment

You should now have already set your latitude using the scale on the side of the telescope and pointed the mount toward Polaris. Remove the covers from the polar telescope and if necessary, rotate the declination axis until the counter weight shaft no longer obscures its view by virtue of the hole through it. Looking through the polar telescope you should be able to see Polaris in the field of view. (Fig. 6.29)

The easiest way to polar align the mount is to use an app such as Polar Finder Pro which gives a clear image of what you should see in the polar telescope. It is then simply a matter of unlocking and rotating the RA axis until the polar telescope reticule is the same orientation as the image in the app and then using the altitude and azimuth adjustment screws, to center Polaris in the circle marked Polaris in the app. Once this has been done, the telescope has been polar aligned.

When the next step, which is star alignment, has been done you will get a report from the handset as to how accurate the polar alignment is and if it is too far out you can try polar aligning again to improve it.

Star alignment Procedure

You are now ready to select the three star alignment option from the menu items in the handset. This is the most accurate of the star alignment procedures.

Select 3-Star Align from the handset and press enter

You will then be presented with an alignment star name, if this is suitable and not obscured by trees or a building, you may press enter to select it at which point the telescope will slew to where it thinks that star is in the sky.

Fig. 6.29 Polarfinder pro screenshot permission of Raffaele Lunari

If the star is not suitable you may use the lower up/down keys in the handset to choose an alternative alignment star and press enter. The telescope will then slew to where it thinks it is.

Look through the main telescope to see if the selected star is visible. If it is not, look in the finder telescope which has a much wider view and it should be visible there. You can now use the main arrow buttons on the handset to center the star in the field of view of the main telescope.

When this has been done press “Enter” on the handset.

You will now be presented with a different alignment star. Follow the same procedure choosing an alternative if it is not suitable from your location. If it is suitable, center it and press “Enter”.

You will do this three times using a different alignment star hence the name 3 star alignment.

When done correctly the handset will then report “alignment successful” it will then show the following display.

Please note the figures will be different and may be positive or negative.

Mel = +000° 02′10″
Maz = +000° 10′05

The figures are in degrees, minutes and seconds and show the altitude error from the celestial pole of your telescope they may be positive or negative but it is important that they are close to zero.

Do not be concerned about the size of the errors. As long as it is in the order of minutes of arc in both axes it should work. Remember, you will have to do this each time you set up your telescope so there will be plenty of opportunity to practice. It is also worth noting that some nights the alignment will be better than others.

Object Selection

You may now choose an object to look at using the handsets database. If you are using a Sky Watcher mount, this can be done by pressing either the button with "Object" on it and then using the lower arrow buttons to select the type of object, followed by enter which may ask you for the object catalogue number, or if a star or planet is chosen, its name.

Alternatively, if you are unsure what to look at you can select an object from the "tour" menu button which will bring up a list that you can scroll through of all the objects that are available to you barring local obstructions.

You may also choose from the inbuilt catalogues directly if you know what you want to look at using the buttons titled.

"M"	Messier objects
"NGC"	New General Catalogue of objects
"IC"	Index catalogue
"PLANET"	Gives you the choice of planets from a list which also includes the earth's Moon.

If you press tour and choose an object from the available list by pressing "Enter" it will show the object name or catalogue number, followed by its position which will be continuously changing as it moves across the sky. This is reflected by the changing digits on the display.

Press "Enter" again and the handset will ask "View Object?"

Pressing enter again will send the telescope slewing to the object and it will beep when it reaches it and starts tracking on it.

Center and Sync

Have a good look through the eyepiece and center the object in the field of view using your finder telescope if necessary and the handset arrow buttons to move the telescope. You can also change the slew speed of the telescope by pressing the rate button, followed by a number button from 0 to 9 and then the enter button. This incrementally increases the speed until at rate 9 the mount is slewing as fast as it is able.

You can now also sync the object to the handset computer using the pointing accuracy enhancement (PAE). This is done by pressing escape once to back up in the menu system and then holding the escape button until you see center object and the objects name on the handset display. You can also reach this PAE function through the utility menu. Please note; with newer handsets, you may need to press the right and up buttons together to end the centering operation.

If you make a mistake you can also use the Clear PAE Data function from the Utility/PAE/ menu to delete it.

Time to Explore

Start by limiting yourself to visually finding objects for the first night. This will help you to gain lots of experience using your telescope and its handset, whilst exploring some of the delights of the night sky. Pick some objects from the first objects to image list as they work well visually and photographically. Track the objects down and look forward to the challenge of the next step.

Chapter 7

Your First Imaging Session

Preparation

It is now time to take the first images using your telescope and camera. Having already done much of the hard work needed, now it's time to start putting that knowledge to use and enjoy seeing some results. It is assumed here that following the previous chapters you already have a good working knowledge of setting up your telescope and its mount system and these are set up and ready to receive the camera that is going to be used. This will preferably be done outside in enough light so that you can point the telescope at a distant object to get a rough focus established before pointing it towards the stars.

Fitting Your Camera Using Adapters and Extension Tubes

The camera will need the correct adapter to attach it to the telescope focuser tube in place of the eyepiece; it could possibly need extension tubes to achieve a focus. This isn't a fault it is just that there are so many combinations of cameras and telescopes that they are sometimes needed to ensure the correct spacing of the camera. Now is the time to find out if you need any of these adapters or extension tubes and how to fit them. You can do this by consulting the manufacturer's documentation or through one of the many

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_7

Fig. 7.1 Canon DSLR Camera adapter

online forums or local astronomical societies who would be able to help if you are having difficulty with this.

Figure 7.1 shows a typical T-Mount adapter. These are camera specific and the one shown is for a Canon DSLR. The camera adapter screws into a nosepiece see Fig. 7.2 and then the assembly can fit into the focuser drawtube of your telescope. The nose piece shown is a 1 1/4″ fitting; however, you may need a 2″ nosepiece depending on your telescope focuser size.

Filters

After this first session, you will be in a position to decide if you need to use any filters to combat light pollution, depending on what type of object you are going to be imaging and your local sky conditions, but for now don't use any filters. I am mentioning filters at this stage because unless you are using a filter wheel, you will need to fit the filter to the camera nosepiece before it is attached to the telescope in future imaging sessions (Fig. 7.3).

Operating the Camera

If you are using a dedicated astrophotography camera that needs a computer to operate it, your only real choice will be in the software that you use to operate it. If however, you are using a DSLR you have choice and flexibility as they can be operated in different ways. These include; a built in interval-

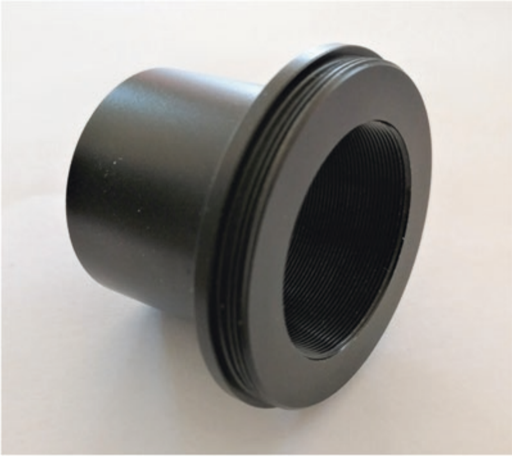

Fig. 7.2 Camera Nosepiece

Fig. 7.3 A Hydrogen Alpha Narrowband filter

ometer, an external cable release, which may feature an intervalometer or via a computer. There is also a choice of software programs that may be used as long as your model of camera is supported and has this facility.

DSLRs

- Setting the camera to its manual setting (Usually denoted by an ‘M’ on the control dial or button) and pressing the shutter button to initiate an exposure. This is not recommended unless the camera is equipped with a delay timer that can be used, as operating the camera by hand with no delay will result in a large amount of vibration. This vibration will result in images that have stars that will, in extreme cases, look like balls of wool and will blur any objects in the field of view. A delay timer will help to reduce the effect of this vibration as long as the delay used before the image is taken is sufficient for the vibrations to die down. This method is alright when there is no other choice but is not recommended unless it is the only option available to you.

- Basic cable release. This is a device that plugs into a socket on the camera and comprises of a short cable and at its most basic, a shutter button. This enables you to start an exposure without touching the actual camera and the vibration induced through the cable is therefore much less. This is a great improvement on the previous method and can be used in conjunction with the cameras delay timer. You may find however, that the camera doesn't have sufficiently long exposure times that can be selected, meaning you may have to operate an exposure lock and manually stop the exposure when the correct amount of time has passed. You will need to set the ISO speed in the camera before you start as the cable release has no way of doing this.
- Cable release with intervalometer. This is the next step from the previous method and uses a cable release fitted with an intervalometer. It allows you to program exposure settings which will then be carried out automatically with only one button press to initiate the process. These settings usually comprise of the number of exposures to be taken, possibly a pause between exposures and the actual length of the exposures taken. For example, you could set up 10 exposures of 3 min with a 5 s delay between them and all you would have to do is press the intervalometer button once to start the process. You will need to set the ISO speed in the camera before you start, as previously mentioned, because a cable release has no way of doing this. As a basic way to operate a DSLR this method is recommended, particularly where there is the need to take minimum equipment.
- Snap port. A growing number of telescope mounts are fitted with a snap port, which is basically designed as a cable release, complete with intervalometer that is integrated into the mount and its handset software, for a range of supported cameras. To be able to use the Snap Port you will need the correct cable for your camera, which can be obtained from the mount manufacturer, typically at an extra cost. This can then be plugged into the Snap Port on the telescope mount and the cable release port on the camera. Using the handset you can then set the number of exposures, their duration and delays between exposures. This is quite an elegant solution,

in practice works very well and is recommended. As with a cable release you will have to manually set the camera ISO.

- Control of the camera using a computer and suitable software. This method gives the most flexibility, as in most cases you have almost total control of the camera including setting its ISO speed. The method employed varies between software packages which vary from those supplied by some camera manufacturers to commercial software such as Backyard EOS, APT or Nebulosity to name a few. This method needs a USB cable connection from the computer to the camera and it is usual to power the camera using an external power supply.

As previously described DSLRs are usually fitted by an adapter particular to the make of camera, which usually screws onto either a 2″ or 1 1/4″ nosepiece that can be inserted into the telescope focuser drawtube, instead of an eyepiece. The nosepiece will be internally threaded at the end furthest from the camera so that filters of the appropriate size may be installed.

CCD or CMOS Astronomy Cameras

Dedicated astronomy cameras usually come with some form of control software to operate them. This software varies from being quite basic to being very sophisticated. Most astrophotographers will find a software package that is capable of controlling their camera to suit their needs and method of working; it is important to feel comfortable with the software that you are using. There are some excellent free to use software packages that offer comprehensive control of your camera. If you do choose to buy a software package, it makes sense to try those that offer free trials, before spending money only to find out that you don't like the way it functions or that it doesn't quite suit the way you work.

Dedicated astrophotography cameras need a USB[1] connection to a computer which enables operation of all the required camera functions. If it is cooled, as most deep sky imaging cameras are, it will also need an external power supply which is usually 12volts, this is because the cooler will take more power than a USB port can provide. These cameras tend to have a built in T2 thread[2] as well as being supplied with a nosepiece to attach it to the telescope or even have a flange that fits directly into the focuser tube.

[1] Much older cameras may use an RS232 interface but these are quite scarce now.

[2] A T2 screw thread is used as the basis of a universal camera adapter system.

Fitting Your Camera

The camera needs to be fitted securely using whichever method is suitable for your particular setup and it needs to be free from any movement. This is most important as even the slightest movement will be enough to spoil an image.

Dealing with Cables

Trailing cables such as those for USB control of a camera and other devices and power cables need to be secured so that they will not get caught or drag on anything which might cause tracking problems or damage. This is really important to improve reliability and help you get consistently good results and it is worth getting right. It is very helpful, if you are intending to use your telescope mainly for astrophotography, to equip it for a very fast setup and breakdown at the end of a session as this will make it easier and more enjoyable to use. It will also ensure that you can make more use of any clear skies by reducing the setup time. The way to do this is to permanently fit the necessary wiring to the telescope optical tube. This doesn't mean that you have to do any drilling or make any permanent changes to the telescope tube thus invalidating any warranties on new equipment or affecting the resale value.

A simple way to attach the wiring is to use tie wraps and self-adhesive tie wrap pads which are removable see Figs. 7.4 and 7.5. This will hold wiring securely and neatly in place. Self-adhesive Velcro tape may be used for securing control boxes, such as in projects 1 and 2 and can also be used to attach the primary mirror fan in project 3. This tape is very secure and also removable which allows for repositioning of items if you need to change your telescope configuration for different types of imaging and equipment being used. The aim in mounting the electrical wiring and control boxes on the telescope tube is to make it much faster and easier to set up without the necessity to search for the correct cables before beginning the imaging session. It is also possible to reduce the amount of wiring going from the computer to the optical tube and telescope mount by using a USB hub on the optical tube and making the power distribution box. (Shown in project 2 at the end of the book). This will give the same benefit of reduced cables to the 12v power system as the hub does for the USB system. Another benefit of this approach is that it ensures that you have all the wiring needed to image successfully and avoids traveling to a remote imaging site only to

Fig 7.4 A self-adhesive pad and plastic tie wrap used to secure cables to a telescope tube without the need for any cutting or drilling

Fig. 7.5 Large cable bundle secured by the use of Pads and tie wraps

find you have forgotten vital cables. It is advisable however, to carry a few spare cables with you so you don't get caught out by cables that may become damaged in transit.

Using this method on my telescope I have reduced the cables going to the telescope tube from five USB cables and six 12volt cables to two USB cables and one 12v cable. This makes it very easy to setup and reduces the chances of cables snagging and dragging, which can affect its ability to track accurately.

As can be seen in Fig. 7.5 even large bundles of cables can be secured neatly using this method and they can easily be altered which may be needed if you add or remove any equipment. Securing cables like this might seem unnecessary at first and probably is until, you decide you would like to do more and need to add extra bits of equipment and then you are faced with a lot of loose wiring which can cause endless problems. Once the camera has been fitted securely and the wiring connected, the camera can be started, following any specific procedure given by the manufacturer. Manufacturer's instructions should be followed, particularly in the case of a cooled camera which may need gradual cooling to avoid damage to the imaging chip due to thermal shock.[3]

Achieving An Initial Focus

Start the software you are using to control the camera or connect the cable release, if that is what you intend to use. Once that has been done take a test image to make sure everything is working. If you have already lined up your finder telescope, use it to help point your main telescope at a distant object such as trees or a T.V. aerial. Now set the DSLR to live mode, if available, or the astronomy camera to its focus mode and start to focus the image that you can see on your camera or computer screen. You will immediately see the large amount of vibration that touching the telescope causes; this does make focusing a little difficult. The best way to achieve a good focus is to get close to a focus, let the image settle down, then focus again and repeat this procedure. When the focus is as sharp as possible use either the live view zoom or the magnify function, in the software you are using, to enable you to get to an even sharper focus within the capability of your equipment.

3 Thermal shock in this case is physical damage caused as a result of cooling or heating an imaging chip too rapidly. Most modern camera drivers automatically implement a stepped approach to the cooling to avoid thermal shock, if you are in doubt check with the manufacturer.

At this point it is a good idea if your focuser has a numerical scale to make a Make a note of this position for future reference via the numerical scale on the focuser (if there is one), make a pencil mark on the draw tube to indicate where it should be or put a small sticker on it making sure that it won't interfere with its movement or operation. This will give you a starting point when you are trying to achieve a sharp focus on subsequent nights. It is also worth noting, that if you remove and replace your camera for any reason or if you fit a filter you will probably need to refocus.

So now the telescope should be set up with the camera fitted and focused as close as possible without being under the stars.

Planning Your Imaging Session

Choose the objects to be imaged carefully. A good place to start is with the list of objects mentioned in Chap. 6. Messier objects are a great place to start and have helped many amateurs become proficient at visual observing as well as imaging. These objects are suitable because many of them are bright and easy to find and you can use the objects that are more difficult to find to develop your skills as you become more proficient.

Make sure that your chosen objects are visible from your location at the time of year you are going to image them. This may be done with the use of a good star chart and planisphere. You can also use a planetarium program, of which there are many freely available.

The following Computer based Planetariums are recommended as they all offer really good charting facilities along with telescope control should you need it. With the exception of The Sky X, they are all free to use.

Stellarium	https://stellarium.org/
Cartes du Ciel	https://www.ap-i.net/skychart/en/start
HNSKY	http://www.hnsky.org/software.htm
C2A	http://www.astrosurf.com/c2a/english/
The Sky X	http://www.bisque.com/sc/pages/TheSkyX-Professional-Edition.aspx

Now that you have chosen a list of prospective targets to image you need to check if they are suitable for the telescope/camera combination that you are using. This is to ensure that the objects you wish to image are not so small that they will not show any detail, and also not be too large to fit in the field of view available with your camera telescope combination. To do this you can use a FOV app such as the one by Blackwater Skies mentioned in Chap. 4, Fig. 4.18.

Have all Your Equipment Ready in Advance

Before you begin, check that you have all equipment ready and accessible. By now, you will start to be aware of all the equipment that you need in order to setup your telescope and use it successfully.

Make your own check lists, they will save you wasting time looking for things that you forgotten.

- **Telescope**
- **Tripod and accessory tray**
- **Mount and power cable**
- **Handset and its cable**
- **Correct counter balance Weights**
- **Power supply either battery or mains adapter and suitably long extension cable.**
- **Ground fault circuit interrupter** (called RCD in the UK). These can be built into the mains distribution box, integrated into the power outlet socket or can be a separate plugin device. If you are using mains power these can be a life saver in the event of a fault as you will likely be standing on damp grass or ground with live equipment which depending on the time of year will be prone to gathering dew and becoming wet itself.
- **Low power eyepiece** preferably with cross wires, a medium power eyepiece can also be helpful.
- **A suitable camera, CMOS CCD or DSLR Camera** As previously mentioned, this needs to be a camera suitable for astrophotography and you will need an adapter to connect it to the telescope.
- **Power cable for camera or fully charged batteries**
- **Cable release** or if your mount has a **snap port** which is an intervalometer built into the telescope mount you will need a camera specific cable.
- **A coma corrector or field flattener;** these may be needed to reduce the coma effect seen at the edge of an image. Consult your telescope manufacturer's advice. See Chap. 4, Fig. 4.10.
- **Filters;** you may need to use a light pollution filter depending on your local sky conditions.
- **A red torch** will allow you to see and avoid fumbling in the dark and won't spoil your eyes' dark adaption more than necessary.
- **Planisphere;** this will help you to orientate yourself in the sky.
- **Star charts;** these will help you check the alignment stars are visible at your location; they may also be used for star hopping.
- **Small step ladders** may be needed in order to reach the eyepiece if you are using a large telescope system, especially as the eyepiece of Newtonian

reflectors on German equatorial mounts are sometimes in an awkward position. Be cautious using step ladders, do not exceed your safe reach; move the ladders or choose another target and be aware that the legs might sink in grass unexpectedly.
- **Old towel;** great for wiping down damp equipment at the end of a session.
- **Warm clothing;** this is important, as you are likely to be standing or sitting still for extended periods of time and the cold will creep up on you unless you are suitably equipped with warm clothes. A good investment is a pair of USB heated insoles which slip inside shoes.

Capturing Images with a DSLR and Cable Release

- Slew the telescope to a bright star near the object to be imaged and then use the finder telescope to ensure that it is centered in the main camera field of view. This will allow you to place the camera's field of view more easily.
- Set your camera ISO speed, a good starting point is ISO 800 and the mode dial is set to manual.
- Set the camera into live view mode and using live view along with the display zoom function, locate the bright star.
- Use the telescope focuser to ensure that the star is as sharply focused as possible.
- Using a Bahtinov[4] mask can be helpful to achieve a sharp focus.
- Once a sharp focus has been achieved, slew your telescope to your intended target and take a test image to check that you have your target in the field of view.
- Make test exposures using different exposure settings until you have the peak of the camera histogram located in the first 1/3 of the graph.
- If your camera has a mirror lock function, set it so that it is locked in the up position.
- Set the cable release to the exposure time and number of images that you require. Include a short delay of about 2–3 s between exposures to allow any vibrations from the shutter and mirror to die down.
- Take your images.

4 See Chap. 4, Fig. 4.19

Capturing Images with Nebulosity

As well as being used for processing images, Nebulosity is capable of controlling many astronomical cameras and also DSLRs' to automate the capturing of images; the dialogue panel for this is seen on the right hand side of the user interface screen see Fig. 7.6.

Refer to the full documentation that comes with Nebulosity, as any software updates may change its method of operation, and only a broad outline of instructions are provided within this book which are applicable at the time of writing.

It is within this panel that you can select your model of camera, set the duration and number of exposures to take and any delay between exposures. You can also use a preview mode to take a preview image without saving it;

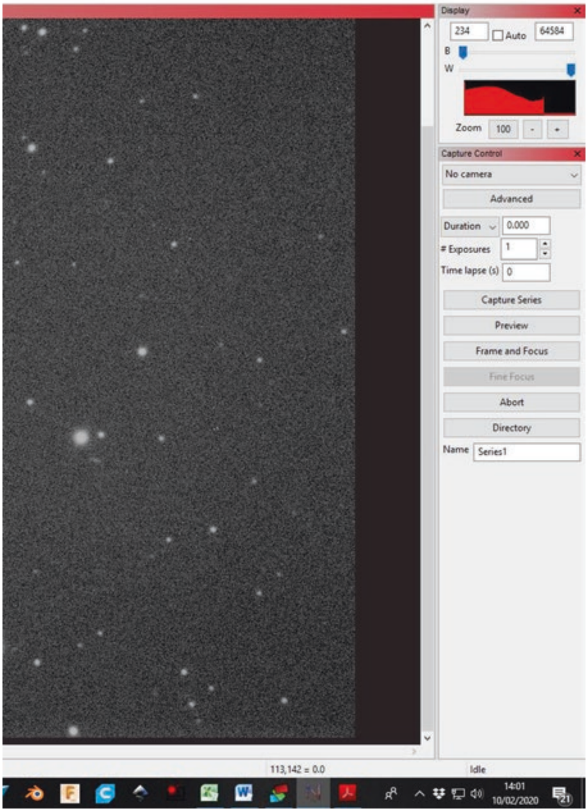

Fig. 7.6 Nebulosity Camera Settings. (Screenshot permission of Stark-Labs)

this is useful to check framing. There is also a frame and focus mode which is helpful in achieving sharp images. The focus mode also has a fine focus function which gives a magnified view. You may also define the directory and assign a file name under which the images are saved. This is useful in providing a way of organizing images as they are produced by object type, date or whatever method meets your needs at the time.

Selecting Your Camera

Once you have opened Nebulosity, you need to select your camera. This is done by pressing the "No camera dropdown box" and then choosing the appropriate camera from the drop down list. If your camera model isn't in the list you may have to select ASCOM from the list and then select it from the ASCOM chooser box. From the camera selection panel, you should also select the tick box above the histogram which will cause Nebulosity to perform an automatic stretch on the images displayed, and this will make them much easier to see and evaluate. This stretch is only performed for the screen display and does not affect the actual data in the images saved.

Fine Focusing Your Camera

- Once the camera has been selected, you can check the focus of your camera by slewing your telescope to a bright star using the list of stars in the hand controller. Center the star in the field of view of the camera which should be almost be in focus, if you have followed the earlier instructions. You may need to use the finder telescope if necessary to help centering the chosen star.
- Set the exposure time to around 1–2 s, (the duration isn't really important as long as you can see the star) and you don't have to wait too long to see the difference between images as you are altering the focus.
- Press the frame and focus button to see a "live" constantly updating image from the camera.
- Pressing abort will now allow you to access the fine focus window.
- Pressing the fine focus button will allow you to place the cursor over a star and clicking on it will display the fine focus window.
- Undo the focus lock and adjust the focuser to get a sharp image of the star. You will notice, in the fine focus window that to the right of the updating star image there is a graph showing the star profile. The aim here is to get the peak of the profile to be as sharp and narrow as possible.

You may use a Bahtinov mask if you prefer which will also ensure you achieve a sharp focus.

Taking Your First Image

- To take your first image of an object you need to slew the telescope to it and check it's in the field of view by taking a brief image. Hopefully if you have chosen a bright object you should either be able to see it in the image or using your star charts be able to look at the star patterns in the field of view and recognize that you are pointing at the right area of sky. Understanding where the constellations are is helpful as you will know if the telescope is roughly pointing in the right direction.
- Assuming all went well in the first bullet above, you can now set the exposure time and look at the histogram to ensure that the peak is within the first 1/3 of the graph and adjust the exposure time if required.
- You may now set the number of exposures that you wish to take in the camera control panel of Nebulosity.
- To take the series of images you need, press the capture series button.

At this point, you have done a very basic setup of the telescope and camera, but in doing so have gained vital experience. For your first full imaging session you will learn how to set the telescope up more accurately, so that you can obtain the best images possible at this stage.

First Full Imaging Session

Now it is simply a case of building on what you have already done. I make no apologies for repeating setup details as it is so important that it becomes a habit and if carried out the same way each time will become easier to remember and quicker to complete. It will also help you avoid missing steps which will would require correction later and may result in missed imaging time while problem solving. As I have suggested in the last chapter, making a check list is an invaluable tool to use while you are getting started.

Setting Up the Telescope

Next, you are going to set the telescope up so that images can be captured. Start off the same way as you did for the first night; this is followed by a few questions that are designed to help you with any issues you might have encountered.

Cooling Time Required

Please note that your telescope (especially if it's kept in a house, garage or shed) will need time for the optics to reach the ambient temperature. If you use it before it has had sufficient time to acclimatize, the image quality will not be at its optimum. This isn't a fault and won't cause any damage to your telescope it just means that you won't get the best views through it that you could until its temperature has equalized with its surrounding environment.

Depending on the size of your telescope lens or mirror it might take from 30 min to a few hours to teach ambient temperature. If you can't allow the time because the sky has suddenly cleared or due to other factors, just use it anyway. If you are using it during this cooling time you may notice the focus changing, this is perfectly natural and you will need to be aware of it and refocus as necessary.

Setting Up

Put your telescope on a firm and level surface, orientating the tripod so that the polar axis is pointing to the north. If using a Sky Watcher telescope look for a tripod leg with an N on it this must be facing the North. Other manufacturers equipment may vary, check the instructions that come with your telescope if in doubt.

Balancing the Telescope

This is done in order to allow the mount system to operate correctly and accurately without straining the motors or mechanism. The following paragraphs explain how this is done.

Declination Balance

To balance the declination axis unlock the right ascension (RA) axis clutch and turn the RA axis so that the counter weight bar is horizontal and lock it.

Now slowly release the declination axis clutch and look for any movement. If there is no movement, try moving the declination axis and see if the telescope stays in any position with the clutch unlocked. If it moves, you may need to move the optical tube either by its mounting rings or by sliding the attaching dovetail where it is clamped by the telescope mount. This should be done until the telescope can be moved into any position and will stay there with the declination clutch unlocked.

Right Ascension Axis

To balance the RA axis unlock its clutch and turn it so that the counter weights are pointing down, then lock its clutch.

Now unlock the declination axis and turn it so that the telescope tube is horizontal and lock its clutch again. Unlock the RA axis gently looking for any movement that suggests the telescope is out of balance; it is also a good idea to move the RA axis into different positions and make sure that it stays where you leave it with the clutches unlocked.

If the telescope is out of balance, you may need to add or reduce the number of counter weights fitted. Once you get close to the balance point, you can slide the weights up or down the counterweight bar to make fine adjustments.

Please note, you will probably need to rebalance the telescope when changing any equipment such as cameras, eyepieces etc.

When you have balanced the telescope, the next step is usually to put the telescope in its home position before proceeding to turn the power on.

Dark Adaption

When observing most astronomical objects it is important to allow your eyes to adapt to the dark. This process takes a while and can be spoilt in a moment by stray light. The actual time taken for eyes to become fully dark adapted is believed to be around 40 min, during which time there are chemical changes in the eye that make it more efficient. So once you have this dark adaption, it is wise to preserve it as much as possible. Using dim red lights and red or Rubylith film over screens is the first step. Some observers use an eye patch on the eye used at the telescope, if they have to briefly move into a more brightly lit area. This is of major importance to visual observers, but not as important if you are taking images, unless you like to use binoculars while the telescope is busy imaging.

Turn Your Telescope Mount On

You will be greeted with the Synscan Version message, press the enter button and you will be given a warning not to look at the sun or use a solar eyepiece filter. This is vitally important as to do so would result in blindness. There are safe ways to do solar observation and photography but it is not in the scope of this book.

Press enter

- You now need to enter Longitude. and Latitude followed by the time zone.
- Enter the Date in the form mm/dd/yyyy.
- Now enter the time from an accurate source in 24 hour format.
- The time you entered will be displayed as confirmation in 12 hour format.
- You will be asked if daylight saving time is in effect, In the UK known as summer time.
- It will then report polar position in the polar scope but it is much easier, as previously mentioned, to use a polar alignment app that gives you a graphical display of where Polaris should be located.

Polar Alignment

You may just use a compass or actually locate Polaris[5] using a chart as there is no need to be too accurate for the sake of this first night. Set the latitude adjustment on the telescope mount to your current latitude. Look through the polar scope and using the altitude and azimuth adjusters, center Polaris on the cross wire in the center of the field of view. When this has been done, use the latitude adjustment knob to move Polaris up to where it intersects the top of the reticule circle that shows the path Polaris travels around in the course of a day.

Please note in the following steps your telescope may move into a weight up position and you must be careful that it is balanced, secure and not liable to fall over. Make sure that your telescope doesn't collide with the tripod legs, or any part of the mount, while you are moving it.

Please note, that on some German equatorial mounts you may need to rotate the RA axis so that the polar scopes view isn't obstructed by the counterweight bar.

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5 Polaris the north pole star.

Rotate the RA axis so that the circle that indicates the position of Polaris is correct for your time and location. This is easily done by referring to a polar alignment app on a smart phone. When this is done you need to use the altitude and azimuth controls again, to move Polaris into the indicated position.

Star Alignment

Carrying out a star alignment is simply the method of aligning the telescope mounts computer model of the sky with the visible stars so that the Goto function can operate accurately.

The handset will now ask if you want to carry out a star alignment next you will be asked which type of alignment you wish to perform possibly a one, two or three-star alignment. The best one to choose if you plan to take images is a three-star alignment as this one is the most accurate and compensates for other issues. It comprises of choosing an alignment star offered by the handset and the telescope slewing to that star. Then center that star in the field of view of the main telescope only using the direction buttons on the handset and then press the enter button to confirm that it is in the center of the field of view. This is where having the finder scope might help, as sometimes the alignment star might not be visible in the main telescope but the much wider field of view offered by the finder scope should make it visible.

This star finding and centering procedure will be repeated with three different stars if that's the alignment type you choose. If done correctly, the stars used for alignment will usually be closer to the center of the telescope field of view as each one is completed.

The star alignment is best done closely following your handset instructions and when completed it will report alignment successful, along with any polar alignment error.

Fit the Camera

Once the camera has been fitted and any cables attached, you will again, need to check the balance of the telescope to ensure that the mount system can work accurately without being under undue strain, which could cause premature wear or damage.

The camera will need to be focused next; this is usually done on a bright star near to the object to be imaged. If using a DSLR turning the ISO up high and using live view can help if your camera supports the facility. You will use the telescope focus knobs to achieve a good focus and will need to leave the telescope to settle down after each adjustment as you will induce vibration when touching it.

If using a dedicated astronomy camera, you will probably be feeding it into a laptop computer and using the manufacturer's software to control it. But the method of focusing it is basically the same.

Once the camera is correctly focused you may slew the telescope to the object to be imaged and take an exposure to make sure that it is in the field of view. If it is not in the field of view, then you need to use a chart to determine where it is pointing and then use the handset to slew it to the target. If all is correct, you may then start to take your images.

If using a DSLR, start by using ISO800 to 1600 and try exposure times of between 30 s and 5 min to determine the sensitivity of your telescope and camera setup. If you need to use filters, they will require longer exposure times depending on the type of filter used.

The telescope is now polar aligned and star aligned and has the camera fitted and focused, and is ready to take some images.

To assist in finding some easy objects to image I have prepared a list in Chap. 6; otherwise you can research using an internet search or some astronomy planning tools, of which there are many. You will no doubt find that you have a particular liking to some types of objects more than others, Galaxies, planetary nebula, Globular clusters, open clusters or emission nebulae.

Most astronomers have very fond memories of their first night with a decent telescope and the impact it makes on them last a lifetime so make the most of yours.

I have two strong memories; the first from the 1970s was managing to get an image on film that showed the Ring Nebula M57 and also its central star. Today, with the equipment available this is a simple task, and the main problem is keeping the exposures short enough not to saturate or burn out the Ring Nebula. In the 1970s, it was simply getting enough exposure to record sufficient light and managing to process the film so that every tiny part of the latent image on the film is made visible. In some attempts, the film was processed in very hot developer bath, and on one occasion the emulsion detached from its transparent base! The second is from 2013, and was my first attempt with modern experiment using a Canon 7D DSLR to see if it was possible pick up the spiral arms in The Whirlpool Galaxy M51. I was delighted when it revealed, spiral arms and the companion galaxy.

What Did You Learn from Your First Imaging Session?

Setting Up the Telescope

- It will have become apparent that it is essential, in order to be efficient, that you need to be methodical in preparing, setting up and operating an imaging telescope. When setting up the telescope, it needs it to be done quickly, but more importantly, correctly.
- There are quite a lot of simple steps to setting up an imaging telescope successfully, so that you can achieve high quality images.
- Being methodical and writing a check list, relevant to your own equipment, will help to avoid missing steps, or even worse, arriving at an imaging site to find out that you have forgotten to pack a vital piece of equipment which might prevent you from imaging at all.
- It makes sense to have a "go kit" this go kit would comprise of all the basic pieces of equipment that are needed to successfully image with your telescope. In addition, it should also contain, for example, collimating equipment used to check and optically align your telescope. Organizing your equipment means that you are always ready to take advantage of a clear night without having to search for lost pieces of equipment.
- It is much harder to set up a telescope system in the dark, especially if you are inexperienced, so where possible, you will need to set it up while there is still enough available daylight. If this is possible, it also has the advantage of giving the equipment time to equalize to the ambient temperature.
- If you are setting up in the dark at a star party, consider other imagers having images ruined by unnecessary stray light and especially visual observers, who would could be dazzled and lose dark adaption.
- You should allow plenty of time to get the equipment set up; the more practiced you are the faster the imaging can start.
- Make a note of any difficulties that you encountered so that you can concentrate on perfecting them in future sessions.

Operating the Telescope and Camera

- Did you make a note of any aspects of using your telescope and camera that you are unsure of or feel you could do better? Now you can address these issues for more confident operation next time and improved quality of images.

- Were you sufficiently familiar with the camera and its functions? Again, now practice and perfect both your knowledge and skills so that you can get the best performance possible out of your camera. This also extends to any software you will be using.
- If you are using a cooled camera, did you remember to set the temperature and turn the cooling on?
- If your software allows, did you use the warming feature to allow the camera to come back up to ambient temperature gently so as not to cause thermal shock to the sensor?

Finding Objects

- Did you manage to locate the target object or objects easily? If you used star hopping to find objects, how easy was it? And, is there anything you can do to make it easier in the future? For example, better charts and a small table to put them on close to the telescope.
- Would it make it easier to find your way around if you had a better knowledge of the night sky? If this is the case use the time while the telescope is taking images to become familiar with the sky.
- If you used the telescope handset to find objects, how successful were you? If you were not successful try to determine why this is the case?
- Do you need to practice using the handset menus and functions so that you can use it quickly and easily? If the answer to this question is yes, devote some time to become more familiar with its functions.
- Was the torch you used suitable or too bright? If it was too bright a couple of layers of a transparent red film such as Rubylith might dim it to a useful level. Many astronomers use a head torch that has a red light as well as a white light which leaves hands free and also directs the light exactly where you are looking.

Your First Images

- Look at your first images with a critical eye; does anything in particular stand out?
- If you used a DSLR, did you remember to use the delay timer or a remote shutter button?
- If you used a DSLR, did you use the mirror lock to avoid vibration from spoiling your images?

- Did you manage to achieve well focused images? If not, try a different method of checking the focus. One of the quickest and easiest methods is to use is a Bahtinov mask which can be homemade or a commercial product see Chap. 4, Fig. 4.19.
- Were the images of a long enough exposure time to show the desired object and some detail or do they need to be longer? You should take into consideration that after stacking and stretching you should see a much more detailed and less noisy image. If the object shows signs of being burnt out in its bright areas, you may need to reduce the exposure time.
- Is the object correctly framed? Or could it be improved by moving its position in the image? Or even by rotating the angle of the camera? Galaxies framed at an angle to the horizontal look much more dynamic and interesting.
- Was the object you imaged a good choice for your telescope and camera combination and field of view? You can check before imaging next time with a FOV app if you didn't use one.
- Check if the stars are round or can you see them leaving trails? This will cause a loss of sharpness and detail in any objects in the image. Trailing stars in images can be caused by many things including poor polar alignment. If you are struggling to reduce trailing, try reducing the individual exposure times to shorten the trailing until you get better at achieving an accurate polar alignment and checking for other causes. Poor tracking which results in star trailing can also be caused by the telescope being out of balance which can overload the telescope mount and cause it to track inaccurately.
- Are the stars a tight round shape right into the corners of the field of view? Or is there coma present? Coma will make stars look like little comets, especially at the edges and corners of the field of view.
- Are there any areas of the field of view where the stars are even slightly out of focus, particularly around the edges? This might suggest that the camera's imaging sensor isn't aligned perpendicular with the telescope optical axis. Some camera manufacturers supply a tilt ring to help correct this if it is a problem.
- Has the image been affected by light pollution resulting in a bright background? Or is there color gradient across the background? Some OSC (One Shot Color) cameras can suffer from color gradients if they use a shared power supply. If you find sky brightness to be a problem try using a light pollution filter to help reduce it. There are many types available including CLS (City Light Suppression Filter), UHC (Ultra High Contrast Filter).

- There are also a new range of modern filters that allow light of 2 or 3 specific wave lengths through in the one filter; these are designed to be used with OSC cameras. If you are considering one of these do plenty of research and ask questions on the forums as they are quite an expensive investment.

By asking yourself questions following an imaging session you can identify your skills, strengths and weaknesses. This will allow you to take appropriate action so that subsequent sessions produce even better results. It is also important to solve one issue at a time, as this means that you are fully aware of the implications of each change you make.

The first images captured are the start of a journey of exploration of the universe. As you gain experience you will steadily get better results and feel more confident to try and capture more challenging objects.

Lastly, and above all, enjoy the images that you are taking, even with all their imperfections. After all it is a marvel that we can achieve these results at all.

Chapter 8

Computer Controlled Imaging Using EQMOD and ASCOM

A computer controlled telescope isn't suitable for everyone, as they can be very complex and require a reasonable level of computer knowledge in order to set up and operate. However, once up and running the benefits are enormous and there are many fellow astrophotographers to lend a helping hand with the setup and running. Help can also be found on internet support forums for the many software packages available and at your local astronomical society.

The main advantage of this type of setup is the amount of software that is available that can help you operate, or even automate almost all the tasks required to complete an imaging session. This can be especially useful if you intend monitoring a particular object or number of objects such as variable stars or galaxies as the task can be completely automated. This can then be easily initiated in between other images you may be taking or at the beginning or end of a session.

How much or how little automation you choose to use is entirely your choice, nevertheless it is advisable to build it up slowly only adding new features one at a time. When using a computer to control your system it can feel like having to learn how to operate it all over again, but the benefits are worth it.

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_8

Adding Features – A Recommended Order

This list is assuming you have your telescope and camera running and are using dew heaters if needed:

- Ascom and Eqmod, to control the telescope which may require an Eqmod adapter.
- Camera control software, to help take the images.
- Planetarium software, to assist you in finding objects and know where you are pointing.
- Autoguiding software and hardware to correct tracking errors.
- Plate solving software, to accurately position the telescope.
- USB filter wheel, to change filters automatically.
- An electronic stepping motor focuser, to automate focusing.

For a list of telescopes that are compatible with EQMOD, see the EQMOD project page at

http://eq-mod.sourceforge.net/reqindex.html

First Steps

I suggest that you first install ASCOM and EQMOD followed by a planetarium program such as Cartes du Ciel as described here; this is all free to use software. When you have mastered operating the telescope under computer control, you can add an image capture program such as APT, which is described here, to control your camera. This is a basic working setup, capable of taking images but will require some practice to use it confidently. The next logical step is to add an auto guider such as PHD2 which will enable you to take much longer exposures without stars trailing. After an auto guider has been installed and used successfully, I would suggest installing a plate solver. This chapter has details on how to install these pieces of software. If you choose to install the suggested software, the result is a very sophisticated system capable of producing beautiful images and some really serious work.

Installing the Software for Computer Control

Within this chapter, there are details on how to install and learn how to use the following:

- ASCOM and EQMOD and how to use a planetarium with the software.
- Image capturing software
- Autoguiding software
- Plate solver software

The Main EQMOD Interface Window

The following is a description of how to install EQMOD and ASCOM which are the basic programs that will give computer control of the telescope system. These are both free pieces of software: you will, however, need to purchase is an EQMOD adapter (Fig. 8.1).

This is the main EQMOD window that you will see when it is running to control your telescope setup. Despite the huge range of control that it gives you over your telescope it is actually quite easy to run when installed and configured.

The following software setup may seem complex, but most of these tasks only need to be carried out once and when configured, the software is quick and easy to use and adds functionality that makes the effort more than worthwhile.

The top left of the EQMOD main interface screen shows:

The **LST** or Local Sidereal Time.
The **RA** or Right Ascension coordinates for the telescope.
The **DEC** or Declination coordinates for the telescope.
The **AZ** or Azimuth Position of the telescope.
The **ALT** or Altitude position of the telescope.
Pier Side This is the side of the pier or mount the telescope is on. This is useful if you are operating it remotely.

Underneath this there is:

STOP button this button, as the name implies stops the telescope slewing and tracking and parks it in that position. This can be used as an emergency stop in the case of collisions with its mount or cable problems.

Slew Controls This section includes slew buttons to move the telescope and speed settings in a drop down box with a range of one to four with four being the fastest slew. A neat function is the pad button at the bottom left of the slew buttons; this brings up a slew pad, and if you place the mouse pointer in this area and press the left or right button the mount will first slew in RA; pressing the middle button on the mount changes control to the DEC axis. A reminder of the button movements is given at the bottom left of

Fig. 8.1 EQMOD main Interface screen. (Screenshot by permission of the EQMOD Project)

the mouse slew pad window. While the pad is active, you can also use your computer keypad buttons to slew. There are also tick boxes to reverse the RA and DEC motion of the mount which may be needed for modified or custom mount systems. Finally there are also 3 buttons which can bring up additional features which have to be installed separately such as:

- **The EQT our function –** the files for this can be found online and some magazines supply them as a download.
- **A mosaic tool –** for helping to take images of objects larger than the field of view of your telescope.
- **A spiral search –** a tool to help with elusive objects.

EQMOD Pop Out Panel

From the basic EQMOD panel there is a pop out panel accessed by pressing the button with a spanner on it (Fig. 8.2).

Alignment and Sync panel – this contains the controls and input boxes for carrying out a star alignment.

Polar alignment routine – this is accessed through the pole star HA button.

Fig. 8.2 EQMOD pop out panel. (Screenshot by permission of EQMOD Project)

A park and unpark panel – in which you can define custom park positions for things like filter and camera changes

Pulse guiding – settings used to setup the parameters that are used with an auto guider that isn't using an ST4 cable.

Auto guider (ST4 Cable) – settings used to control the rate settings when using an auto guider with an ST4 cable.

Other settings panel – this panel allows you to setup sound options and a Goto rate limit.

Gamepad configuration – a gamepad can be set up to control slewing and other functions such as syncing and parking, which can be much easier to use when next to the telescope.

PEC – this is **periodic error correction** and is used to compensate for mechanical errors, mainly between the crown gear in the telescope mount and the worm gear that drives it.

EQMOD Adapter

An EQMOD adapter is basically a cable with a built in controller. In this case, it is built into the USB plug which plugs into a USB port on the computer at one end. The other end plugs into the telescope mount hand controller port, rendering the hand controller redundant (Fig. 8.3).

Fig. 8.3 My DIY EQMOD adapter

This gives the direct connection between the computer and the telescope mount that controls it. Some telescope mounts may require you to plug an EQMOD adapter into an extra port on the handset. It is advisable to check and follow the manufacturer's recommendations for your particular system and the advice on the EQMOD website. Information can be found in the manufacturer's instructions, and also on websites and online forums.

The first step is to get the correct EQMOD adapter for your mount and there are many sources online where they can be obtained at a relatively inexpensive cost, or you can even make your own which saves considerable expense. With the adapter shown, it was simply a case of attaching the correct plug for the mount being used onto the end of the cable. There are also a number of Bluetooth adapters available, but for the sake of simplicity and reliability a wired adapter is described below.

DIY EQMOD Adapter

http://eq-mod.sourceforge.net/eqdirect2.htm

The above link will enable anyone with electronics building experience to build your own EQMOD adapter at a fraction of the cost. Take extreme care when building the adapter as any errors in the build can cause irreparable damage to your expensive telescope mount, or computer equipment and invalidate the warranty.

You have been warned!

The use of EQMOD and the ASCOM device drivers is recommended; the installation is straightforward and is should be carried out referring to the information in this chapter and the documentation on the EQMOD website as this will reflect any changes and new features. In addition to the documentation, there are many YouTube videos produced by independent contributors and in many cases by the actual developers of the software. These videos can be invaluable in helping you to quickly understand and master this very powerful software.

Installing ASCOM and EQMOD

The first step in installing EQMOD is to install the ASCOM initiative software.

ASCOM

ASCOM is a set of drivers that can control many astronomy devices such as telescope mounts, cameras, Filter wheels, focusers etc. It also provides a common communication protocol that enables many different software programs to talk to and control these devices easily. This is done through a file called an ASCOM driver which is written for each device, sometimes by the manufacturer or by other parties.

The combination of EQMOD and ASCOM allows more than one piece of software to communicate with more than one device such as a telescope mount, camera, filter wheel or focuser.

This is useful in the case of the telescope mount where it may be necessary for connection to a planetarium program, a plate solver and an autoguiding program all at the same time.

Most astrophotography electronic devices that are available now are ASCOM compliant[1] and have a downloadable ASCOM driver for use with them. Some are downloaded from the manufacturer's website, and some are available from the ASCOM website or third parties.

Installing ASCOM

ASCOM is downloaded from, the ASCOM website at:

https://ASCOM-standards.org/

- There is a box on the right of the website screen titled Platform and the current version number, under this is a button labeled Download.
- Press the button to download ASCOM and run the downloaded file following the instructions. It will check your computer, which may require other software installing such as runtime libraries which it will install for you.
- You may now close the installation program.
- You will need to install the ASCOM device drivers for all the devices that you wish it to control. At the most basic level, this will simply be the telescope mount.
- Installing the driver is simply a matter of running the downloaded file and following any instructions.

[1] When a device is Ascom compliant it means that it complies to the standards set by the ASCOM developers so the device or its software is suitable for use with ASCOM compatible software.

If you are using windows 7 there are specific instructions from the download page on the ASCOM website underneath the download button. This includes information on enabling the Microsoft .NET Framework 3.5.1. Once the MS NET framework has been enabled installation should then proceed smoothly.

Installing EQMOD

The installation of Eqmod is very simple as it is now distributed as a self-installing file available from the following website.

http://eq-mod.sourceforge.net

After pressing the Downloads button from the top of the main website homepage, press the highlighted words Source Forge on the page you are taken to. This will open a repository of file folders which are all associated with Eqmod. Choose the EQASCOM folder by double clicking it and download the appropriate version, which will in most cases, be the most recent and will have a highlighted green button above the list. This is labeled Download Latest Version see Fig. 8.4

Once downloaded to a location of your choice, you can simply double click on the file for it to start installing automatically. Once this has completed it is ready to start configuring and using.

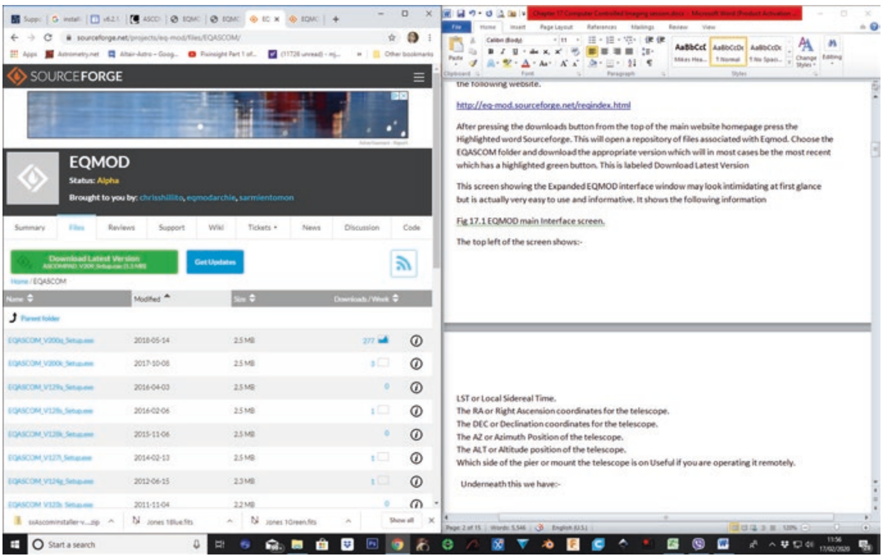

Fig. 8.4 Downloading EQMOD. (Screenshot by permission of Peter Simpson ASCOM)

You will also notice whilst on the main download page that there are other programs that can be added to the basic installation to give it more capabilities; these are programs such as:

EQTour

This enables you to make or use already prepared deep sky tour files that are distributed by other users and some magazines. The magazine tour files often contain the recommended objects for the current month and are now distributed via their websites. The tour files automate the locating of these objects, subject to your telescope being setup correctly.

EQMosaic

This is an addition to EQMOD and helps to define the individual images to take of an object where the object is too large for your telescope field of view, so that they can be stitched together afterwards to produce a seamless image of the entire object. To use EQMosaic you will need to enter the details of your optical system and camera details, so that it can work out the center point and overlap of each of the images to be taken.

ASCOMPAD

This is an add-on that allows the use of a standard game controller such as the type used with a P.C. It can be used to control many of the elements of your telescope system.

EQDIMMER

This allows you to control the brightness of the polar scope illumination on those telescope mounts where it is supported.

Sounds

This directory contains two files; one containing sounds that can be set to give an audible indication of activities carried out by EQMOD; the other is a set of voices that speak the commands such as “slewing to target”, “parking”, etc. This can be a very useful confirmation of what your telescope is doing.

Setting Up EQMOD

EQMOD is usually started by running any of the programs that use an ASCOM driver. This will vary from software to software and will be explained in its documentation.

When EQMOD is run for the first time it will need setting up using the EQASCOM toolbox menu which is installed at the same time as the main program. This brings up the following window (Fig. 8.5).

Start by pressing the Register button, which should report success followed by the driver setup button to see the following window (Fig. 8.6).

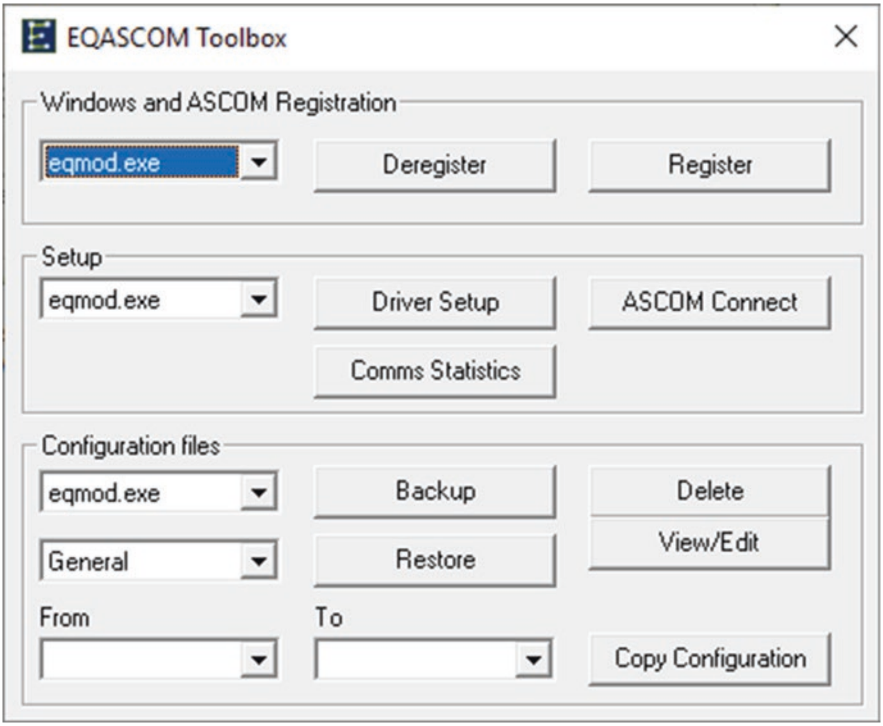

Fig. 8.5 EQMOD Toolbox. (Screenshot by permission of the EQMOD Project)

Fig. 8.6 EQMOD ASCOM setup. (Screenshot by kind permission of the EQMOD Project)

EQMOD ASCOM Setup Dialogue box

This is where you will be entering the main details of how to communicate with the telescope mount and your site location information.

Mount Options

This is where you will start the configuration of the EQASCOM system. The mount options can usually be left at the default settings.

Under the EQMOD port details, enter the port number windows has assigned to the EQMOD adapter. This can be found by opening windows device manager to check the port assignments. There is a button marked with binoculars to help find the port number automatically in the EQMOD setup window. If it doesn't work it can be set up manually instead.

Site Information

This is where you will enter the latitude and longitude for your imaging site as well as the elevation above sea level. These details can be saved along with details of any other sites that you regularly use. Remember to use the save button to store the details for future use. There is also a GPS button which is used to read these details from a GPS unit if you have one.

At this stage, the rest of these settings can be left as default for now as autoguiding or using a gamepad controller is more advanced.

Pressing OK enters these details and closes the dialogue box.

Using EQMOD with Cartes do Ciel Cartes du Ciel

Install Cartes du Ciel according to the instructions given on its website. You will also find details of other deep sky object and star catalogues that may be added.

Start Cartes du Ciel

Once Cartes du Ciel is started press Telescope from the top menu and then press Telescope settings. Choose the Telescope tab and from there, choose the ASCOM radio button as seen in the following picture.

Press Apply then press OK (Fig. 8.7).

From the top menu again choose Telescope but this time, from the drop-down list select Connect Telescope and the following dialogue will be displayed. Note the two red indicators underneath tracking and next to connect signifying that the telescope isn't connected or tracking (Fig. 8.8).

Pressing Select will show the following ASCOM Telescope Chooser Dialogue box (Fig. 8.9).

From this dialogue box choose the correct driver from the drop down box in this case it is selected for a Sky Watcher HEQ5 or EQ6 telescope mount. Next, press the Properties button and choose the correct com port number assigned to the telescope EQMOD adapter. This can be found under Devices and Printers.

Once done, this will drop back to the telescope chooser dialogue box from which you will now press OK.

You will be back at Cartes du Ciel ASCOM telescope interface dialogue box, at the bottom left of this press the Connect button and the red indicator

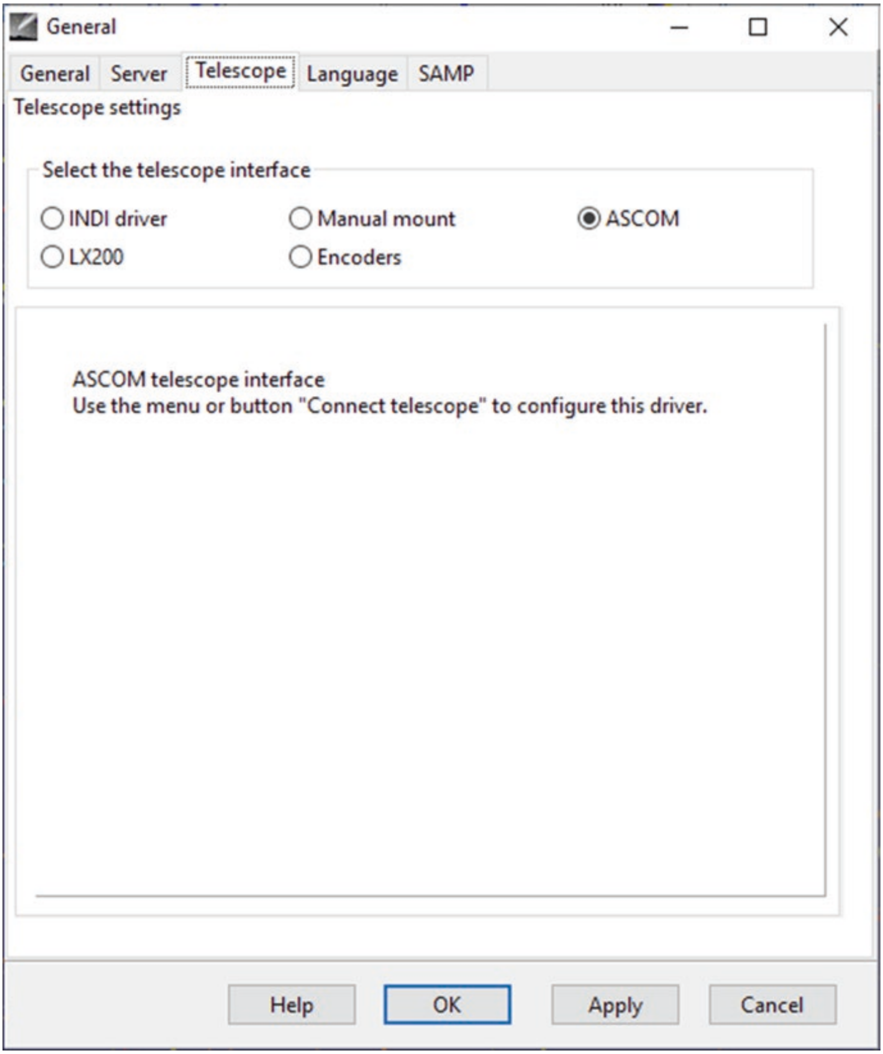

Fig. 8.7 Cartes du Ciel Telescope setup menu. (Screenshot by kind permission of Cartes du Ciel)

box next to it should turn green; then the main EQMOD interface box should be displayed. Press Tracking and the red indicator box next to it should turn green to show that the telescope mount is both connected to EQMOD and tracking.

Press the Hide button to unclutter the screen leaving the telescope connected and tracking. To make using Cartes du Ciel easier, set a field of view indicator rectangle that matches what the camera can see. This is done by

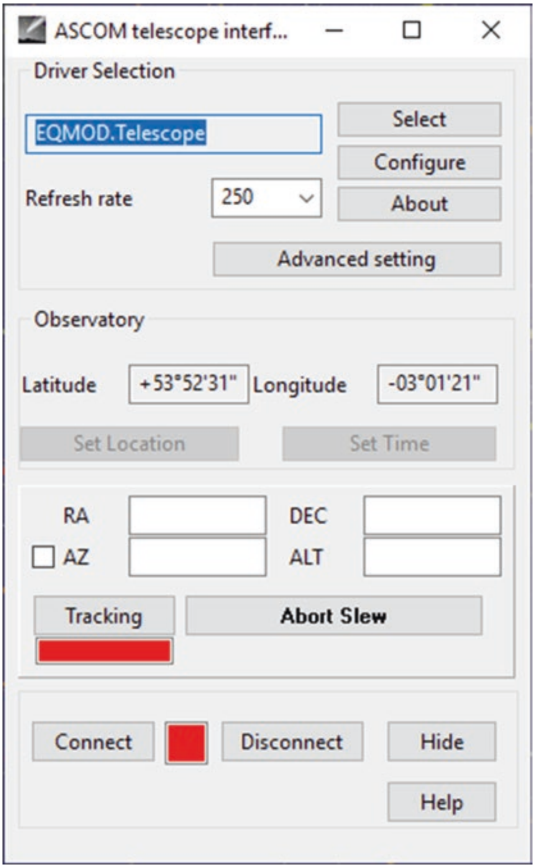

Fig. 8.8 ASCOM Telescope interface menu

going to the Setup Menu and choosing Display and then selecting the last tab at the top which is labeled Finder Rectangle (CCD)

Double clicking in the first of the number fields (The heading is titled "n") brings up a field of view calculator to help you enter the correct figures for your setup.

When you have filled in the required fields on the calculator, pressing Compute will work out the field of view and enter the figures into the table. You will need to work out the rotation value as the field finder rectangle size will be correct when you press Apply followed by OK. The easiest way to work out the rotation value initially is to simply take an image and try different values until a close match is found. The rotational value is entered in the appropriate box in Fig. 8.10. Once this has been done you will now have a rectangle shown on the planetarium display that reflects the size and rota-

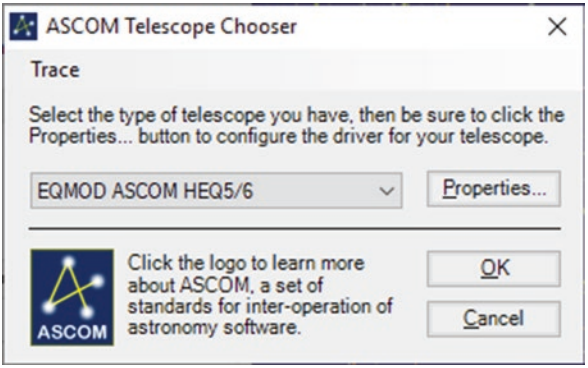

Fig. 8.9 ASCOM Telescope chooser menu. (Screenshot by permission of Peter Simpson ASCOM)

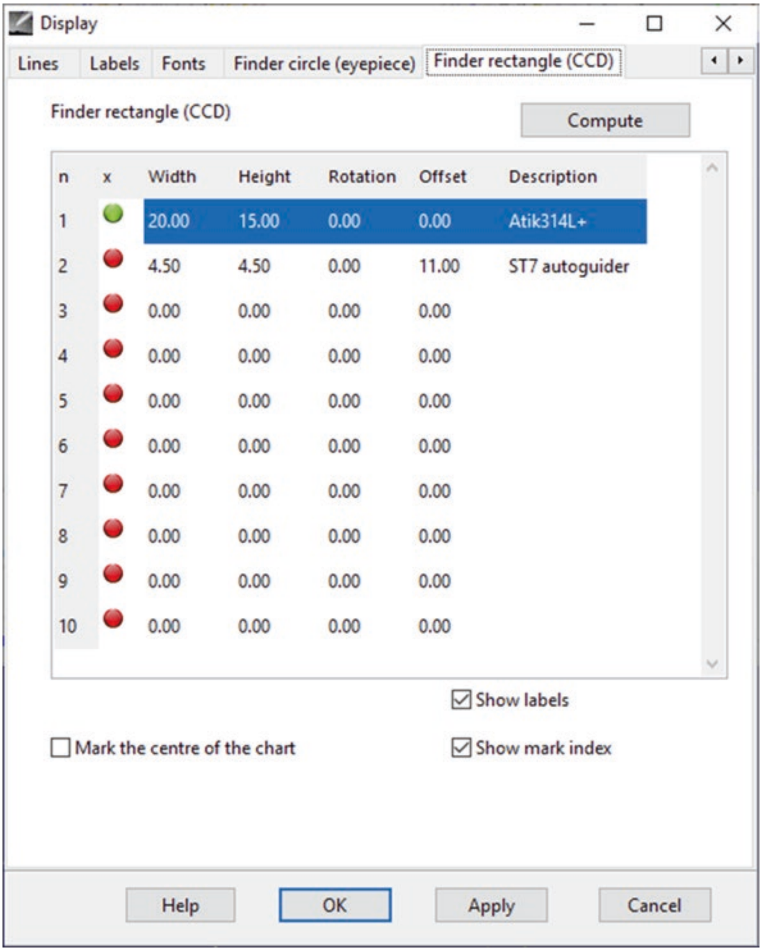

Fig. 8.10 Cartes du Ciel Display menu. (Screenshot permission of Cartes du Ciel)

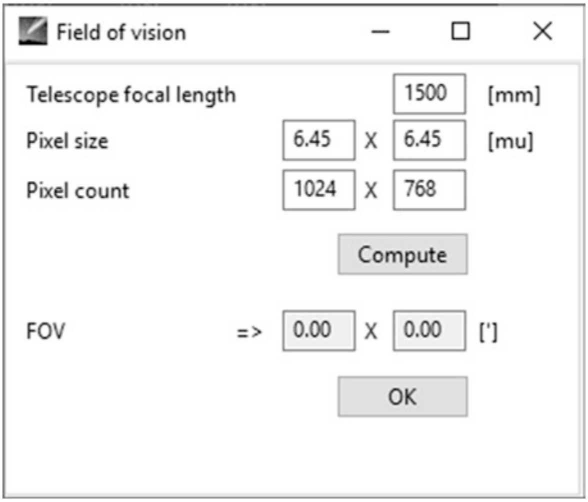

Fig. 8.11 Cartes du Ciel Field of vision calculator. (Screenshot permission of Cartes du Ciel)

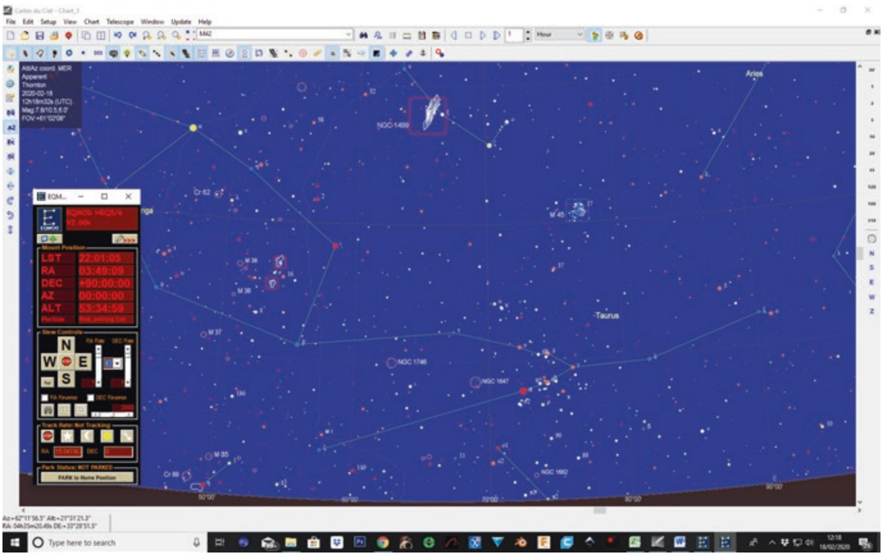

Fig. 8.12 Cartes du Ciel with EQMOD running. (Screenshot permission of Cartes du Ciel)

tion of your camera field of view and can be used to check both the framing of objects and how large they will appear in your images (Fig. 8.11).

Your screen should now look like Fig. 8.12 and show a rectangle indicating the CCD camera field of view and correct orientation.

The EQMOD box will display the RA and DEC position that the telescope is pointing at and a glance at the bottom of the box should show that the telescope is tracking at Sidereal[2] rate.

Polar Aligning the Mount Using EQMOD

- Assuming the telescope is physically setup, leveled, orientated correctly and the current latitude set correctly on the mount, the polar alignment routine in EQMOD is very quick and simple to use.
- To start, press the button with a spanner on the EQMOD window. This will now open a large panel and under Site Information you will see a button with a clock display on it showing the pole star hour angle. The window shown in Fig. 8.13 will be displayed.
- This shows where Polaris should be in your polar scope and has buttons and two drop down menus on the right.
- Using the Alt and Azimuth controls on your telescope mount, center Polaris on the crosswire in the polar scope reticule.
- When this has been done, move Polaris by using the altitude control only, until it intersects the large circle at the 12 o'clock position.
- Rotate the mount in R.A until the smaller circle is centered over Polaris.

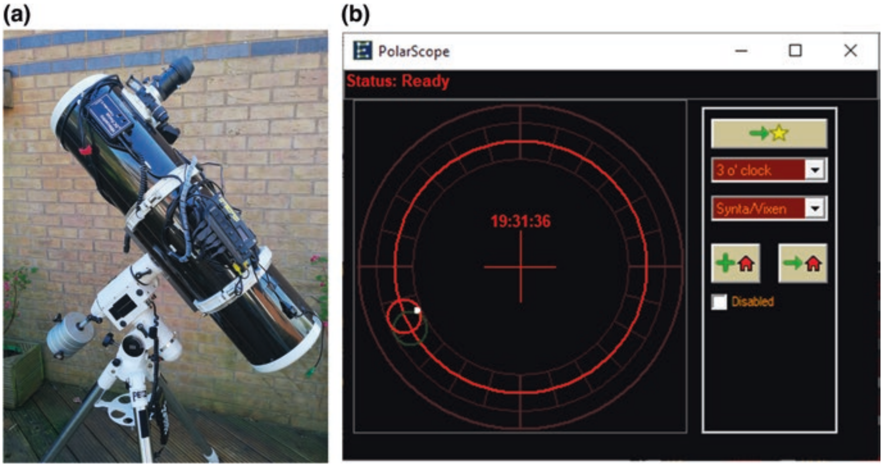

Fig. 8.13 EQMOD Polar Scope Window. (Screenshot permission of The EQMOD Project)

[2] Sidereal rate is the rate at which the stars appear to cross the night sky.

- Make sure that the first drop down menu shows 12 o'clock unless you decide to use one of the other available positions.
- The second drop down menu should show the make or type of telescope mount. In the case of a Sky watcher telescope, it will show Synta/Vixen. This is so that the reticule shown is similar to the one used in your polar scope.
- Press the button that has a green plus sign and a picture of a house on it which defines the polar alignment home position.
- Press the button with a green right pointing arrow and picture of a star on it; you will now get a message warning you that the telescope mount may slew into a counter weight up position this is fine as long as the telescope is properly balanced.
- Being careful to watch for any problems and then press "Yes".
- The mount will now move to a position where the small circle indicates where Polaris should be positioned when looking through the polar scope.
- Using the Altitude and Azimuth controls move Polaris so that it is centered in the small circle.

This completes your polar alignment and is now ready to set an accurate home position.

Setting an Accurate Home Position

The telescope home position is a reference position that is used for the mechanical components and the electronics and handset or computer to synchronize with each other.

On the Sky watcher German equatorial mounts (Gem) the home position is typically with the counter weights pointing down and the optical tube pointing toward the pole as shown here. Check if your mount is different.

The suggested method used to achieve an accurate home position, is basically one described in the Astronomy Shed YouTube series of videos on mount setup and is carried out as follows:

(Please note you may need to refer to a diagram of your mount to identify the necessary components and controls if you haven't already familiarized yourself with them. The mount shown in Fig. 8.14 is a fairly standard Skywatcher HEQ5 Pro German Equatorial mount and is shown parked in its home position).

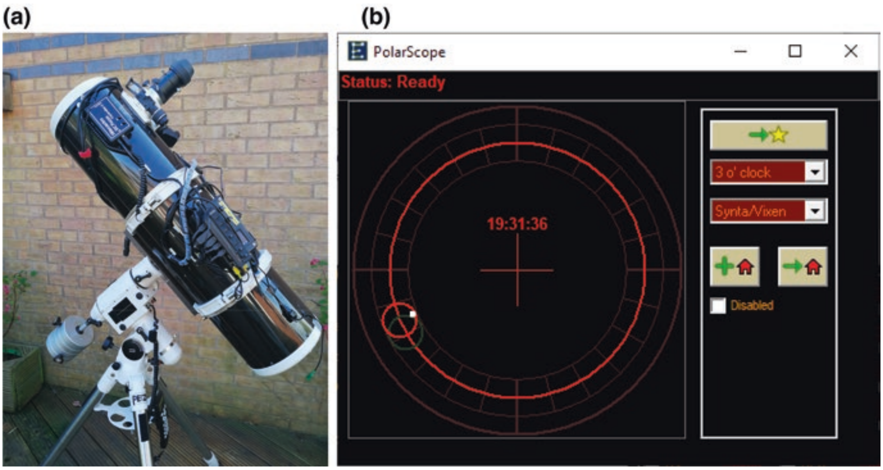

Fig. 8.14 Skywatcher home position

Procedure for Setting an Accurate Home Position

Right Ascension Axis

- Turn the Right Ascension axis so that the counterweight bar is horizontal with the weights pointing to the west and lock its clutch. You can either use a spirit level or electronic level box to check this.
- Unlock and Rotate the R.A. setting circle so its indicator points to 6 hours, and then lock the setting circle.
- Rotate the mount, having unlocked its RA clutch, until the RA index mark is aligned with 12 h on the RA setting circle, and lock the RA axis.

Declination Axis

- Unlock and rotate the declination axis until the optical tube is horizontal and check with your spirit level or electronic level box.
- Unlock and rotate the declination setting circle to show 0 degrees against the index mark and lock it.
- Finally, unlock and rotate the declination axis so that the index mark is aligned with 90° on the Dec setting circle and the telescope tube is pointing up.
- Finally lock the declination axis.

- In EQMOD, make sure that the telescope is set to Not Parked, by pressing the Unpark button if necessary.
- Now go back into the expanded panel of EQMOD and under Park/Unpark make sure the top dropdown item has PARK to Home Position selected. Press the button to the right of this field with two blue arrows forming a circle. This will reset any encoders and sync EQMOD with the telescope park position.

The mount is now in an accurate home position and ready to move on to star alignment

Star Alignment

This is very simple and is carried out as follows:

- Choose a convenient star and select it by clicking on it in Cartes du Ciel. You will see an information box for it on the top left of the chart window. Now you can either press the Slew button from the top menu bar, which by default is on the right hand end of the screen. The other way of accessing the slew command is to right click the mouse and then choose Telescope and press Slew to cursor position.
- The telescope will now slew to the position it thinks the star is in and then start tracking. The position it arrives at may not be the correct one as it is yet to be synchronized to the sky.
- If the star is in the center of the camera field of view, miss the next step otherwise continue to the next step.
- Using your finder telescope if needed and the arrow buttons on the EQMOD window center the star. Next, take an image with the camera to make sure it is now in the camera FOV. There is a drop down field to the right of the direction buttons in EQMOD which allows you to change the slew speed. 1 is the slowest slew speed and 4 is the fastest slew speed.
- Center the star in the FOV using the arrow buttons in EQMOD.
- When you are happy that the star is in the center of the camera field of view press the Sync button from the Cartes du Ciel top menu.
- Carry out this alignment routine for at least 3 stars in different areas of the sky.
- The telescope should point more accurately to the selected stars as you add them to the star alignment model.[3]

[3] The star alignment model is the computers model of where the stars actually are that is used to improve the accuracy of the Goto system.

- The star alignment has now been completed.

This completes the setup of your telescope so you may now select an object that you wish to take an image of using Cartes du Ciel by clicking on it and using the slew command to instruct the telescope to point at it.

Other Planetarium Programs

Cartes du Ciel is used in this example but of course there are many other planetarium programs such as those in the following list that are also free to use and able to control a telescope.

- Stellarium
- Hallo Northern Sky
- C2A

These are all good programs and you just need to find the one that you like and that feels intuitive to use. They are all capable of having expanded catalogues of stars and deep sky objects. Asteroids and Comets details may also be easily updated as new discoveries are made available.

Image Capture Software

There is a good choice of image capture software available and some usually comes bundled with dedicated astronomy cameras; others may need to be downloaded or purchased. The list below details some recommended software.

APT Astrophotography Tools

Very inexpensive commercial product
Authors: Ivo and Maria
Incanus Ltd.

Astrophotography Tools (APT) – this program is very inexpensive and boasts a huge feature set which has all been carefully thought through and is very easy to use. It is capable of controlling most telescopes, cameras, filter wheels, focusers and many DSLRs. It has a database of deep sky objects built in which can be expanded and added to manually. The interface is very well laid out and easy to use. APT links with PHD2 for autoguiding and also directly supports two free plate solvers which will need to be installed separately.

APT has many tools available to help with tasks such as focusing, framing, drift aligning for very accurate polar alignment. It also has a tool for helping you to produce flat frames used in the calibration of astronomical images. A handy feature is that once you have defined a sequence of images to take it stores it for reuse.

Ivo is very friendly and approachable if you have any queries and need support regarding APT

NINA

Free to use open source software

NINA is an astronomical imaging package that has extensive features and enables you to fully automate an imaging session by making a list of objects that are of interest, setting exposure times filters to be used and automatically focusing where the equipment is available. It has a built in sky atlas framing assistant which includes a mosaic tool and will download images from the internet to help with this. NINA has an excellent autofocus routine and the image scheduling contains almost every feature you will need. It is currently being developed with a new advanced sequencer whilst retaining the existing simple one.

Given that this is free to use software the support offered by the developers and other users through their Discord server is exceptional, with responses usually within a few minutes.

Nebulosity

Commercial product
Stark Labs

Nebulosity is an image capture and processing program for your astrophotography images. It supports many cameras natively and also through ASCOM drivers. It has many tools and is also capable of controlling focusers, filter wheels and linking to autoguiding software. It has a very clear uncluttered interface. The image processing tools are very powerful and easy to use.

Astroart

MSB Software
Commercial product

Astroart has been written as a "does it all" package and will control almost any astronomy device; it has full image capture capabilities. Astroart also has a built in star atlas with plate solver and autoguider among many other tools. It is also enables you to carry out astrometry and photometry on your images. This is a very full featured package containing all the functions that you need to run a telescope and can even be programmed to do an automatic supernova hunt.

Using Astro Photography Tools

APT is a very comprehensive and inexpensive piece of software and will enable you to control almost every aspect of taking astronomical images as long as you have the appropriate hardware fitted to your telescope. It links with PHD2 to allow guiding and dithering during programmed imaging runs. APT will also link to plate solvers such as Plate Solve 2 and All Sky Plate Solver, ASPS. It does this through a point craft panel. APT can be used to control a DSLR or CCD/ CMOS Astronomy camera a telescope mount, a USB filter wheel and a USB focuser and if you have one, it will operate a field rotator. APT will also read a temperature sensor or a combined temperature/ humidity sensor. It also has the capabilities to allow you to set the temperature of a cooled camera and display the sensor temperature on a DSLR.

APT allows automated control of most of these devices using imaging plans which are basically, a list of instructions that APT will perform when the plan is run by pressing the start button; it also has basic scripting capabilities.

Installing APT

Installing APT is very easy. Simply download the current APT installation file from the website and double click on it. You then need to select a directory to install it in, or use the default one that is suggested. The installer will also install other components such as Microsoft Visual C++ if needed. When the installation has completed, it will display the latest notes for that release (Fig. 8.15).

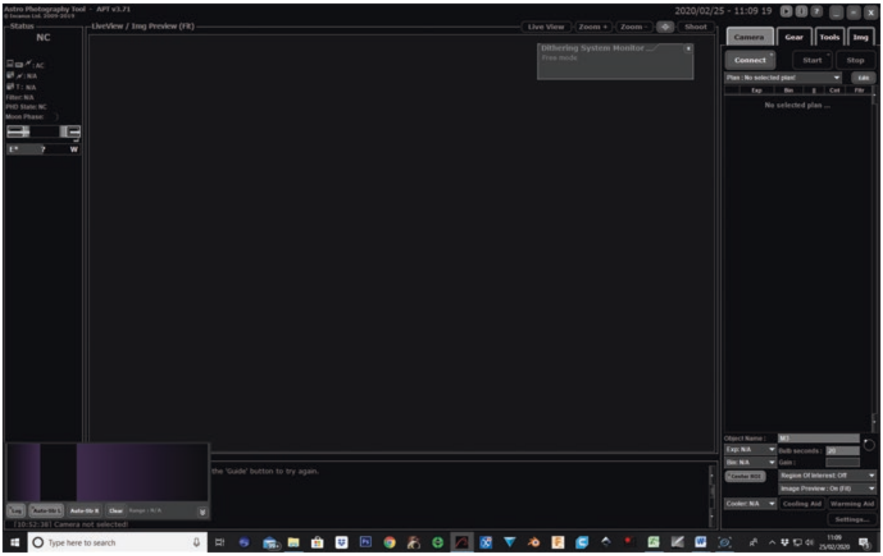

Fig. 8.15 The main APT window. (Screenshot Permission of Astro Photography tools)

In the main APT window there is a lot of information, which is clearly and logically laid out making it intuitive and easy to use. The first step in using APT is to connect the equipment to it. It is less problematic if you adopt a checklist routine regarding starting up all the software you will be using. It is assumed, for this exercise, that you are only connecting your telescope mount and camera along with PHD2 to auto guide your system and a planetarium program.

The following is a suggested order that works well:

Start your planetarium and start EQASCOM by telling it to connect to your telescope.

The EQASCOM window should automatically open and display your telescopes' position.

If you are autoguiding start PHD2 or your choice of auto guide software and connect the camera and mount, making sure its server is running (PHD2 Tools/ Enable Server).

Start APT.

Setting Your Location in APT

Press the tools tab followed by the location tab in the settings window and then either enter your location into the dialogue boxes directly, or select the import coordinates from ASCOM / INDIGO / INDI option.

Connecting Your Camera to APT

Select the camera tab on the top right of the screen and you will see a connect button. Press the keyboard shift key and click the connect button together. This will bring up a menu from which you can choose the type of camera you are connecting, either a Canon or Nikon DSLR or a CCD astronomy camera (Fig. 8.16).

If you have chosen CCD camera you will be presented with the ASCOM chooser window to select its ASCOM driver in the usual way (Fig. 8.17).

This ASCOM camera chooser shows an Atik camera has been selected, press OK and the camera will be connected and the connect button will change to disconnect, for use when you have finished and wish to shut it down.

Cooling the Camera

If you have a cooled camera you may now press the Cooling Aid button at the bottom of the camera tab; this allows you to set the temperature to which the camera will be cooled during your imaging session (Fig. 8.18).

Running down from top to bottom of the camera cooling aid window we see:

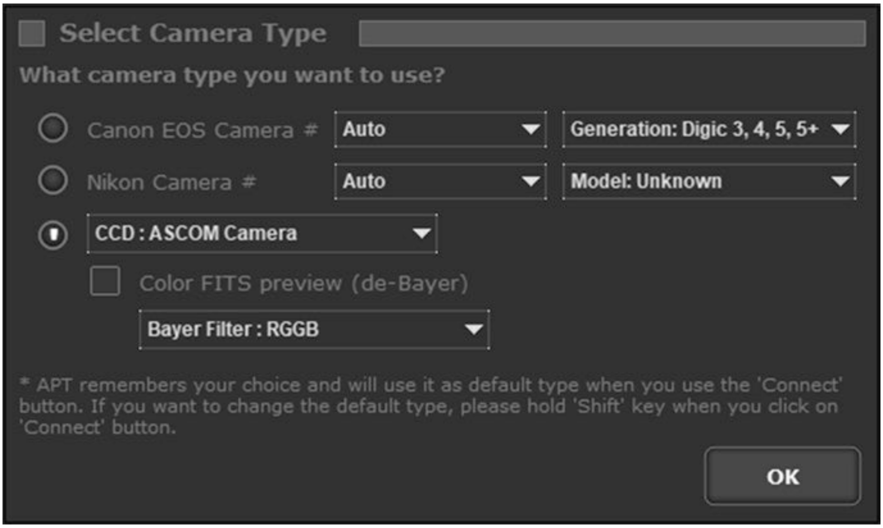

Fig. 8.16 APT Select Camera type window. (Screenshot by Kind Permission of Astro Photography tools)

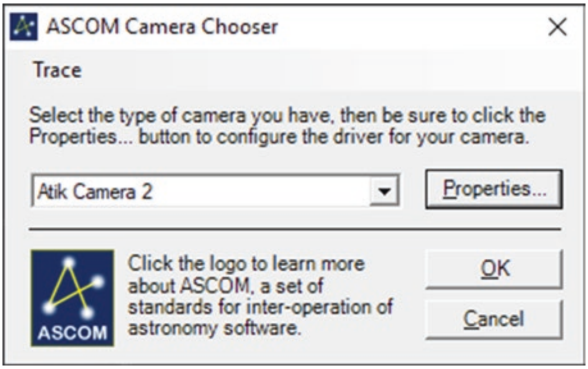

Fig. 8.17 Select camera type ASCOM chooser window. (Screenshot by permission of Peter Simpson ASCOM)

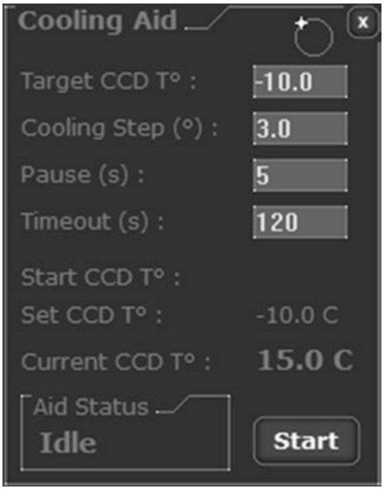

Fig. 8.18 APT Camera Cooling Aid. (Screenshot by Kind Permission of Astro Photography tools)

- **Ringy Thingy**. The "Ringy Thingy" is the little circle with a plus sign intersecting it which is used to change the values in a numerical dialogue box using the mouse. To use it, select the box to be changed and then click and hold down the mouse left button on the "Ringy Thingy". Drag a circle around it you will see the numbers in the dialogue box changing. The closer you are to the "Ringy Thingy" the faster they will change and if you move further away and draw a larger circle the slower and more precise you can change the numbers. This is great for single handed operation in the dark.

- **Target CC T°,** this is where the required temperature for the camera is set. It is tempting to set the maximum cooling that the camera is capable of but this isn't always the best option and can cause dew and icing problems. It is recommended to start with the cooling set to −10 °C and if you want to, progress from there.
- **Cooling Step °C** this is the size of the cooling increments used to reach the temperature chosen.
- **Pause (S)** The length of pause between cooling steps
- **Timeout (S) –** This is the length of time that it will use to try and reach the set temperature; if it fails it will report an error message.
- **Start CCD T° –** This is the temperature of the camera at the start of cooling.
- **Set CCD T° –** This is a confirmation of the temperature you have set for the camera to reach.
- **Current CCD T° –** The current temperature that the CCD has reached.
- **Aid Status – Displays** verbal messages showing its current activity.
- **Start Button –** This button initiates the cooling process. This button changes to a stop button when the cooling process is active.

After setting the above parameters pressing the start button will initiate the cooling process. Once this has been completed the status box shows idle and the box can be moved out of the way or closed leaving the cooling active.

Connecting the Telescope Mount to APT

On the right hand side of the main window are four tabs labeled Camera, Gear, Tools and Img.

Select the Gear tab and in this you will see a Connect Scope button, press this as it is the first time you have selected it will show the telescope ASCOM chooser window. Select your telescope mount from the drop down list and press OK.

You will now see a message in the bottom log panel on the left of the APT main window that shows the time and displays connected to: followed by your telescope type.

The Connect Scope button has now changed to disconnect scope ready for when you are shutting your system down at the end of the imaging session.

If you are using PHD2 to auto guide, make sure that it has the server option ticked under its tools menu; this will enable it to communicate with APT and other software.

Linking Phd2 Auto Guiding Software to APT

From the Gear tab press the Guide button and you will be presented with the following window (Fig. 8.19).

At this point all that needs setting in this window is the top drop down menu item, which needs setting to PHD2 Guiding and near the bottom, make sure there is a downward pointing arrow in control guiding and press

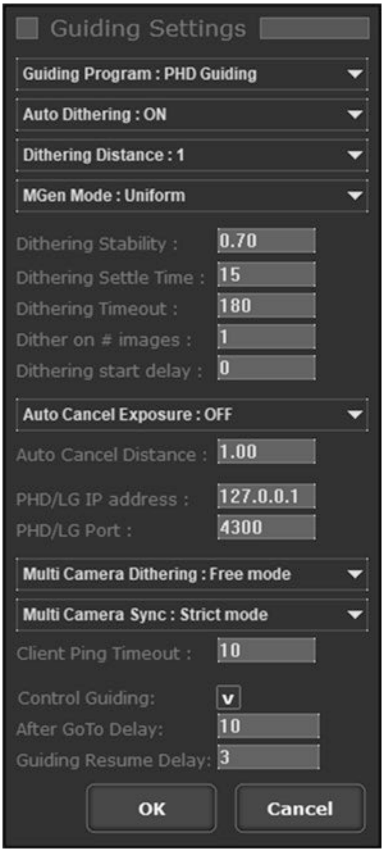

Fig. 8.19 APT Guiding Settings Window. (Screenshot by Kind Permission of Astro Photography tools)

OK. You will see a message in the log window saying connected to PHD guiding and the guide settings window will close.

Setting Up Your Planetarium Software in APT

The planetarium you are using can be set in APT so that the two can communicate. This is done using the APT settings window which can be found under the tools tab by pressing the APT settings button at the top right (Fig. 8.20).

Select the planetarium tab and choose your planetarium from the choices given (Fig. 8.21).

Press the Radio button next to the planetarium that you are using, in this case Cartes du Ciel and press the OK button.

Focusing the Imaging Camera

If you have not already focused your imaging camera, this should be done now. Locate a suitably placed star to focus on that is visible from your location and instruct your telescope to slew to it using APT as follows.

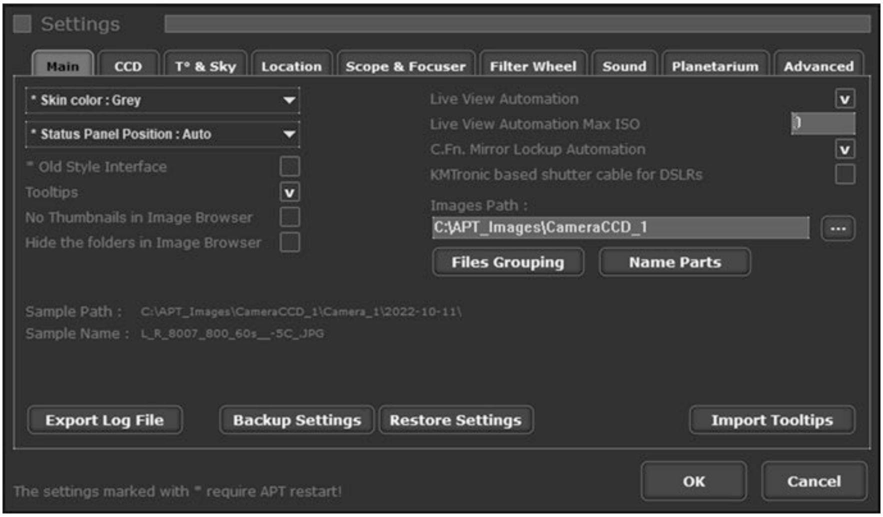

Fig. 8.20 APT Settings window. (Screenshot by Kind Permission of Astro Photography tools)

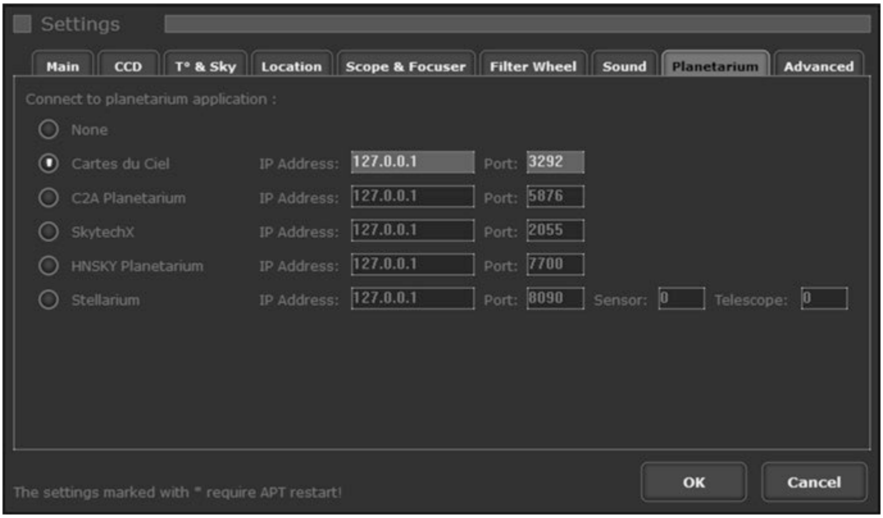

Fig. 8.21 APT Planetarium Settings window. (Screenshot by Kind Permission of Astro Photography tools)

- In APT click the gear tab
- Press the objects button
- Select the stars tab
- Choose the star to focus on and press OK
- This will populate the Goto RA and Goto Dec fields above it.
- Press Goto.
- Watch the telescope carefully for signs of imbalance or cables snagging, the slew can be stopped if necessary at any time by pressing stop from the EQASCOM window.
- The telescope will now slew until it reaches the star and if the autoguider is active it will stop guiding whilst the slew takes place. This will be followed by a settling period and recommencement of guiding.
- From the main APT window choose the Camera tab.
- At the bottom of the Camera tab select object name and enter the name you wish.
- Set the exposure time, usually about 1 s will suffice.
- Press Live View and you will see the imaging camera view updating as each image comes in.
- Focus using either your focus knob on the telescope or a remote focuser if you have one fitted.
- It is essential that you achieve a sharp focus to produce high quality images, so spend time getting it right. A good way of achieving this is by the use of a Bahtinov mask.

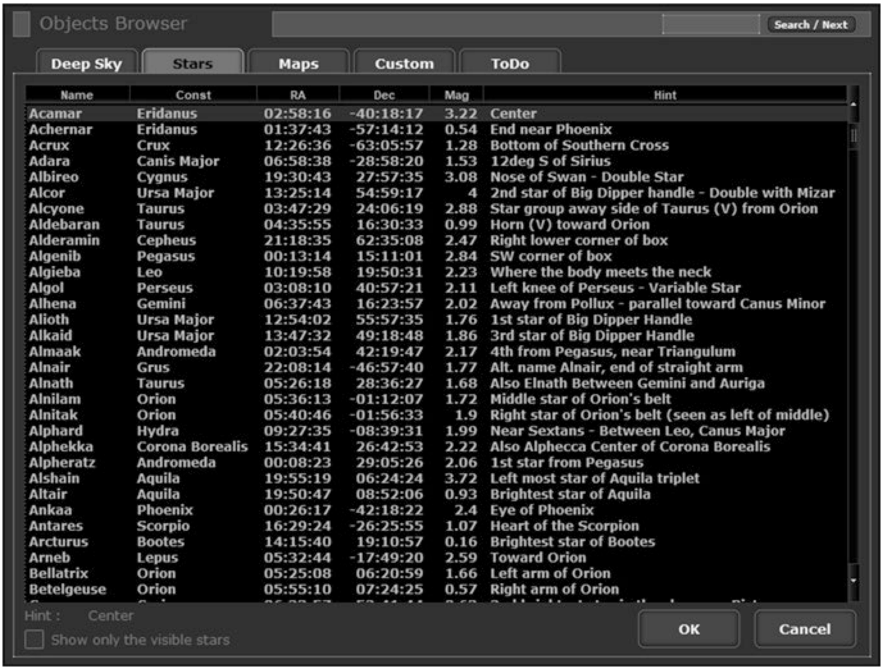

Fig. 8.22 APT Objects browser window. (Screenshot by Kind Permission of Astro Photography tools)

- When you have achieved the best focus possible click Live View again to stop it from taking images and updating the screen (Fig. 8.22).

Choosing Objects to Image

This may be done using some of the objects in Chap. 12 or by doing your own research depending on your level of knowledge and any experience that you may have of the sky.

Taking a Single Image of a Chosen Object

You may select the object in your planetarium program and tell the telescope to slew to it or from the objects browser in APT which is described below:

- Open the object browser from the Gear tab in APT by pressing the Objects+ button, at the bottom of this window click in the show only the visible objects box. There is also a box above it that will show an extended list of objects but for now keep with the standard list.
- The list starts in catalogue order but can be sorted to display the brightest objects first by clicking in the mag heading which denotes magnitude. Just as you did to choose a focus star, select your object to image by highlighting it then pressing OK.
- From the gear tab press the Goto+ button and the telescope will slew to the object that you wish to image. When it arrives at the object, it will automatically start the auto guiding software if you are using it.
- Go back to the Camera tab and at the bottom set the object name and exposure time that you wish to use in seconds and press Shoot and your image will be taken. It is worth noting that your image will be saved in the directory defined in the settings window under the main tab. The image will be displayed on the main APT screen when it has been taken and downloaded from the camera.
- The image may appear very dark and not have much visible, in order to make it more visible and understand the image in more detail there is a histogram window as shown here (Fig. 8.23).

This window shows a standard image histogram and also has buttons which will enable you to do a stretch to the image to make it more visible onscreen without affecting the image data itself. The Auto Str L and Auto Str R buttons bias the stretch to the left most and right most peaks respectively. The Log button presents the data using the log function. If both the Stretch buttons are inactive you may manually stretch the image by pointing at the graph and pressing shift and double click and shift and click to set the

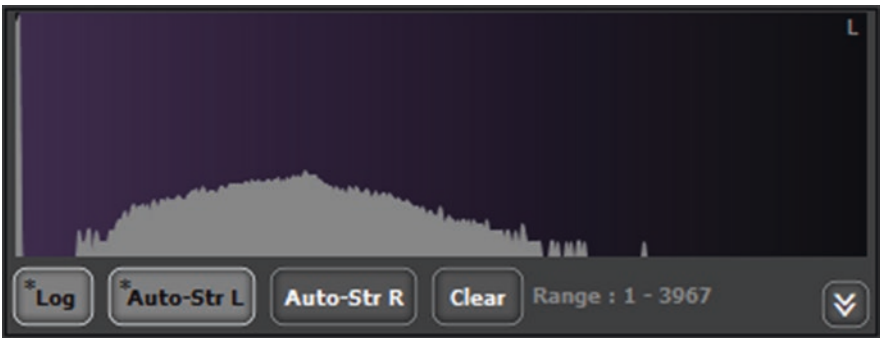

Fig. 8.23 APT Histogram Basic window. (Screenshot by Kind Permission of Astro Photography tools)

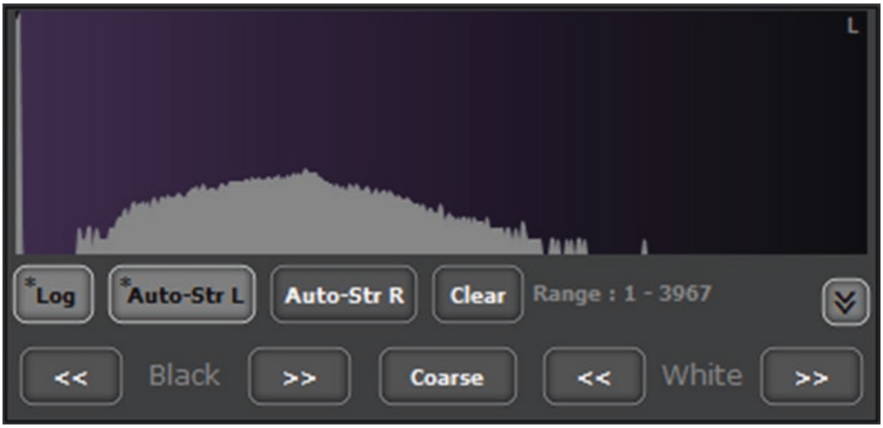

Fig. 8.24 APT Histogram window with extended panel shown. (Screenshot by Kind Permission of Astro Photography tools)

black and white points. You can press Clear to remove any settings that you have made (Fig. 8.24).

The down arrows open more buttons to enable manual control of the black and white set points with a button to set either coarse or fine control between them.

In order to get the best deep sky images multiple images need to be taken and then stacked. The next section will look at how to use the imaging plan feature in APT to take multiple images automatically.

Creating and Using an Imaging Plan with APT

Below is a simple imaging plan that will take 6 exposures of 5 min each and 5 exposures of 1 min each of M1 the Crab Nebula. This plan assumes the use of a CCD camera and not using a filter wheel.

If you are using a DSLR, the dialogue boxes will be slightly different to reflect this, for example, you will have an ISO setting instead of a binning setting but the basic operation is the same.

- From the main APT window make sure that the camera tab is open and press the Edit button to the right of the drop down box labeled Plan: No selected plan! (Fig. 8.25)
- This opens the Plans Editor window.
- In the plans editor window, press the down arrow to open the dropdown box labeled Plan to Edit (Fig. 8.26).

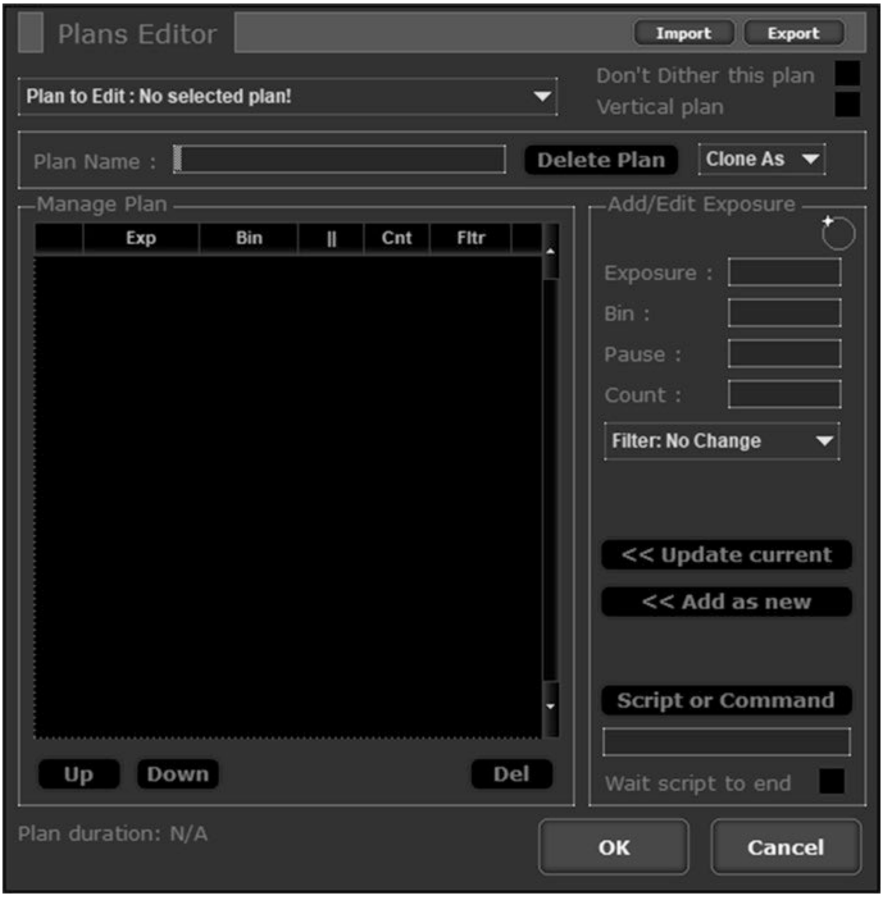

Fig. 8.25 APT Plans Editor Window. (Screenshot by Kind Permission of Astro Photography tools)

- From the dropdown menu select: Add New Light Frames Plan.
- You can now type into the Plan Name Box a suitable name for your imaging plan.
- Under Exposure type the number of seconds for your first set of exposures 300 (5 min)
- Under Bin enter 1 which is a shortcut for 1 × 1 Binning.
- Enter a pause between exposures, which in the case of a CCD camera can be 1 s. If you are using a DSLR you may need longer especially if the mirror hasn't been locked up to prevent vibration.
- Enter 6 as the count which is the number of exposures to be taken.
- For the first set of exposures in this plan that's all we need to enter so press Add as New.

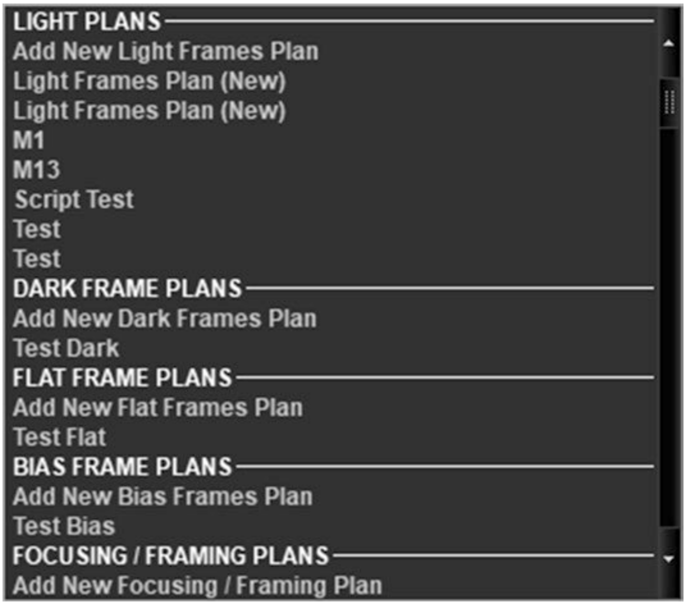

Fig. 8.26 APT Light Plans Dropdown Menu. (Screenshot by Kind Permission of Astro Photography tools)

- You will now see that the details have transferred to the Manage Plan Information Panel (Fig. 8.27).
- The next step is to enter the details for the next set of exposures which will be 5 exposures of 1 min.
- This time all that is needed is to change the exposure duration to 60 s and the number of exposures to 5 and press the Add as New button.
- You will see that in the Manage Plan Panel we now have two rows of details; the first row showing the 5 min exposures and the second the 1 min exposures.
- Press OK and the Plans Editor window will disappear and the information will now be seen at the top right of the main APT window under the Camera tab.
- To start the plan running it just press the Start button again under the Camera tab.
- You may get a warning if you haven't cooled your camera already.
- You will be asked to enter the object name to be used as part of the saved image file name (Fig. 8.28).
- Press OK

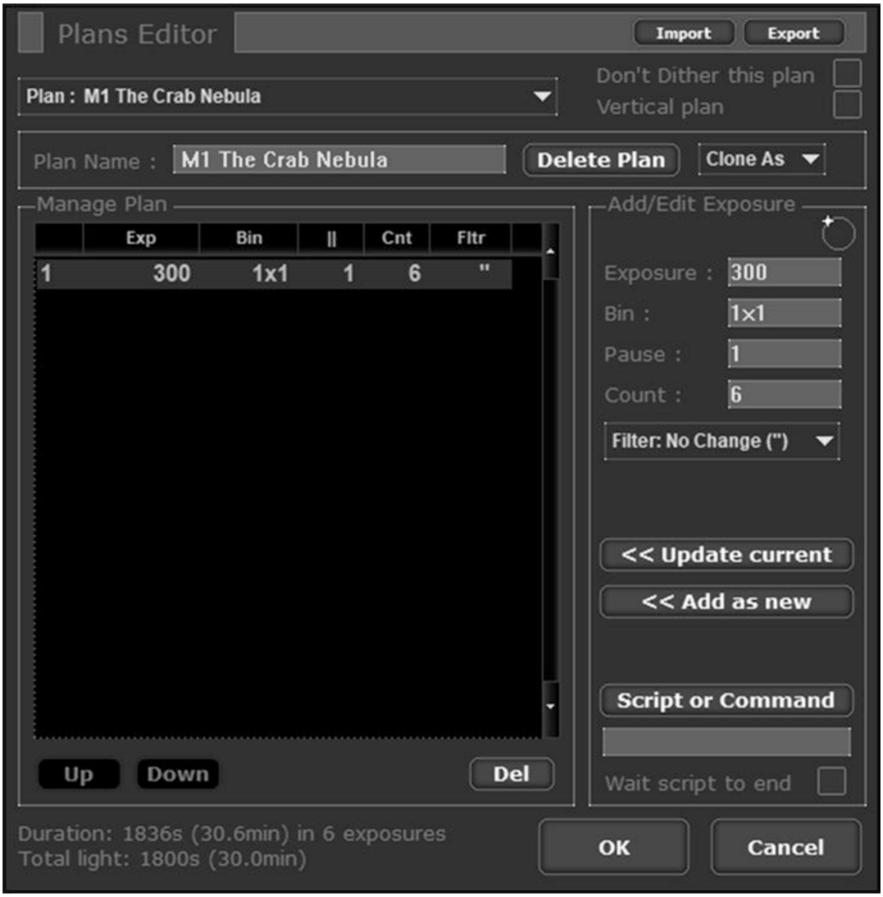

Fig. 8.27 Plans Editor first set of image details entered. (Screenshot by Kind Permission of Astro Photography tools)

Fig. 8.28 APT Object Name window. (Screenshot by Kind Permission of Astro Photography tools)

- If you look at the plan list under the Camera tab you will see the first line is highlighted which shows that part of the plan is currently active. There will also be a message at the bottom left in the Log window that says Started Plan and the plan name.
- When the first set of exposures has been completed, the next line down will be highlighted and the 1 min exposures will commence automatically.
- You can stop the plan at any time by pressing Stop, and if you wish to go back to the plan and edit it, you press the Edit button to bring up the Plan Editor.
- If you wish to change an existing line in the Plan Editor, highlight that line by clicking on it and make the changes in the dialogue boxes required.
- This time press Update Current to apply the changes to the selected line and press OK.

It is suggested that you spend time becoming familiar with setting up and running your telescope using EQMOD and APT before you move on to the next step which is autoguiding .

More Advanced Imaging

Now start to add more features to your system in order to get better results. This starts with using an autoguider which greatly lengthens the length of exposure times that you are capable of using, enabling you to capture fainter objects and reduce the noise present in your individual images. This will be followed by a description of plate solving.

Autoguiding

Auto guiders compensate for inaccuracies in polar alignment and in the telescope mount system itself. Despite this, you should still aim to set the telescope up to the best of your abilities in order to achieve maximum efficiency. The way an auto guider improves the accuracy of the telescope mount is by using a dedicated camera which either looks through a separate guide telescope piggybacked on the main imaging telescope, or as previously mentioned by using an off axis guider. This is basically an optical device that allows the guide camera to look through the edge of the main telescope field of view without obscuring the imaging cameras view.

The autoguider is then locked onto a star in its field of view and a calibration routine is run; this works out the directions and distances the telescope mount moves in order to send accurate corrections.

When the calibration has been carried out, the autoguider switches to guiding mode and the guide star's position is monitored. If any movement is detected, corrections are sent to the telescope mount in order to keep the guide star stationary in the field of view of the camera, which ensures perfect tracking and sharp images.

Auto guiders are available in two main types; those that are standalone units which don't require a computer and those that do.

The easiest way to start auto guiding is to fit a guide scope and camera to your telescope and it doesn't really matter if it's a stand-alone type or software based, the guide telescope and its associated camera need to be fitted to the telescope very securely in order to guide accurately. The guide scope is usually a small refractor and you can even use the finder scope that came with your telescope as long as it is of reasonable quality and is then known as a finder guider.

A finder guider is the easiest to fit as all you need is an adapter ring that allows you to remove the finder telescope eyepiece and replace it with a camera. It is recommended to lock the finder scope adjustments so they are very secure and it doesn't matter if the finder guider isn't aligned with the main telescope view as it will still work.

If you wish to fit an additional telescope to carry out the guiding so that you retain the finder scope, you will need to fit a set of guide scope rings on which to mount it and again, the main requisite is that it is secure and cannot move in relation to the main telescope assembly.

Standalone Auto Guiders

Standalone auto guiders usually comprise of a dedicated camera and a control box and an ST4 type cable that plugs into the guide port on the telescope mount. These are a great to use for simple portable system as well as a permanently mounted setup. They are quite expensive and can be difficult to setup the first time. Once setup however, they are easy to use and can provide very accurate guiding.

Examples of Standalone Auto Guiders

Sky Watcher Synguider

The first generation Synguider can be difficult to focus but once that is achieved it is easy to use and does a good job of guiding. The menus can also be a bit sluggish to respond. Hopefully, this has been sorted out with the Synguider 2.

The Synguider comprises of a camera with a backlit display and a pluggable hand controller with buttons that is used to navigate the menus and a separate battery box which can be used if required.

Celestron NexGuide

This appears to be the same device as the Sky Watcher Synguider rebadged.

Lacerta MGEN-II- Superguider

Made in Hungary, the Lacerta MGEN-II Superguider comprises of the camera itself and a control box with buttons and a backlit display, which can show a live picture of the guide star or guiding graph. It can also display a graph to help you achieve a sharp focus and it supports exposure control of a Canon EOS type camera.

StarAid Revolution

This is a relatively new autoguider and uses AI to autoguide and plate solve. It has a polar alignment tool which is being offered free at the time of writing, but will probably be a paid for add on. It uses Wi-Fi to connect it to a tablet which is the means of setting up and controlling. This auto guider is capable of tracking from 1 to 20 stars simultaneously and claims to send 5 corrections per second which helps with some of the seeing. It is quite expensive as just an autoguider but as it claims to plate solve and help to polar align.

Software Based Autoguiding

Software based auto guiders comprise of a camera of your choice, a guide telescope or off axis guider and a software package. You have the choice of using an ST4 cable plugged into the telescope mount port or a system called pulse guiding which doesn't require the cable to be used.

Many imagers use a finder guider, as previously described, by removing the eyepiece from the finder scope and replacing it with a camera and adapter as shown in Fig. 8.29.

Fig. 8.29 Finder guider Picture

If using an ST4 cable the camera chosen has to support this by having its own ST4 port. In recent years, most astronomical cameras have this as standard but it is as well to check especially if buying second hand equipment. One of the advantages of this type of autoguider setup is that you can use an existing camera such as a planetary camera that might already have available.

Failing that, you may buy an inexpensive camera of which there are many that are suitable. Another advantage is that some of the best autoguiding software is free to use such as PHD2. It takes a little while to setup, but again once done it is very quick and easy to use. The latest versions of the PHD2 guiding software have both a setup wizard and an excellent guiding assistant tool to help you with the initial settings, which makes things much easier. The guiding assistant also enables you to monitor the performance of the telescope mount and can identify problems such as backlash.

Available Autoguiding Software

PHD2

Free to use software available for Windows and Mac OS (Fig. 8.30).

PHD2, full name "Push Here Dummy 2" is recommended Autoguiding software and is free to use. It also has tools for assisting with polar alignment and comet tracking. This is a very widely used autoguider package with a proven track record.

PHD2 is downloaded from the following website.

https://openphdguiding.org/

Once installed and run, the main window is displayed; it is from here that you will access all the functions needed to use PHD2.

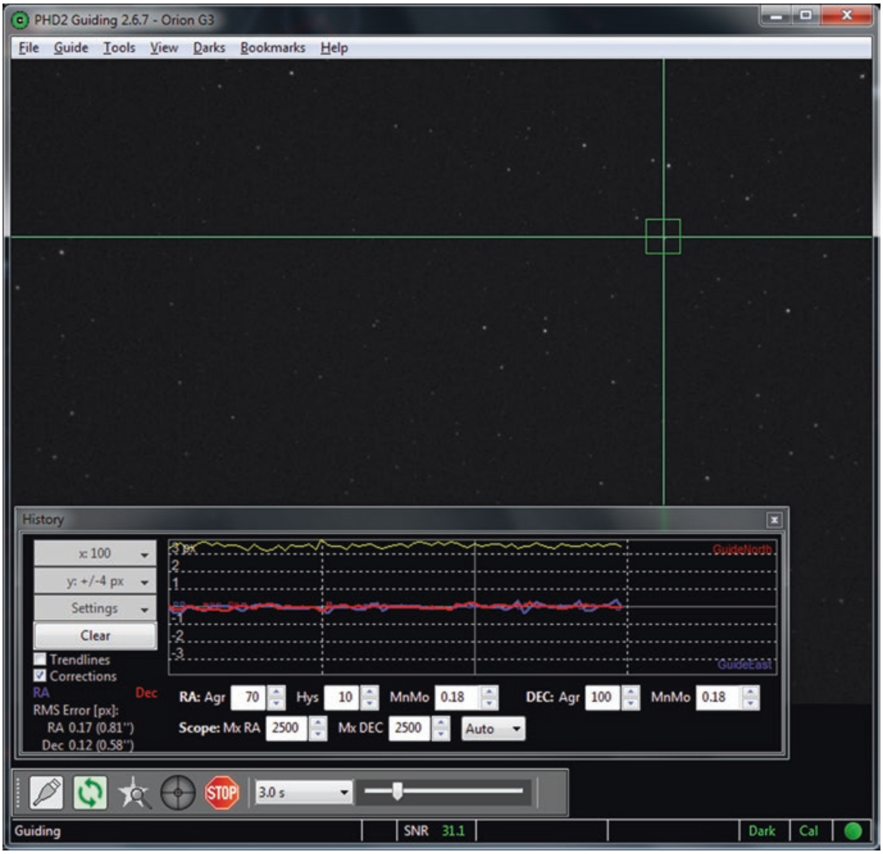

Fig. 8.30 PHD2 Main Window. (Screenshot by kind permission of PHD2)

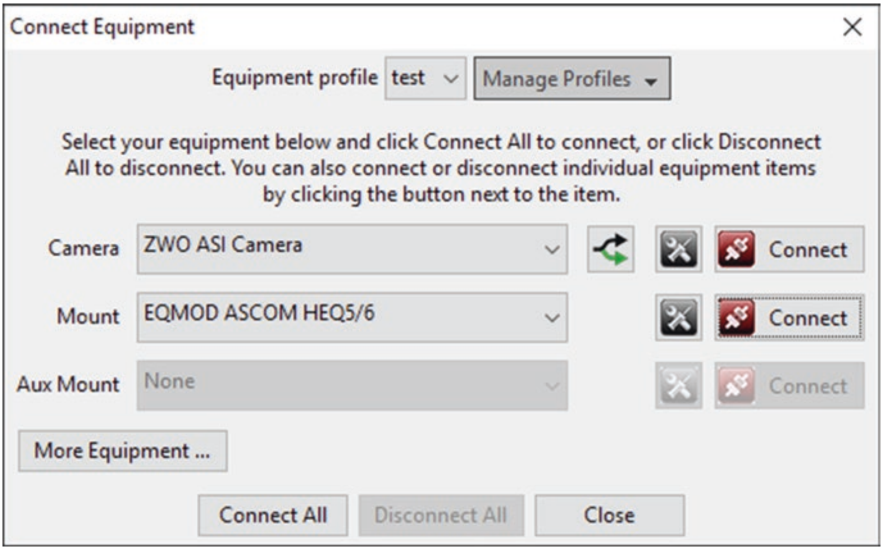

Fig. 8.31 PHD2 Connect Equipment Window. (Screenshot by kind permission of PHD2)

- The first step is to connect your equipment which is basically, the telescope mount and the guide camera. To connect them to PHD2, press the button on the bottom left of the main window which has a picture of a USB plug on it (Fig. 8.31).
- The Connect Equipment window will be displayed as above; this shows a ZWO camera and a Sky Watcher HEQ5 mount chosen. The button to the right of the camera dropdown window with two arrows pointing to the right is so that if you are using two cameras of the same make you can select the one that is to be used as a guide camera. You will also see to the right of the Camera and Mount buttons that there are buttons with a spanner and screwdriver on them; these are to access the camera properties and ASCOM setup respectively. You probably will not need to use them at this point.
- You may either press the connect buttons individually or press the Connect All button at the bottom left of the panel. The Connect buttons will change to Disconnect buttons to be used when shutting the system down or if you need to try and reset the connection in the event of problems with a device (Fig. 8.32).
- If you pressed the connect button the window will shut automatically; if you select the devices individually you will need to press the close button to remove it.

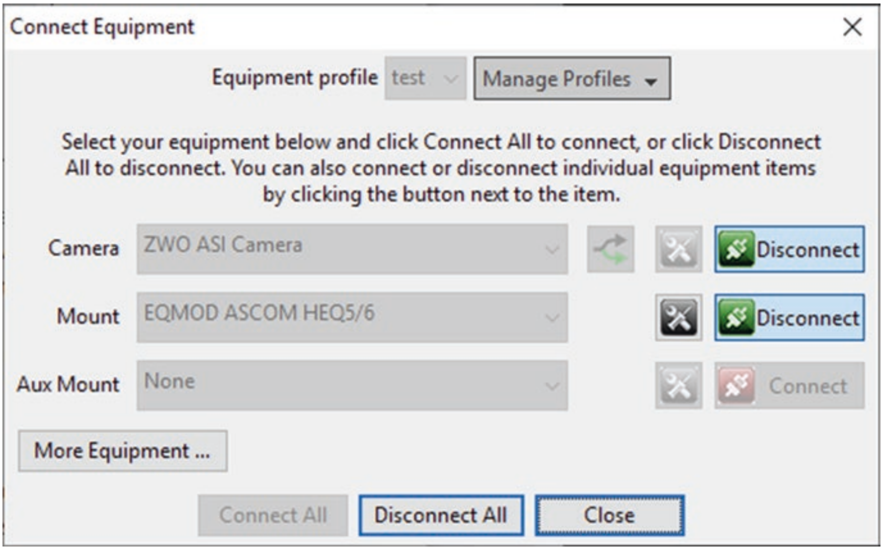

Fig. 8.32 PHD2 Connected Equipment Window. (Screenshot by kind permission of PHD2)

- The next step is to make dark frames for the guide camera which will clean the image up and reduce the chance that PHD2 will try to guide in a hot pixel, which will result in problems.
- From the top of the main PHD2 window press the Darks menu and from the drop down select dark Library which will display the following window (Fig. 8.33).
- Try using the default settings as shown and to do this just press the Start button and you will be instructed to cover the guide scope, so do this and press OK.
- You will see the progress of this procedure at the bottom of the build dark library window and via the progress green bar. Depending on the exposure times that are set, it will take a few minutes to complete.
- When completed, the window will shut and you need to press the Darks menu from the top of the main PHD2 screen again. This time you should see a tick next to the Use Dark Library item. This shows that the darks have been created and will be automatically used when the guide camera is actually guiding or in loop mode.

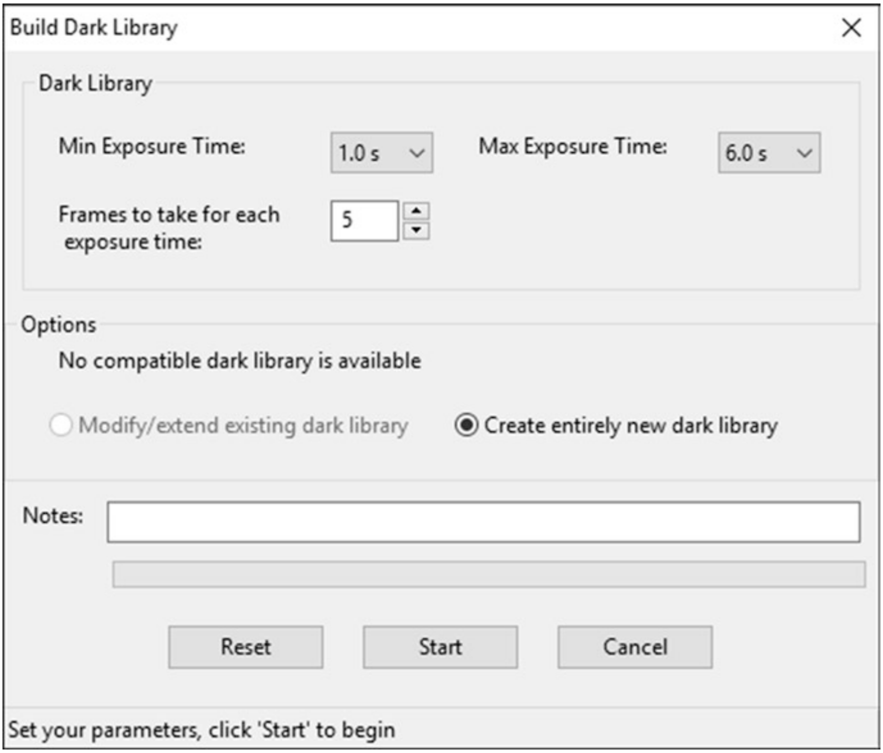

Fig. 8.33 PHD2 Build Dark Library Window. (Screenshot by kind permission of PHD2)

Using PHD2 for the First Time

- Set an appropriate exposure time in the box in the main window, which may be done by typing the duration in seconds or using the drop down arrow to pull up a list of exposure times that can be chosen quickly.

Loop Mode

- To start the camera running in PHD2 , it must be put it into Loop mode by pressing the button with two green arrows pointing at each other in a circle. When loop mode has been selected, the PHD2 window will start updating with the view from the guide camera.
- If the image from the guide camera is too dark, lengthen the exposure or shorten it if it is too bright and over exposed. Typical values will be

between 2 and 4 s. The brightness can also be altered using the slider to darken or lighten the way it is displayed.

Focusing the Guide Scope

- At this point it may become apparent that the guide telescope needs to be focused and that should be done as accurately as possible to ensure good star images, which will help the guiding. This is done by Setting PHD2 into loop mode

Set the Camera Rotation

- Once the guide scope is focused the guide camera needs to be rotated so that the frame is lined up North South East West. This makes interpreting the guide graphs easier when PHD2 is running. An easy way to do this is to set an exposure time long enough to show a star trail if the telescope is slewed. Then while PhD2 is looping, slew the telescope in RA and rotate the camera so that the stars in the guide window show up as horizontal lines. You may need to do this a few times to get it right, but once done it doesn't have to be repeated unless you remove the guide telescope or camera from your setup.

Calibrating PHD2

- You are nearly ready to use PHD2 for guiding but first it will need to be calibrated so that for your telescope and camera combination it knows how far to move the telescope and in what direction, so that it can make accurate corrections.
- To calibrate PHD2 point the telescope near the celestial equator and with it looping use the mouse to click on a star in the PHD2 field of view, or you may press the button at the bottom of the screen which has a star and magnifying glass on it. This is the Auto-select star button. A green box will appear around the selected star.
- Regardless of how you selected the star, press the Green Begin Guiding button that has cross wires on it. If it is the first time you are using PHD2, it will automatically start the calibration procedure.

- As PHD2 is calibrating you will see the guide star moving first in one axis and then in the other axis and finally returning to its start point. At this point the cross wires will turn solid green and the message guiding will appear in the bottom left Log window.

Recalibration

- If you need to re-calibrate at any point you can press the STOP button followed by holding the shift key on your keyboard and then click the green Begin Guiding button this will force a recalibration to occur.

Guiding Assistant

- If you are still having difficulties after carrying out the calibration under the Tools menu there is a guiding assistant which will attempt to fine tune all the settings for your telescope mount including measuring any backlash in the gears and compensating for it.
- Phd2 should now provide you with very accurate guiding that will enable you to take exposures with the correct length of time to capture faint deep sky objects without any star trailing.

Connecting PHD2 to APT

- Connect PHD2 to APT so that they work together is done by starting PHD2 and from its tools menu press Enable Server and a tick will appear next to it as shown (Fig. 8.34).
- In APT open the Gear Tab and press the Guide [D] + button to arrive at the following screen (Fig. 8.35).
- From the first dropdown menu, select the guiding software you are using which in this case is PHD, then near the bottom of the screen click the box labeled Control Guiding which puts a downward pointing arrow in the box next to it.
- The camera should now be connected to your telescope and the Autoguiding software should also be connected.

Spend time getting fully conversant with autoguiding before you move on to the next step which is plate solving.

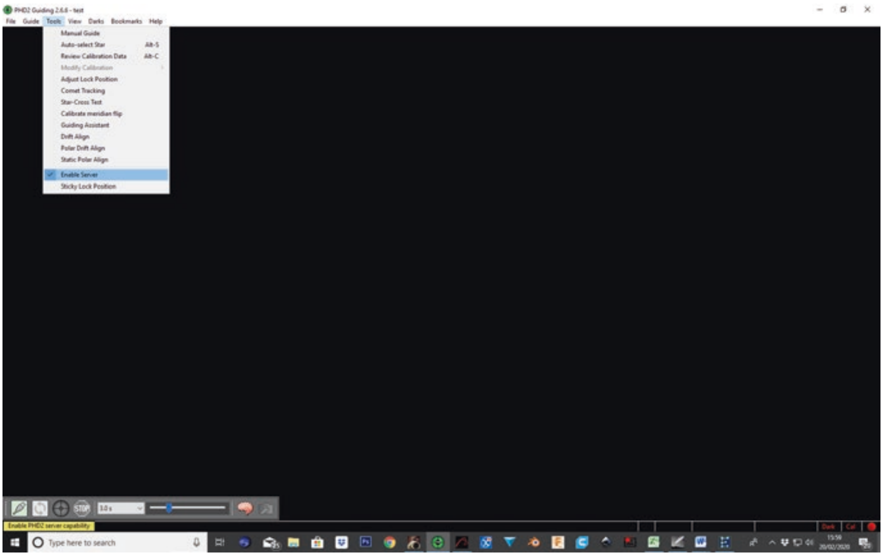

Fig. 8.34 Connecting PHD2 to APT. (Screenshot by kind permission of PHD2)

Plate Solving

Plate solving is the process of looking at an image and determining its celestial coordinates accurately. This is used in astrophotography to position an object or star field exactly in the imaging camera field of view and can be achieved using software with no additional equipment required. Plate solving is achieved by the software examining an image, identifying the stars present, comparing them to accurate catalogues of star positions and looking for a match. When it has found a match it can determine the center of the field of view of the image being solved. This means that for optimum performance most plate solving software needs to know your telescope focal length and the camera details such as imaging chip and pixel sizes. Plate solving software varies in speed; PlateSolver2 is recommended as it tends to solve an image in around 3 s. This speed is achieved by the plate solver reading the position that EQMOD thinks the telescope is at and using that as a start point for its searching.

Due to inaccuracies in setting up the telescope or in the mechanics of the telescope mount it may not be able to place objects on the camera imaging chip every time without a little help from plate solving. This can be essential if you are using a telescope with a long focal length a camera with a very small imaging chip or a combination of each.

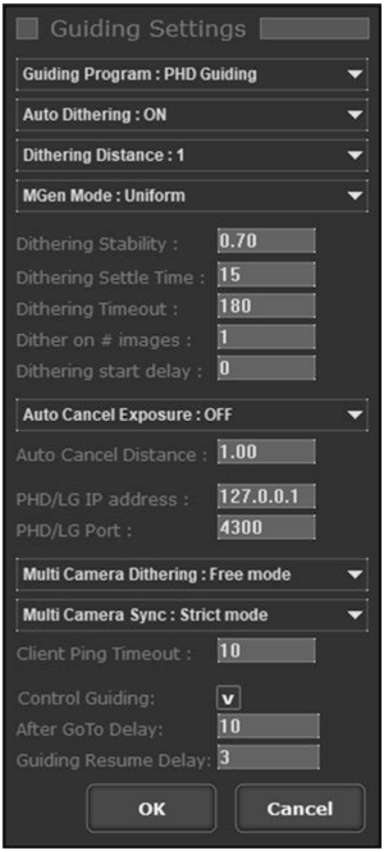

Fig. 8.35 APT Guiding Settings Window. (Screenshot by kind permission of APT)

Plate solving is a useful tool to assist you finding objects that are very faint and require long exposures before they even become visible in images.

There are a few different types of plate solver:

- **Online Plate solvers** – these need an internet connection and can be slow as submitted images will be in a queue of many other images.
- **Offline plate solvers** – these require you to download a catalogue of stars for them to use to identify the position of the images taken.
- **All sky solvers** – these can be given an image without any details of where it has been taken and will identify its position. However, as they have to search the whole sky they can take a while to work.
- Generally the plate solvers widely used with an ASCOM computer system read the telescope coordinates and use that as a starting point for identifying the image position.

- This tends to be faster than the all sky solvers as the software knows that the telescope should be close to the position so only has to search a smaller area to get a match

Plate Solve 2

Free to use

Plate Solve 2 is a fast and efficient plate solver program which can be used directly or called by programs such as APT, NINA or SGP to plate solve and sync the mount to its actual position. The telescope can be re-slewed if needed to ensure that your camera field of view is exactly on target.

Plate Solve 2 Download and Installation

Plate Solve 2 is downloaded from the plane wave website at.

http://pw-ecommerce.com/download/platesolve2-v2-28/

Once downloaded, simply extract the files into a suitable folder and then download one of the catalogues from the same website such as.

APM Catalogue Installer zip file.
UCAC3 Catalogue installer zip file.

When the appropriate catalogue has been downloaded it is extracted and placed into a folder. For example; C:\Platesolver2\UCAC3\

Next, within the same folder, run the file palesolver2.exe by double clicking on it to open the main PlateSolve 2 window as shown (Fig. 8.36).

From this window press File and then Configure Catalogue Directories to see (Fig. 8.37).

- Press the Select Directory button for the catalogues that you have installed you have installed and navigate them to where you have placed the directories. Upon successfully finding the appropriate catalogues their status message on the left of the Select Directory button will change and turn green to indicate that the catalogue is ready for use.

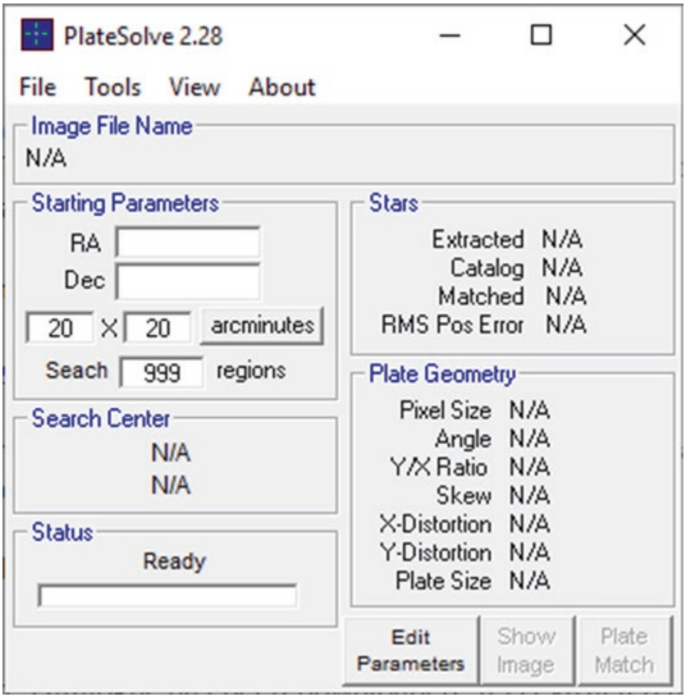

Fig. 8.36 Plate Solve 2 Main Window. (Screenshot by permission of PlateSolve2 and Planewave)

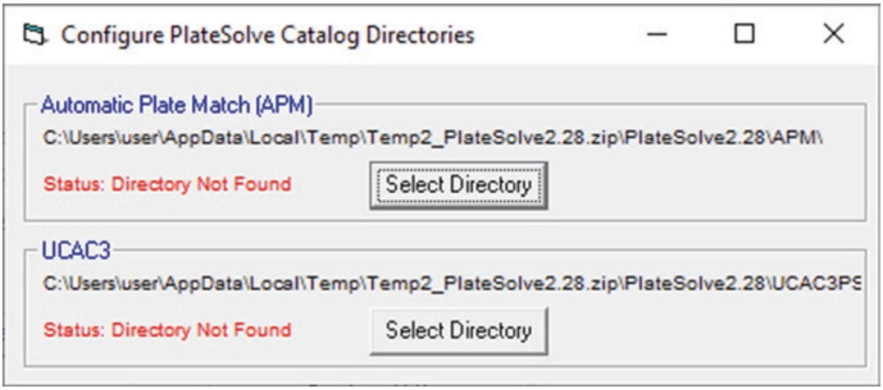

Fig. 8.37 Configuring Plate Solve 2 Catalogue Directories. (Screenshot by permission of PlateSolve2 and Planewave)

Field Size

- From the main Plate Solve 2 window, enter the field size of the images from your main imaging camera telescope combination. This can be calculated as explained in this chapter under the heading “Field of view size”.

Using Plate Solve 2

Below are the two methods of using plate Solve 2 the first being manual use and the second being called directly from an imaging program.

Loading the Image Manually in Plate Solve 2

It is suggested that this is where you start after installing Plate Solve 2 as you can make sure that it is working reliably with images you have already taken before trying it at night under a clear sky. Plate Solve 2 can be used by pressing File and Open Image from the drop down menu, then choose the image that you have taken and need to solve by clicking on it after locating the directory where it has been saved. You will also need to supply a starting point for it to search from so that it doesn’t have to search the whole sky which would take too long. This is entered as the RA and Dec coordinates of the object or center of the field of view to be solved. This may not be necessary if the software you are using stores the coordinates in the file header of the image.

This should result in a successful solution being given but if it fails to solve the image, you may need to press the Edit Parameters button and alter the star detection settings to tune it to your particular system (Fig. 8.38).

Pressing the Show Image window will show the image and displays a key to the Symbols shown as follows:

- Detected stars using a red plus sign
- Catalogue stars are shown with a blue X
- Matched stars are shown by yellow circles

This is very useful when you have to tune the parameters settings for giving feedback on what is happening.

Once you have the correct settings and Plate Solve 2 is solving reliably, you can use it by opening an image you have just taken and asking it to solve the image.

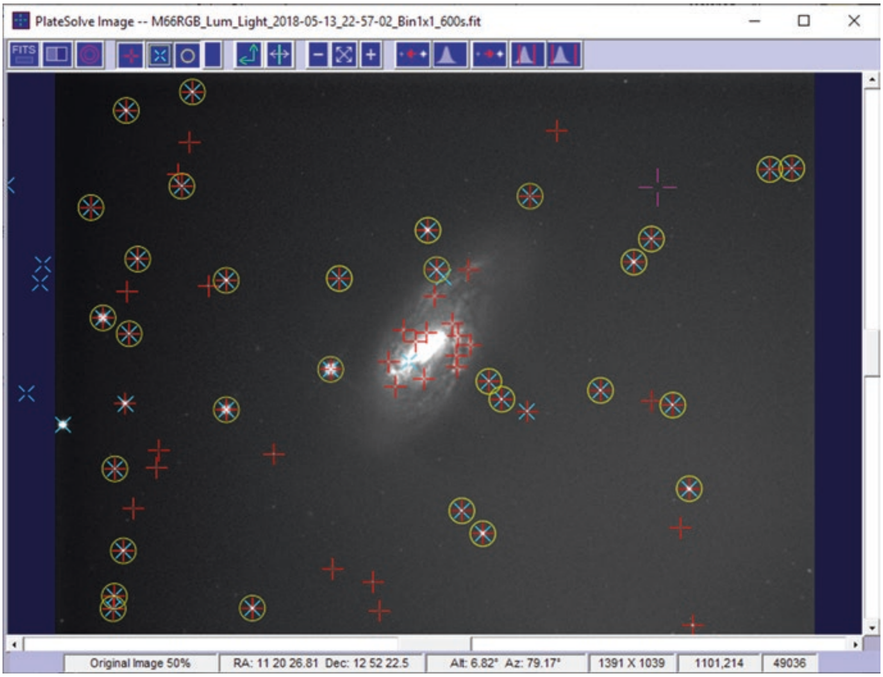

Fig. 8.38 Plate Solve 2 Show Image Window. (Screenshot by permission of PlateSolve2 and Planewave)

Using PlateSolve2 with APT

This is done by setting up Plate Solve 2 in the settings of the application to be used. The example uses APT.

- Plate Solve 2 is setup as previously described and its settings should be checked and proven to be working.
- Open APT and connect all the devices needed (Fig. 8.39).
- Press the Gear tab on the top right of APTs' main window followed by the Point Craft button which is located further down the screen (Fig. 8.40).
- In the Point Craft window press the Settings button at the bottom (Fig. 8.41).
- This window has direct links to install Plate Solve 2 and another Plate solver called ASPS. If you have followed the directions Plate Solve 2 will already be installed and working. APT needs to know where it is installed. This is done by pressing the button with three dots on it for the plate solver you are setting up. Next, locate the directory that the plate

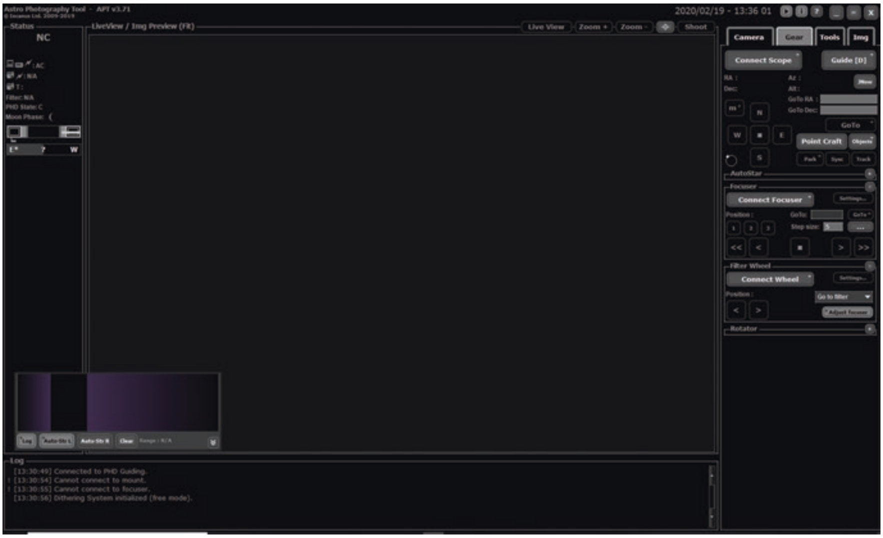

Fig. 8.39 APT Main Window. (Screenshot by permission of APT)

Fig. 8.40 Point Craft window in APT. (Screenshot by kind permission of David Rowe)

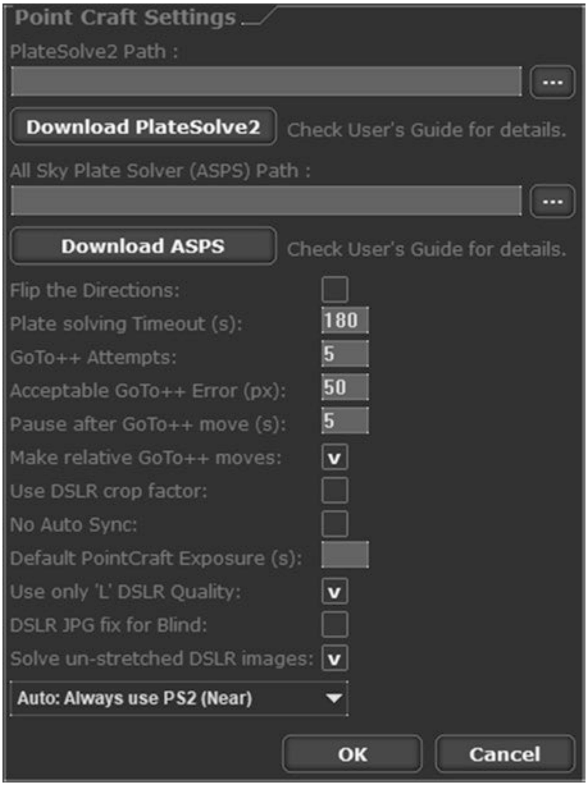

Fig. 8.41 Point Craft Settings Window in APT. (Screenshot by permission of APT)

solver is installed in and press OK. If you know what length of short exposure will result in a reasonable star field you can set that exposure time in the Default Point Craft Exposure(s) field dialogue box. You can leave the rest of the settings as default for now and press OK.

Doing Your First Plate Solve with PlateSolve2 Running Through APT

- Assuming you have a fully setup system and you have told it to slew to an object using either your planetarium program or the Objects Browser in APT set a camera exposure time and press the Auto button from the Point Craft window (Fig. 8.42).
- This will automatically take an image and attempt to solve it using the telescope position as reported by EQMOD as its start point. When the

Fig. 8.42 Point Craft Main Window. (Screenshot by permission of APT)

image has been solved its actual co-ordinates will be passed to EQMOD and it will sync to that position.

Auto

The "AUTO" button can be set to use either solver or to ask which of the plate solvers to use. This can be followed by taking an image, getting the telescope position, solving the image using the method selected in the settings panel and then syncing the telescope position automatically.

Under Plate Solving Results Box

Sync

The Sync button manually synchronizes the telescope position with that of the solved image.

Store

The Store button opens the object browser and creates a new custom record with the RA and DEC populated with the details of the last plate solve.

Show

This button shows the field of view as detected by the last solve in your planetarium application. It gives an indication of the solved image position.

Under Center FOV at Position Box

Objects +

This is used to load an objects coordinates into the center FOV coordinates boxes in preparation of doing a Goto++. You may also enter the RA and Dec of an object into the boxes directly; this may be of use for an object that is not in your catalogues.

>>Solved

Populates the Goto++ coordinates boxes with the information from the last solved image.

Goto++

This starts an automatic sequence that slews to an object or coordinates and takes a picture and plate solves it to confirm it is on target. If it is unsuccessful, it will be repeated up to the number of times set in the Goto++ Attempts box under the Point Craft settings dialogue box. If it is still unsuccessful an error message will be displayed. The Goto error and number of attempts before showing an error message can be entered in the Settings box using the Settings button at the bottom of the Point Craft window.

Aim

This button is used to select a point in a solved image that you wish to center in the FOV; this can be a great aid in composing an image. Once done the Goto++ function is automatically invoked to center the telescope at the selected position.

Once the plate solving has done its work and the telescope is pointing at the desired object, Autoguiding can be started if being used and then taking images can commence.

Another plate solver that can be installed and used in APT is ASTAP this is also highly recommended and is very fast in operation.

Finally, another plate solver that can be used in APT is a blind solver called ASPS

ASPS All Sky Plate Solver

This is a blind solver and does not require the telescope position as a starting point for its searches and as the name implies it does a whole sky search in order to identify the telescope position. This takes a little longer, but is still a very valuable tool to have available.

Installing All Sky Plate Solver

Download the installation file and run it. When it has installed click on the icon to run All Sky Plate Solver; it will then come up with the following message (Fig. 8.43).

Pressing the Yes button will open the next window (Fig. 8.44).

In the dialogue boxes on the right, enter the appropriate details for your telescope and camera combination. The remaining details will be calculated including the size of your field of view for that combination which is useful to use when setting up a field of view indicator in a planetarium program. Looking to the right of the window you will see highlighted in yellow, the catalogue files that will be needed for All Sky Plate Solver to work.

Click on the button on the bottom right of the window labeled Install Indexes Highlighted (Fig. 8.45).

Click on Yes and wait while the files are downloaded which might take some time depending on how many index files are required for your particular setup.

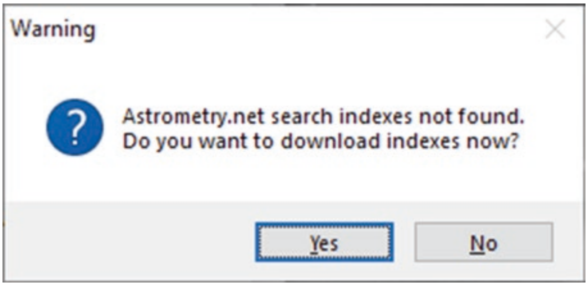

Fig. 8.43 All Sky Plate Solver warning window. (Screenshot by permission of All Sky Plate solver)

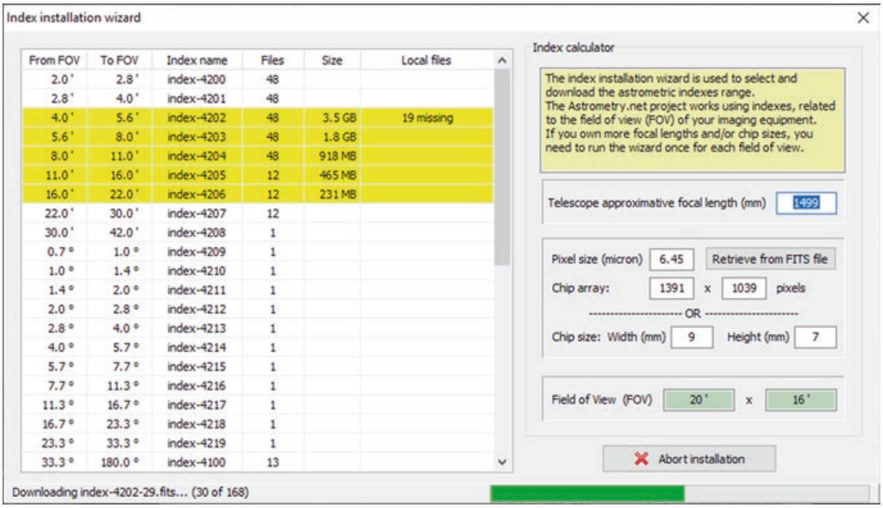

Fig. 8.44 All Sky Plate Solver Index Installation Wizard. (Screenshot by permission of All Sky Plate solver)

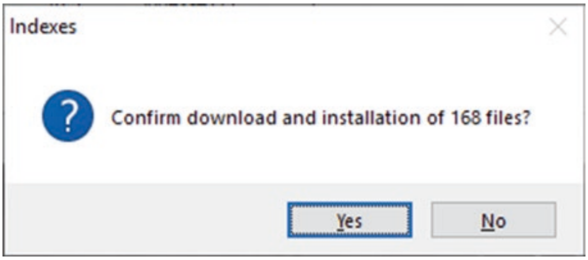

Fig. 8.45 All Sky Plate Solver Index Download Confirmation. (Screenshot by permission of All Sky Plate solver)

The above screenshot shown is for a Sky Watcher 300Pds telescope and an Atik314l+ CCD camera and is in the process of downloading the index files selected as can be seen by the green progress bar and messages displayed.

Once the files have been downloaded, the following window will confirm that the catalogue files have been downloaded and installed correctly (Fig. 8.46).

All Sky Plate Solver is nearly ready for use. Start the program; check that the telescope and camera details are correct and that your location is set.

Setting the Field orientation of the Finder (CCD) Rectangle in Cartes du Ciel

- Having taken an image with your telescope open it up in All Sky Plate Solver by using the button to the right of the file name dialogue box.
- Once this has been done press the Plate Solve button with the large icon of a star on it labeled Plate Solve. As this is an all sky plate solver it may take a little while to solve the image (Fig. 8.47).
- Once you have successfully solved the image, you can transfer the camera angle value in this case −149.78 into the finder rectangle rotation field in Cartes du Ciel. This will set the correct rotation of the finder rectangle displaying the telescopes position on the charts and is found under the Setup Menu, Display, Finder rectangle (CCD) tab.
- If you are having trouble getting your first plate solve to work, you can try using the Settings Assistant in All Sky Plate Solver which is under the Settings menu (Fig. 8.48).

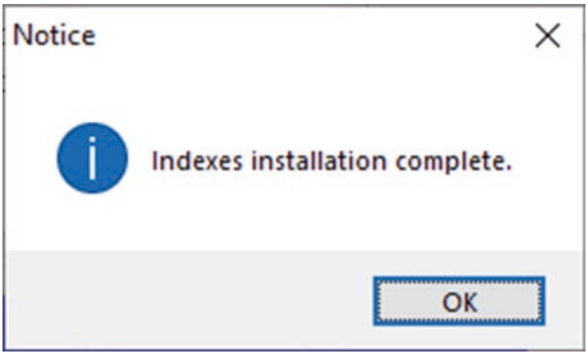

Fig. 8.46 Catalogue installation confirmation. (Screenshot by permission of All Sky Plate solver)

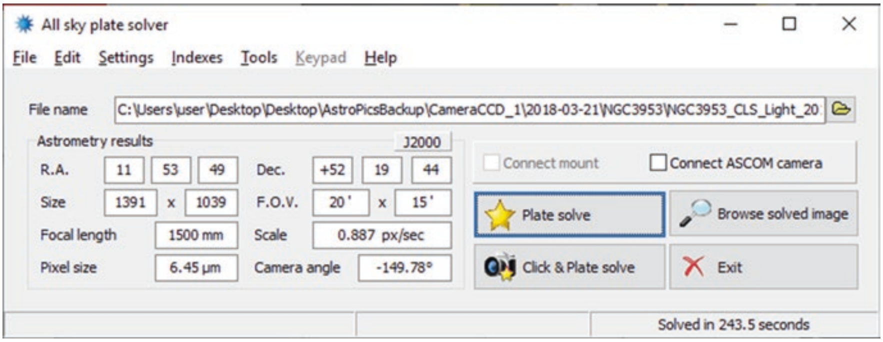

Fig. 8.47 All Sky Plate Solver successful image solve. (Screenshot by permission of All Sky Plate solver)

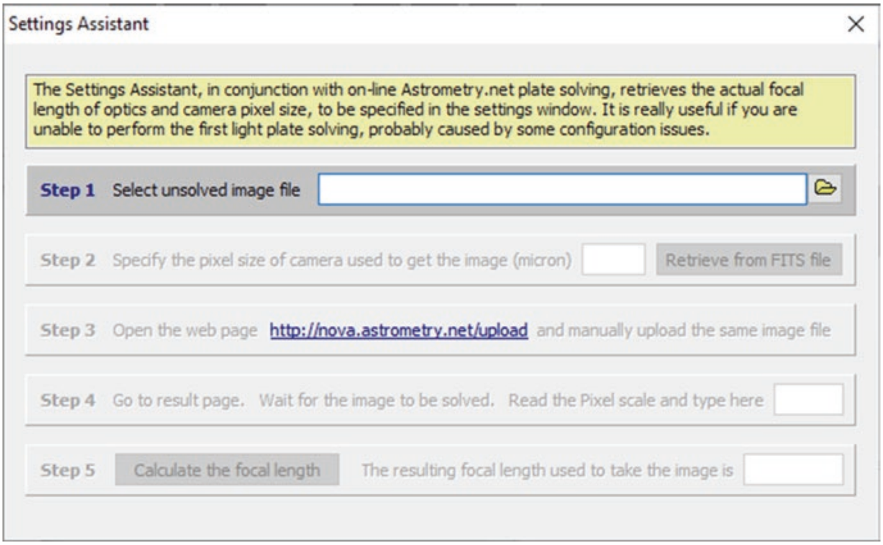

Fig. 8.48 Settings Assistant in All Sky Plate Solver. (Screenshot by permission of All Sky Plate solver)

- By following the instructions given and entering the details requested it will help you ensure that you have the correct details to perform a successful plate solve (Figs. 8.49 and 8.50).
- Opening Cartes du Ciel you will note that the rectangle indicating the camera Field of view has now rotated to the correct orientation for you camera. This can be confirmed by opening the solved image using the

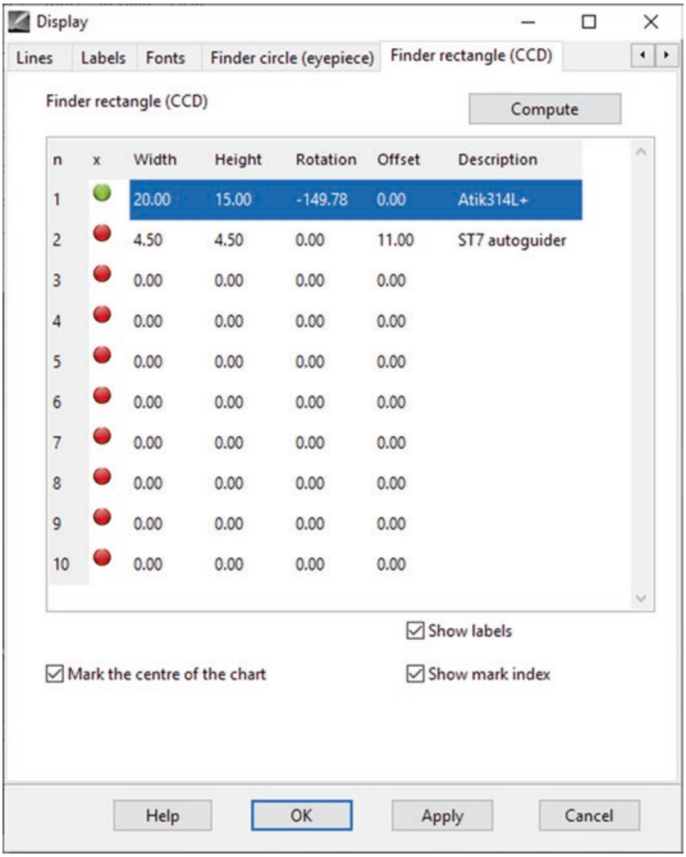

Fig. 8.49 Setting Rotation Value in Cartes du Ciel. (Screenshot by permission of Cartes du Ciel)

View Image file button from All Sky Plate Solver main window and comparing them (Fig. 8.51).

- Connect your telescope mount and ASCOM camera using the tick boxes from the main window which will require you to use the Ascom chooser boxes to select your camera and telescope.
- When your telescope and camera have connected, press Settings from the menu bar followed by Plate Solver Settings which will open the main settings window where you can set the exposure to use when automatically plate solving and performing a sync on the telescope position and the binning. There are two tick boxes to note (1) On successful Click & Plate solve, execute sync mount and (2) Synchronize ASCOM mount, both these should be ticked in normal use.

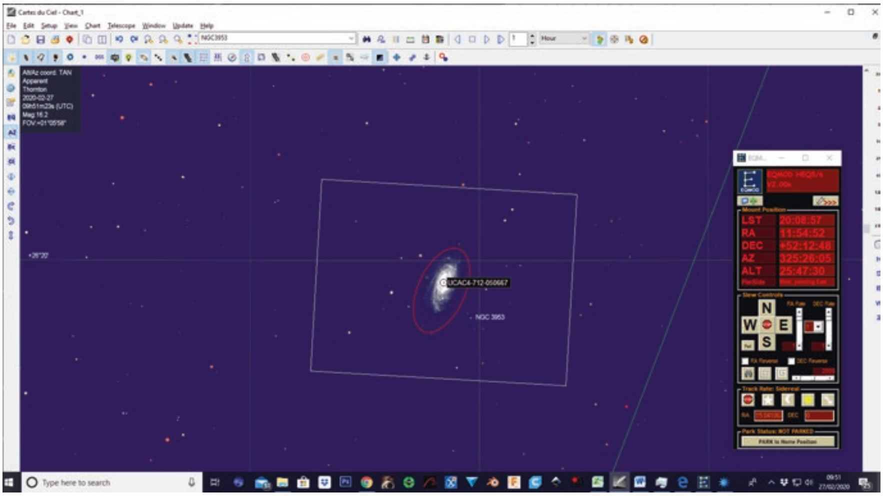

Fig. 8.50 Cartes Du Ciel showing rotated (CCD) FOV indicator. (Screenshot by permission of Cartes du Ciel)

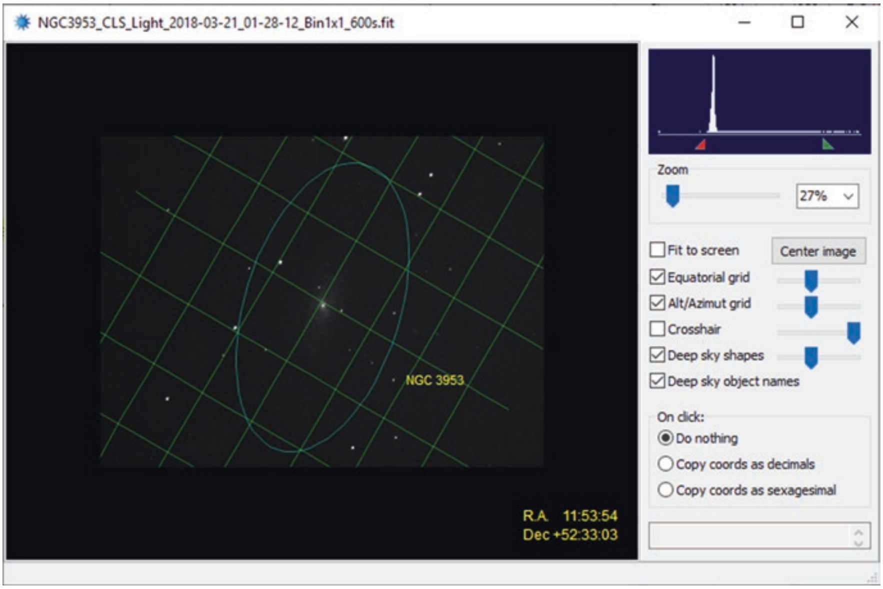

Fig. 8.51 All Sky Pate Solver View Image file window confirming correct orientation of FOV indicator when compared to FOV indicator in Cartes du Ciel. (Screenshot by kind permission of All Sky Plate Solver)

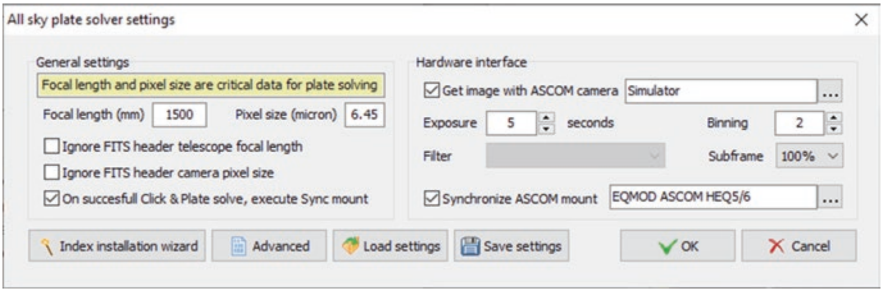

Fig. 8.52 All sky Plate Solver Settings window. (Screenshot by Permission of All Sky Plate Solver)

- You can now save these settings to a file of your choice using the Save File button after which press OK to go back to the main window (Fig. 8.52).

Using All Sky Plate Solver

- Using All Sky Plate Solver stand alone at its simplest is now just a matter of pressing Click Solve & Sync. This will automatically take an image using the settings you entered into Plate Solver settings and solve it, then sync the position of the telescope with its actual position in the sky.

Astrotortilla

This is a very popular free to use plate solver and is easy to setup and use. Once configured it only needs one button press and the telescope and camera slew and take pictures automatically until the desired object is in the center of the camera field of view.

The setup procedure requires a calculation of the size of the telescope camera combination image field of view, but this is easily done using one of the Field of View online calculators or apps. It is also explained in Chap. 9 (Fig. 8.53).

Once this is calculated and entered during setup, the correct catalogues of stars for your equipment are automatically suggested and if accepted, downloaded. Then, enter the details of the image taking software in use and connect it to the telescope using the disconnected dropdown box from the main control panel. The main control panel has three tick boxes that enable the following functions:

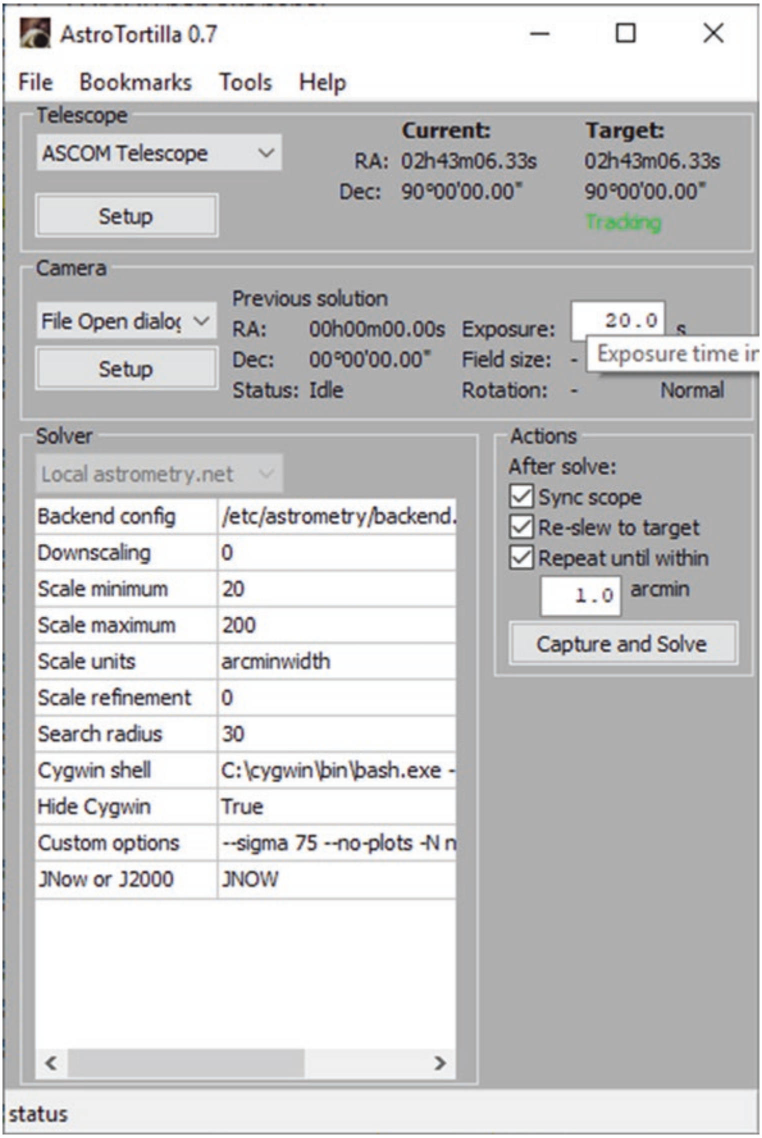

Fig. 8.53 Astrotortilla Main Window. (Screenshot by permission of Astrotortilla)

Sync Scope

This synchronizes the actual position of the telescope with EQMOD and hence any planetarium or telescope control software in use.

Reslew to Target

Once the plate solver has identified the telescopes actual position, it checks to see if it is pointing in the correct area. If there is a pointing error, it automatically reslews the telescope to the correct position.

Repeat Until Within "X" Arcmins

This box instructs the telescope to keep slewing and taking confirmation images until it is pointing within the number of arc minutes "X" you have set of the target position.

Star Alignment and Plate Solving

If you are using a plate solver, there is no need to do a star alignment, as the plate solving software will find out where the telescope is pointing and synchronize its position with EQMOD and your planetarium software as long as the rest of the telescope setup is done accurately. Some Astrophotographers like to use one or the other or even both.

Using Your Computerized Imaging Setup

Following the instructions on how to set up and configure some of the common software packages available to take astronomical images it is advised that you practice using them to control your telescope. Once familiar with their use, there are more advanced features to explore which are not covered in this volume.

A great help in learning to use some of the pieces of software is the use of the Camera and Telescope simulators found in the ASCOM chooser boxes. These will enable you to practice when it is not possible to setup your equipment and can be used to clarify a set up. Some of the simulators have dialogue boxes that can be set to emulate equipment similar to that which you are using.

Searching on the internet you will find many general and specialized pieces of software that will now link into your telescope using the EQASOM platform. This will open many imaging possibilities that you may wish to pursue in furthering your interests in the sky.

Typical Computer Controlled Imaging Session

This description starts from the point at which the software is fully installed and setup and the telescope is balanced, in its home position and roughly in focus.

- Once all the equipment has been set up the computer is started and the telescope and its equipment powered up.
- Plug the USB devices in to the computer and make sure they appear in the windows devices and printers window. By right clicking on a device, clicking on Property, followed by selecting the Hardware tab you can find the COM port assigned to a device.
- Start the software you will be using.
- Connect the software to all the devices such as telescope, camera, focuser, filter wheel etc.
- Check that the planetarium software is showing the telescope in the correct position which for most mounts is pointing near the celestial pole star Polaris if you are in the northern hemisphere.
- If not using a plate solver, follow the star alignment procedure given in the EQMOD documentation. This will ensure that the telescope is informed where it is pointing in the sky.
- If using an autoguider, use the planetarium software; slew the telescope near to where the meridian and celestial equator meet. This only needs to be approximate.
- Start the autoguider calibrating. When this has completed move to the next step.
- Slew to a bright star and locate it in the FOV.
- Using a Bahtinov mask or a tool in your imaging software, focus the telescope as accurately as you can; this might take some time to be accurate. If you plan on using a filter it should be fitted before you focus the telescope.
- Using the planetarium or other software instruct the telescope to slew to the object of interest.
- If you are using plate solving software you may now use it to check where the telescope is pointing and if necessary re slew the telescope to center the target object in the FOV.
- If you have used a plate solver you will have an image taken that will show the object or the star field around it if it is too faint to show up in a short exposure. If you are not using a plate solver take a brief image and manually check you are on target.

- Once you are happy that you have your object in the FOV start the guiding software and give it time to settle. This can be monitored by observing its graph.
- While you are waiting for the guiding to settle, enter the details for the image or images of interest. This will include exposure duration, number of exposures, the name of the image files being taken and the location of the directory in which to save them.
- When the guiding software has settled, start the camera imaging. During this time watch the guiding graph and look for any spikes or deviations that might indicate problems such as dragging cables, balance issues etc.
- When you have taken your images of the first target you may then stop the auto guiding, slew to the next target, restart the auto guiding and take images of the next target of interest.

Fast Setup of an Imaging System

Setting up an imaging telescope can take a long time which may be imaging time lost unless you are able to do it before it is dark. The following steps described here will ensure that the set up time of the system is reduced and reliability of the setup is improved.

Overview of Steps to Be Taken to Ensure a Fast Setup

1. Where possible keep the equipment attached to the telescope optical tube in place.
2. Fix the wiring connecting the devices in such a way that it is permanently fixed to the telescope tube.
3. Use a USB hub fixed to the telescope tube to reduce the amount of wiring that goes from the telescope to the computer.
4. Make a 12v power distribution box that can feed all the necessary devices with 12v power and also fit it to the telescope tube; this means only one 12v power cable is needed to the telescope tube.
5. When everything is installed and the telescope is properly balanced put labels marking where the dovetail should be in its clamp so that it can be installed in the correct position and there is no need to to balance it every time you set the telescope up.
6. Mark the correct focus position with a pencil as a rough guide showing where it should be; that way it can be returned to that position quickly if it gets disturbed and it will be close to being focused.

Fig. 8.54 Self-adhesive pads and Tie wraps

The equipment used to take images with the telescope such as a camera, finder guider, focuser, heaters and fans should, where possible stay, attached to the optical tube. This is not always possible and where it might make the telescope tube difficult to handle or be unsafe due to the possibility of damage the advice should be ignored. If it is necessary to remove them, setting up time can still be improved by having all the wiring in place fixed to the telescope tube which can be done using self-adhesive tie wrap pads (see Fig. 8.54).

The first thing to decide is where the USB hub is going to be mounted and the power distribution box. These need to be mounted so that they are accessible and will not get in the way or foul the free movement of the telescope. The best way of mounting them is with the use of a good quality hook and loop tape. This means that they can be removed if needed or even relocated without making any holes or permanent changes to the telescope which would invalidate any warranty and reduce resale value.

Once this has been decided it is then a case of planning the routes the cables will take along and around the telescope tube carefully. This is individual to each telescope setup.

Consideration should be given, where the camera is concerned, that the focuser will need enough slack cable to be able to move the full length of its travel, without being impeded by the cables feeding the camera being too tight.

It is helpful to plan the cable runs on paper first enabling you to catch many problems before you are committed to the final layout (Fig. 8.55).

Once the cable runs have been decided it will dictate where the adhesive pads that will attach the cables to the telescope tube should be placed. The pads can then be fitted and the process of installing the cables can begin. It can be helpful to put short lengths of a thin gardening wire through the loops on the adhesive pads, as that allows you to twist it around each cable as they are installed. Using these ties means that they can be undone at any time to add or remove cables. Once all the cables are fitted correctly the gardening wire can be replaced with the plastic tie wraps for a more permanent solution.

When all this has been done you will have a fully wired telescope that just needs putting on its mount and then lined up with the marks you made to ensure it is balanced. The system then requires one power cable to be plugged into your 12v supply and one USB to be plugged into the computer, the telescope is then ready to be polar aligned, star aligned if required and used.

The effort required to set up a telescope like this saves so much time it is well worth doing and makes it possible to set up and use gaps in clouds that otherwise would not be possible.

Fig. 8.55 Cable run fixed to the telescope tube

Chapter 9

Introduction to Image Processing and Stacking

Choice of Software

This chapter describes the basic operation of some of the image processing software, currently available that is easy to use and produces great results. There is no one piece of software that offers all the best features required to process an image so it might be necessary to use more than one package to get the best results from the images that you capture. This tends to be the norm amongst imagers you will need to find which software you are comfortable using for particular operations to get the best results. It may be necessary to use different elements from a number of software packages to create the results you want to achieve.

Image Processing

Image processing is the technique of taking the images captured by the camera, and extracting every possible bit of information from them. This can be to produce visually stunning pictures, or enables the data within them to be used in scientific studies.

The images that come directly from the camera are likely to be noisy dark and only show bright detail and they will probably suffer from both electrical noise, hot pixels and optical effects such as, vignetting and dust

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_9

spots. To combat these problems, it is necessary to employ a number of techniques in order to calibrate the image, which reduces the effects of these problems considerably and enables the extraction of more faint detail than would be possible otherwise, using a process commonly called stretching.

Different Types of Images

The following is a description of the different types of images that are used to produce a fully calibrated astronomical image:

Light Frames

These are the actual image frames taken of the objects of interest; they will contain some or usually all of the previously mentioned defects. It is these "lights" that need to be applied to the calibration frames using the image processing software. This process relies on the production of good quality calibration frames and understanding how you use them properly; it isn't difficult but requires care and attention to detail to carry out successfully, ensuring that you get the best possible images from the data collected (Fig. 9.1).

Fig. 9.1 Typical light Frame

Calibration Frames

Calibration frames are basically images that are taken in such a way that they specifically contain the errors or effects that we are trying to remove from the images of an object. This then allows the use of the information contained within them to correct the actual image.

Calibration frames should, ideally be taken with the optical and camera system, exactly as it was when it was used to take the actual images being calibrated. This is why it is suggested that they are taken at the end of an imaging run. This is not usually convenient as the extra time needed to produce the calibration frames may not be available late into the night. Just produce the calibration frames when you can without moving the focuser or taking the camera off the telescope if possible. Set the camera at the same temperature that the images were taken at for the dark frames as they are temperature dependent, ensuring that stray light will not interfere with them. For the flat frames the temperature is not important but the focuser position should be the same as when the images were taken. It therefore, does makes sense to take these calibration frames at the end of an imaging session if at all possible especially if using a standard DSLR, where you have no control over temperature. If you are using a dedicated camera with set point cooling or a DSLR with a cooler fitted this isn't as much of a problem.

In order for calibration frames to work properly, take many calibration frames and let the software combine them and then apply them to get the end result which is a cleaner image with reduced noise and hot pixels and also a flatter field or background that can be stretched to show more detail.

Dark Frames

Dark frames are simply images that are taken at the same temperature and exposure duration as the images but with all the covers on the telescope. This produces an image which contains the electrical noise inherent in the camera system, and also the difference in sensitivity between all the pixels in the imaging chip in the camera. The dark frames are then used to even out these differences in sensitivity and reduce noise. It can make things easier if you decide on set standard exposure times for your images. It is recommended to use 5 min and 10 min and occasionally 20 min and then make matching dark fames that can be applied to them (Fig. 9.2).

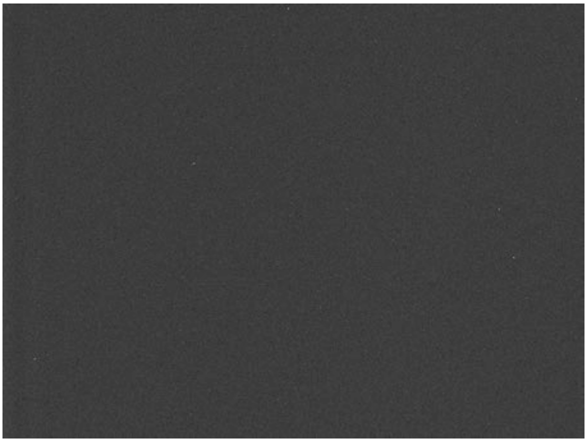

Fig. 9.2 Typical Dark frame

Flat Frames or Flats

Flat frames are images which pick up undesired effects in the telescope system such as vignetting which is usually a darkening of the image towards the edges of the frame, and also dust marks which show up as doughnut shapes in the image. Interestingly, the size of the doughnut is directly related to its proximity to the imaging sensor, this can be useful to determine which optical component the dust is on. When correctly taken flats are applied to an image the effect that they have is to flatten the effects of vignetting. This makes the background even across the image and they also remove dust spots resulting in a much cleaner image which is capable of being stretched to show more detail.

Flats work by taking an image of an evenly illuminated light source and using it to calibrate the actual images. This is done by dividing the pixel values in the light frames by the values of the flat frames and results in an even illumination of the image frame with dust doughnuts and vignetting removed. Flat frames are not temperature dependent as some of the other calibration frames are. Flat frames do need to be taken for each filter used and then the appropriate flat frame is used with images taken with that filter (Fig. 9.3).

Producing Flat Frames

Flat frames are usually taken using one of two methods sky flats and light box flats. The method is not important and is simply a matter of convenience and whichever is the easiest to produce. There are two main consid-

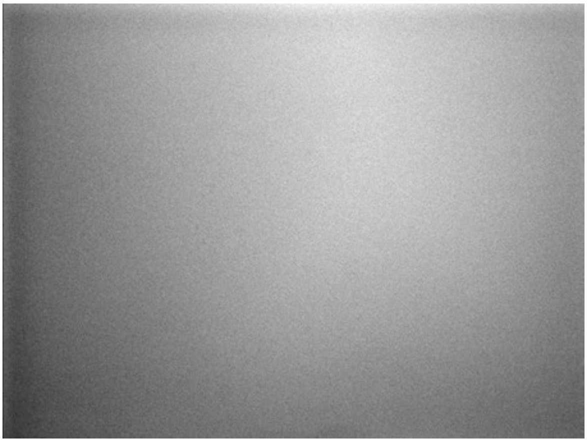

Fig. 9.3 Typical Flat frame

erations when taking flats; the first is using an even light source and the second consideration when producing your flat frames, is the exposure time used to produce them.

Sky Flats

Sky flats are usually taken at dusk or dawn and are images taken of a blank area of sky or cloud usually with a white T-Shirt or some form of diffuser stretched over the telescope aperture. The diffuser is needed as the aim is to take an image of any blemishes such as dust spots and the vignetting in the optical system, which is a darkening towards the edges of the field. This produces an image which maps any vignetting and shows dust spots. When this flat is applied to an actual object image it cancels out the vignetting and dust spots (Fig. 9.4).

Light Box Flats

Light box flats are flats that have been taken by putting an evenly illuminated light box over the telescope aperture and shooting the flat frames. These light boxes are available commercially, or are quite easily made at home with relatively few tools, or even adapting a flat panel ceiling light. The advantage of using a Light box to produce flats is that you can take your flat frames anytime as long as there is no other light leaking into your telescope tube, which would make them ineffective.

No matter what types of flat frames have been produced they are applied to the image in the same way and serve exactly the same purpose (Fig. 9.5).

Fig. 9.4 Sky flat setup

Fig. 9.5 Light box flat set up

Hints for Taking Good Flat Frames

It does not matter if you take light box flats or sky flats; the following basic rules still apply:

- The camera should still be connected to the telescope.
- The focus and rotation of the camera needs to be unchanged from when the original images were taken for use with the flats.
- Around 21 flat frames are needed to get good results.
- The temperature at which you take flat frames is not important.

Producing Flat Frames with a DSLR

To produce good flat frames with a DSLR you need to shoot them at the same ISO setting as your image or light frames were taken.

- Set the camera to aperture priority mode. Using this mode the camera will calculate the best exposure time to use when shooting the flat frames. Check the camera histogram to ensure that the flat frame is not under or over exposed.

Producing Flat Frames with a CCD or CMOS Astronomy Camera

Producing good flat frames with a dedicated astronomy camera takes a little more work, but the benefit is high quality images.

CCD and CMOS Camera Automatic Flat Frame Production

Programs like NINA and APT have tools to help create good flat frames and are worth using as they reduce the work. Enter the desired ADU number which is typically 25,000. It will be necessary to approximate the starting exposure length, usually in seconds. Also, set the minimum and maximum exposure times to try. The software will then determine the correct exposure value to use and create an imaging plan that will automate the process.

Producing Manual Flats

It is also possible to produce the flats manually without the use of the software described.

The following list details helpful facts about the image histogram needed in order to produce the flats.

- The value of white in an image using a 16 bit camera is 65,536.
- The value of black in an image using a 16 bit camera is 0.
- The average ADU value of a typical good flat frame varies from camera to camera but a good starting point is 25,000 to 30,000 ADUs. As a rough guide, the ADU level of the flats should be approximately 1/3 to 1/2 the maximum ADU level of the camera, and when looking at the histogram it will appear approximately symmetrical.
- It will be necessary to take various exposures and the starting point depends on the brightness of the light box or the sky. From this first exposure, use the histogram in the image capture program and utilize its statistics tool to determine if the exposure taken is too long or too short by looking at the ADU value. By repeating this process and making changes to the exposure time it is possible to find the correct exposure needed for the flats.

Bias Frames

Bias frames are frames that are taken like dark frames with all the covers on but use the shortest exposure time that is available. The intention is to pick up the electrical noise in the camera imaging chip and amplifiers and subtract that to get a cleaner image. These are only very slightly temperature dependent for most cameras (Fig. 9.6).[1]

Applying Calibration Frames to Your Images

Once you have a set of calibration frames they are applied to your images using your chosen processing software; this is done before any stacking or stretching takes place as the calibration frames are applied to the raw data from the camera individually. Once this has been done then the resulting calibrated images are ready to be stacked and should be free from vignetting, dust bunnies, hot pixels and the noise within the image reduced.

[1] Article showing temperature dependence of a QSI 532 CCD https://canburytech.net/QSI532/BiasFrames.html

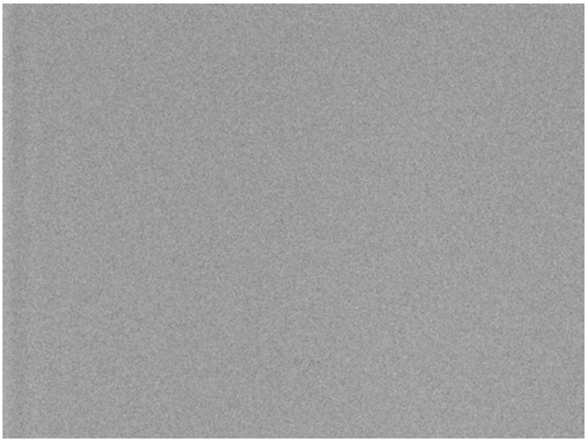

Fig. 9.6 Typical Bias Frame

Aligning and Stacking

Once images have been calibrated, they will need to be aligned and stacked. In most image processing packages this is treated as a combined operation in which the chosen settings are carried on all your selected images and at the end, a single aligned and stacked image is produced and saved.

Aligning Images

Aligning images is the process of making sure that all the objects in each image are in register with all the others correctly so that when they are stacked together the resulting image retains all the detail. The alignment process may simply require images to be aligned in an X, Y direction or there may be a need to rotate images so that they are aligned. This will largely occur when the telescope has done a meridian flip part way through an imaging run or when images to be aligned are taken on different nights. Scale can be a factor if images from different telescopes and cameras are to be aligned with each other.

Astronomical image processing packages usually have automatic and manual modes of aligning your images.

Automatic Image Alignment

Fully automatic image alignment is a case of loading your images and the software calculates the alignment of the images including working out any X, Y movement, rotation and rescaling.

Stacking

The resulting images are then added together using a process called stacking to produce a final image that is then capable of being stretched in order to show the maximum possible detail from the images that have been captured (Fig. 9.7).

Common Methods of Stacking and Alignment

Stacking is the process used to ensure that when multiple images are combined it is done in such a way that all the features in each image are in register with each other. This preserves the detail in the image and helps reduce tracking errors between individual images.

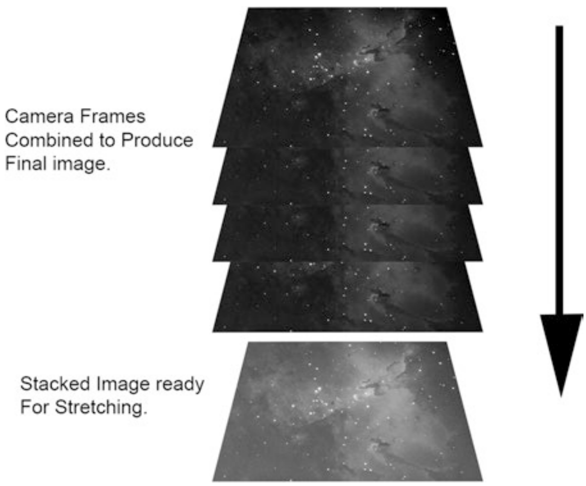

Fig. 9.7 Illustration of stacking

No Alignment

This may be used in the unlikely event that all your images to be stacked are in perfect registration with each other or you have previously carried out the alignment.

Translation

Translation is used when there is only a vertical and horizontal direction shift between images to be stacked.

Translation Rotation and Scaling

Translation may also include rotation and scaling correction. These corrections may be used to stack images taken with more than one telescope or camera or where the telescope has carried out a meridian flip midsession resulting in some images being inverted.

Drizzle

Drizzle is a technique developed by Andrew Fruchter (STCI)[2] and Richard hook (STECF)[3] to ensure the best detail when processing Hubble space telescope images.

Stacking Functions

The following stacking functions may be available along with others depending on the stacking software you are using.

Average

This is a stacking function that is designed to further reduce noise in the final image.

[2] Space Telescope Science Institute

[3] Space telescope European Coordinating Facility

Standard Deviation

Standard deviation is designed to help eliminate outlier pixel values such as hot pixels and even satellite trails which do not occur in every image.

The Advantages of Stacking

- Stacking results in images that have reduced levels of noise. This enables finer detail and fainter objects to be seen.
- Stacking enables you to use shorter individual exposure images which means if a single image is spoilt by bad tracking, wind catching the telescope or an aircraft going through the field of view only that frame is spoilt instead of a single very long exposure frame being spoilt.
- The telescope tracking doesn't have to be quite as accurate as a lot of short exposure images can be taken and added together.
- The best images can be chosen from than those taken and the best ones can be chosen for stacking.

The Disadvantages of Stacking

- Requires more storage space for a series of images on your computer.
- Requires more steps and takes slightly more time to process your images.

There are many software packages that can be used for processing astrophotography images, some are free to use and others are commercial. Nebulosity 3 and 4, Astroart and Pixinsight all of which are commercial products are recommended.

Deep sky Stacker is widely used to do the calibration and stacking and then either Nebulosity or Pixinsight with a final noise reduction done in Adobe Lightroom or Photoshop. Workflow and image processing software is available to meet a range of needs.

Deepsky Stacker

This is free to use and has been specifically written to apply calibration frames to images and then stack them with very little intervention from the user. It does a fantastic job and is quick and easy to use. All the user needs to do is load the appropriate images into DSS using the Open Picture files section of the dialogue box, look through the images to check them for quality and make sure the tick box next to each of the images is ticked and press Stack checked images.

It then shows errors such as missing calibration files, offers recommended settings and allows you to alter stacking parameters using two buttons at the bottom of the dialogue box.

When the OK button is pressed it will proceed with the stack and display an upstretched stacked image which you may save with the Save picture to file button. Deepsky Stacker will also stitch together images that have taken as mosaics which can be very useful when an object is too big for the field of view of your telescope camera combination.

ASTAP

ASTAP is free software designed to plate solve images as well as stacking them and does a particularly good job of stacking mosaics automatically. ASTAP will also perform photometric measurements and automatically annotate images, as long as you load the appropriate database which is very easy to do. It also has a very useful tool for imagers called CCD inspector which takes the HFD value of the stars in an image and from these figures out and displays any sensor tilt and curvature of the field. This can be a real help in determining problems in an imaging system.

Once your images have been stacked follow the instructions of the chosen stacking software and load your image into image processing software such as Nebulosity, Pixinsight, Photoshop or Gimp to stretch it and bring out its detail. In order to use Photoshop or Gimp you will need to save it in a lossless image format that they can read such as TIFF.

It must be noted that Nebulosity and Pixinsight along with Astroart and Maxim DL are also capable of image calibration and stacking.

After the image has been calibrated and stacked, it is now ready to be stretched as it will still not be showing the full detail contained in the data you have captured and it will probably still appear to be quite dark.

Stretching an Image

Stretching an image allows scaling of all the information contained in that image so that it can be easily seen. Looking at an astronomical image straight from the camera it will usually appear to be very dark and have little detail showing. This needs to be addressed so that all the information contained in the image is visible.

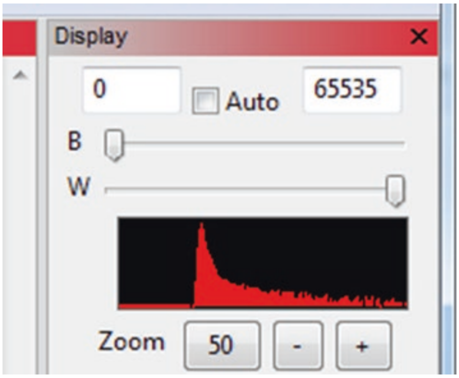

Fig. 9.8 Histogram showing most of the data is at dark end. (Screenshot by permission of Nebulosity)

Most software packages have an automated stretching routine which can be a good start if you are new to processing images. Whilst automatic stretching often does a good job, better results can be achieved by doing it manually (Fig. 9.8).

Looking at the graph, you will see the horizontal axis shows the value or brightness level of pixels in the image, and the vertical scale shows the number of pixels of that particular value. It can be seen from the first histogram picture above, that the number of pixels containing actual image information is quite small and usually bunched together forming a narrow peak. This is because most of the image is simply the blackness of space.

So in order to see the information that the image contains more easily rescaling of the information within the mage is necessary, so that it is distributed across the graph, which at one end shows black tones and at the other end shows white tones (Fig. 9.9).

The next histogram shows the result of stretching an image and contains data from the black end of the histogram to the white end. This means that when the image is displayed or printed, all of the information contained in it will be visible as either shades of grey or color tones.

Levels Control

The basic tools that are used to stretch an image manually tend to be level controls and curves, in level controls markers are moved on a histogram to show the start and end of the information. This is known as setting the black and white points; in astronomical images it not advised to move the white

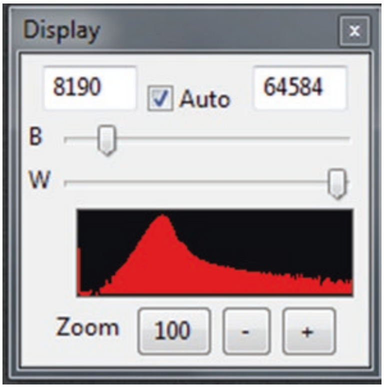

Fig. 9.9 Histogram showing data stretched to fit the full width of the histogram. (Screenshot by permission of Nebulosity)

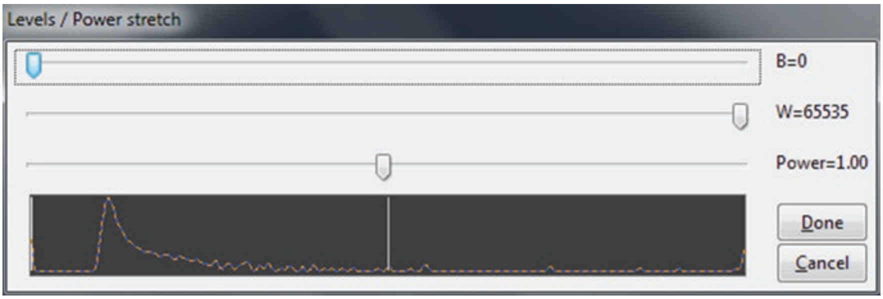

Fig. 9.10 Level graph. (Screenshot by permission of Nebulosity)

point as this will exaggerate any noise that is still in the image. There is also a midpoint marker which will scale the midtones and has a huge effect on the overall brightness of the image (Fig. 9.10).

Curves Control

The next function that can be used is curves; this allows us to scale the image information in a nonlinear way which allows boosting of individual brightness levels to make them visible. It is implemented by manipulating a scaling curve over the histogram to get the desired effect and is a very powerful tool. The curves tool has to be used very carefully as it is easy to overstretch an image which can result in degradation by raising the level of noise which will make it visible (Fig. 9.11).

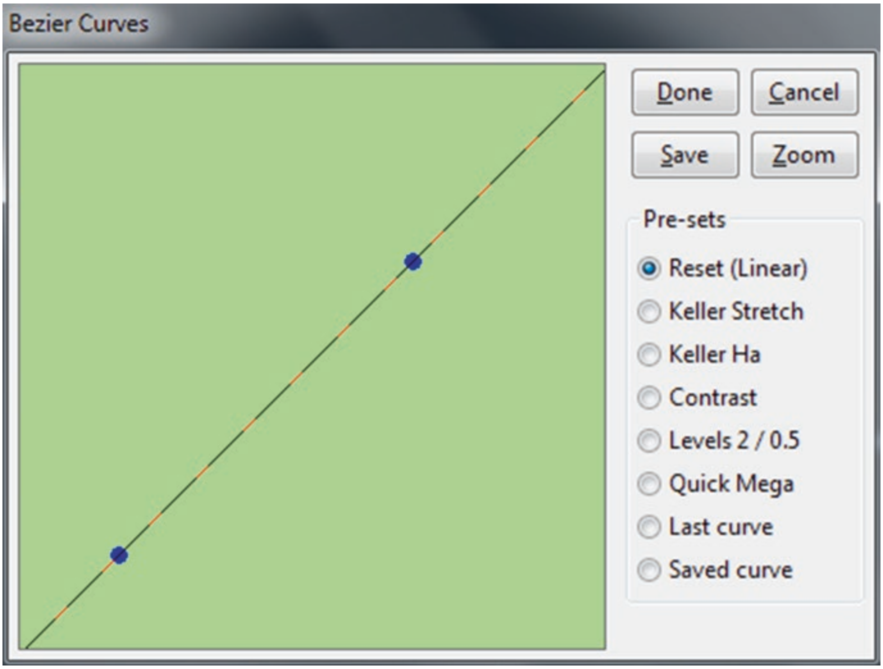

Fig. 9.11 Curves Graph. (Screenshot by permission of Nebulosity)

Combination of Controls

Of course, when processing astronomical images there is no single solution and images will benefit from the use of both levels and curves.

Mono Images

If you are simply taking mono images, apart from using sharpening and noise reduction functions you may not need to do any more, other than save the final image. Saving captured images should be done in a lossless format such as FITS or TIFF from the original file; it is then possible to create JPEGS for sharing which are smaller in size. This way there is a backup master image containing all the information captured.

Color Images

If you are shooting with a OSC or DSLR camera you will also need to color balance the image as it is usual for there to be a color cast. This may be a tool to simply do an overall color balance or a tool to neutralize the background caused by light pollution. As with a mono image the next step would be to save the image in a lossless format such as FITS or TIFF as a master that can be used to create JPEGS for use in emails etc.

RGB Color Image from a Mono Camera

It takes a few more steps to produce a color image using separate filters and a mono camera, but the basic process is the same up to the point where the images are calibrated.

Remember to use flats taken with the correct filter for the file they are to be applied to; this way any dust bunnies present will be removed from the filters used.

The images will then need stacking according to the filter they have been taken with. So for an RGB image all the red filter frames will be stacked together, all the green filter images will be stacked together and all the blue filter images will be stacked together. This will produce a stacked red file a stacked green file and a stacked blue file.

So if using red, green and blue filters to produce a standard color image you will have a stacked red filter master image a stacked green filter master image and a stacked blue filter master image that need combining to produce a color image.

These master images will need to be aligned with each other as in the stacking process but saved individually and not stacked together. This is to ensure that when they are combined as the color channels that make up the final image, that they are all aligned with each other and will produce a properly registered color image without color fringes.

When this stacking and aligning has been completed the images are used as the color channels in your processing software to produce the final color image. The resulting image must then be stretched to produce the final image showing all the detail and structure that it contains.

Narrowband Images from a Mono Camera

Narrow band filters such as Ha OIII and SII can be used in place of R, G, B filters to produce an image that whilst not visually accurate is capable of showing lots of detail at these different wavelengths. The images are then combined in the same way that is used to make an RGB image, but this time as this is producing a false color image, there is a choice in the way the image is displayed. This is done by choosing which of the Red Green and Blue channels in the image we place the individual narrowband images in.

Hubble Palette

The Hubble telescope combines its narrow band images using what is called the Hubble palette which is designed to show as much detail as is possible. This is done by remapping the color channels which is the process of using an SII filter image in the standard red image channel, Ha Filter image in the green channel and OIII in the blue channel.

So for a Hubble palette image the channels are combined as follows:

SII filter image is put in the red channel
Ha filter image is placed in the green channel
OIII filter image is placed in the blue channel

This is simply done by loading the appropriate image into each of the color channel dialogue boxes used in your chosen software package and watching as it produces a color image. The image will be, as mentioned, a false color map of the object but will show considerable detail due to the interaction of the mixed color channels.

The Hubble palette is only a starting point and any combination or mix can be used in order to show the detail required.

Bi Color Images

It can be useful to produce images that are captured using only two filters, if the object to be imaged doesn't contain information in all three channels. An example that works well with this technique is planetary nebulae. It is possible to achieve very successful color images of planetary nebulae only using two filters. This can be done by using Ha and OIII filters. The images need to be combined as follows:

The Ha image was placed in the red channel and The OIII image was placed in both the green and the blue channel. This produces an image which looks to have quite natural colors for the planetary nebula.

The Palette recommended for planetary nebulae using only two filters is:

Red	image channel contains Ha
Green	image channel contains OIII
Blue	image channel contains OIII

Luminance Channel

A luminance channel is another image channel like red, green or blue and it is added to an image to enhance detail, brightness and contrast. It should be taken at the full resolution of the camera. An advantage of using a luminance channel is that the R, G, B, channels or Ha, OIII, or SII channels do not have to be taken at the same high resolution. This means that the other channels can be discarded in order to increase the camera sensitivity and hence reduce the exposure time needed. This works because the high resolution is supplied by the luminance channel is used for the fine detail and the other channels supply mainly the color.

Stacking Software

There are many software packages that are used to stack and process images, and one such widely used program used is called Deep Sky stacker.

Stacking with Deep Sky Stacker

- In order to use deep sky stacker to stack your images you first have to ensure that you have your image files ready along with any calibration frames that you are going to use. This means the lights, darks, bias frames and flats.
- The first step is to open your image files or lights as they are known (Fig. 9.12).
- Using the menu on the left under registering and stacking load the images to be stacked, followed by the dark frames, the flat frames and the bias frames.

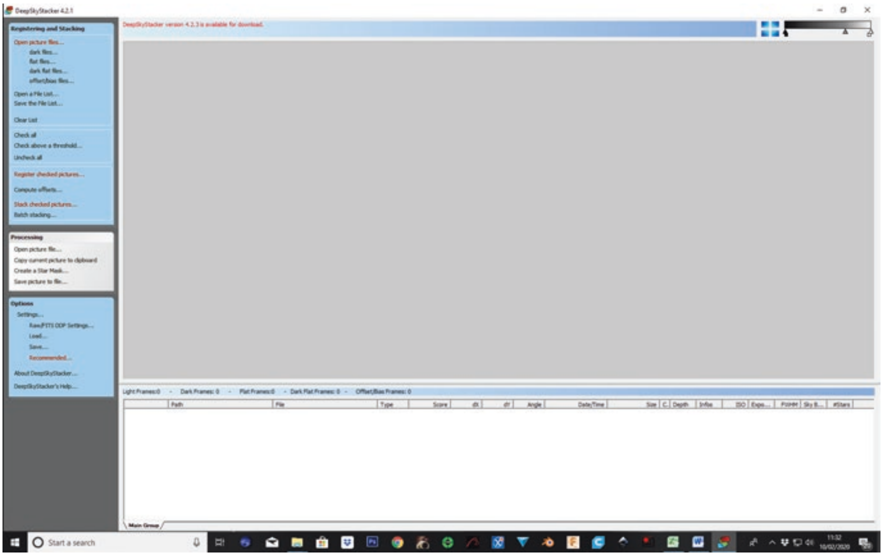

Fig. 9.12 Deep Sky Stacker Main Window. (Screenshot by permission of David Partridge)

- Once these have all been loaded make sure that they have a tick in the check box on the left next to each frame; this can be done using the check all menu option if you have looked through your files and are happy that they appear to be of good enough quality.
- This is followed by pressing register checked pictures which will bring up the following menu (Fig. 9.13).

- Pressing the recommended settings button will show the settings that the program recommends you use along with a brief summary of what it is going to do.
- Pressing stacking parameters will give you access to the manual settings available to you, for now however it is best to go with the suggested settings. So from the Register settings dialogue box press the OK button. This will show a stacking steps dialogue box which will show the stacking mode and alignment method to be used. It also shows the number of frames to be combined in the final image and the total exposure time of the frames to be used.
- This is followed by RGB details in case it is a color image that you are creating. Further down there are details of the calibration frames that will be used.

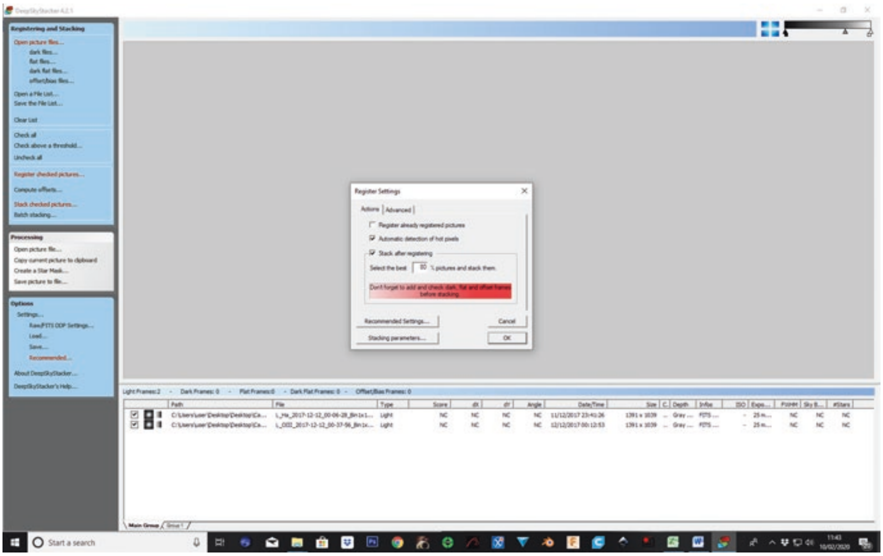

Fig. 9.13 Register pictures Dialogue. (Screenshot by permission of David Partridge)

- Again there is the option of recommended settings and stacking parameter buttons press OK to accept the software's recommended options.
- The images taken will now have the calibration frames applied and be stacked according to the recommended settings. Finally, your calibrated and stacked image should appear like so (Fig. 9.14).

- Below left of the image there is a histogram of the image information along with sliders denoting the black, white and mid tones that can be used to make the image data easier to see. The image can then be saved using the save picture to file option from the menu on the left of the screen. It is best to choose an image format that is lossless which means that it will not use a form of compression that might lose any of the original data within it. You now have an image which is ready to be further processed in order to bring out all the information contained within it. This is achieved by stretching the image using another piece of software.

Basic Technique for Stretching an Image Using Nebulosity

Nebulosity is a commercially available program that is very easy to use and has some very powerful features. The first step is to load the image into Nebulosity by using the File open file options from the menu at the top of the user screen.

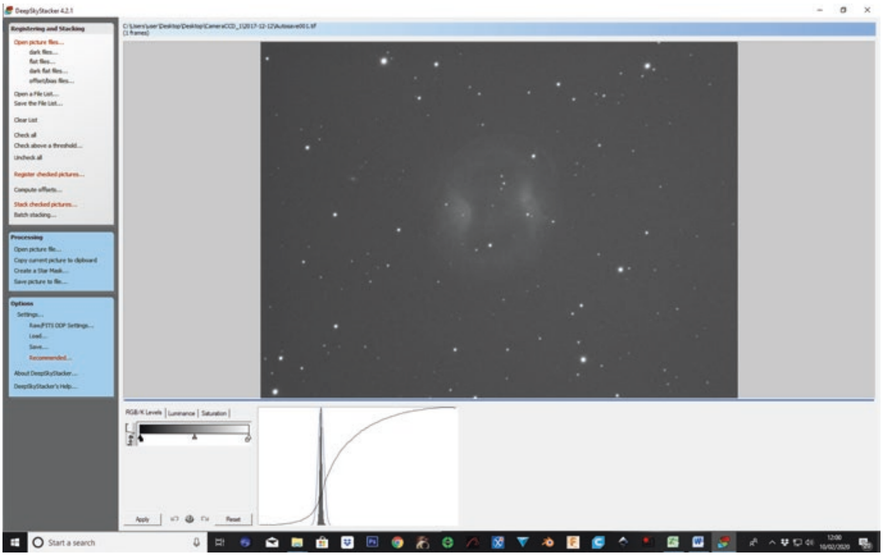

Fig. 9.14 Stacked image Display window. (Screenshot by permission of David Partridge)

Be aware of the histogram at the top right of the user interface; this has sliders for setting the black and white points and a check box to set these automatically. It has to be noted that this doesn't affect the actual image data and is purely applied to what you see on the screen to enable you to see what the image contains whilst you are working on it. One big mistake to avoid that many new astrophotographers make is to darken the background of their images too much and by doing so they lose detail contained in that part of the image by what is called clipping the black point (Fig. 9.15).

- When the initial image is loaded, the first screen doesn't look very promising but the data is hidden within this apparently featureless and dark image, all we have to do is make it visible by manipulating this data which is called stretching the image. This can be done quickly in Nebulosity by using one of its inbuilt tools called Digital Development Processing or (DDP), this can be found under the image menu (Fig. 9.16).
- The process starts by pressing the DPP button. This produces a stretched image and brings up a small slider dialogue box which contains the following controls.

Bkg	This sets the level for the background in the output image.
Xover	This sets a transformation point from a linear to a curved function.
B Power	This slider is also used to darken the background.
Edge detail	This smaller slider, at the right of the dialogue box, controls the amount of sharpening done during the DDP process.

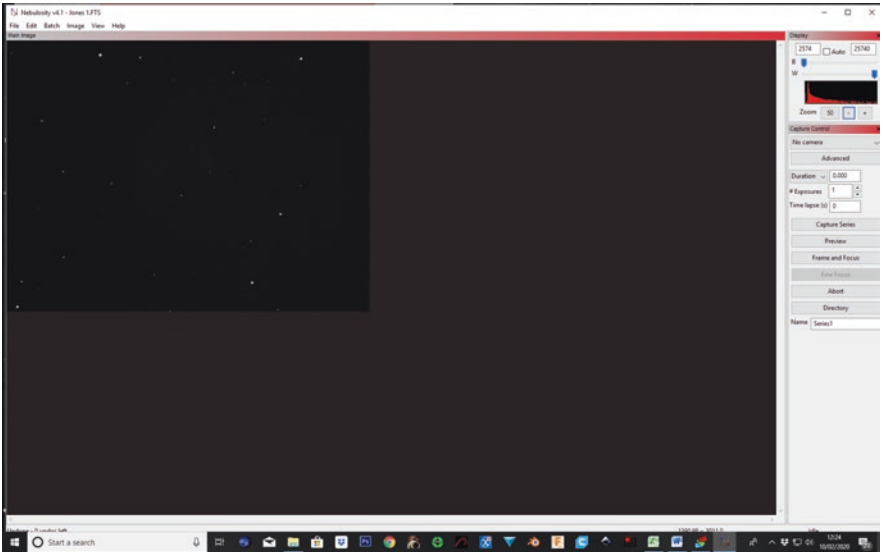

Fig. 9.15 Opening an image in Nebulosity. (Screenshot by permission of Stark-Labs)

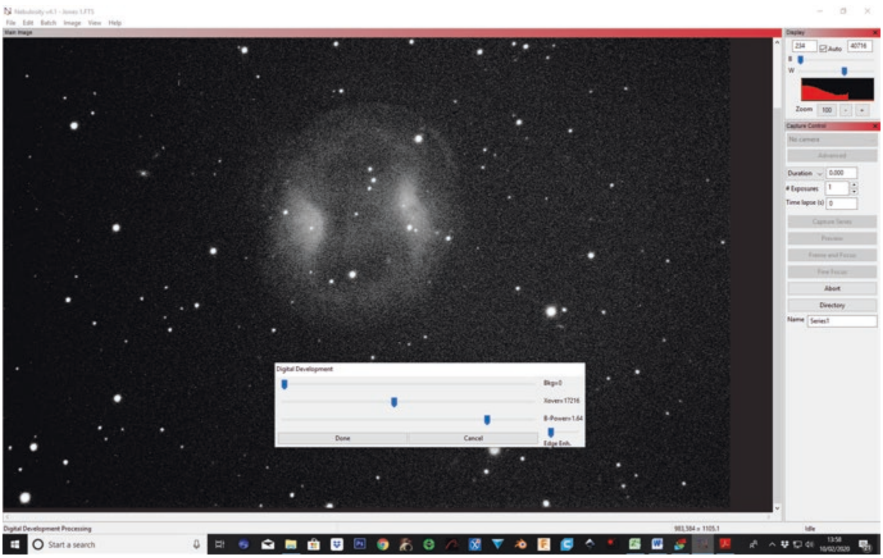

Fig. 9.16 Using DDP in Nebulosity. (Screenshot by permission of Stark-Labs)

- Once you start to move these sliders around it becomes very easy to both appreciate what they are doing, because they work in real time, and helps you produce a very fast stretched image. Please ensure that you move the sliders as little as possible as many beginners spoil their images by being heavy handed in the processing which introduces noise and processing artifacts.
- DDP might not produce the best image possible from the data in the image but it does give a fast and easy introduction to processing images which is necessary at this point as there is so much else to learn.
- More advanced techniques can come later but the images produced using this quick easy method will be much admired by family, friends and other astrophotographers.
- Nebulosity also has levels and curves controls which are available for a more manual control of processing images but this requires practice and care to get right
- Nebulosity has tools for reducing noise in images, for sharpening and for combining images taken through filters to produce both full color and narrowband color images (Fig. 9.17).

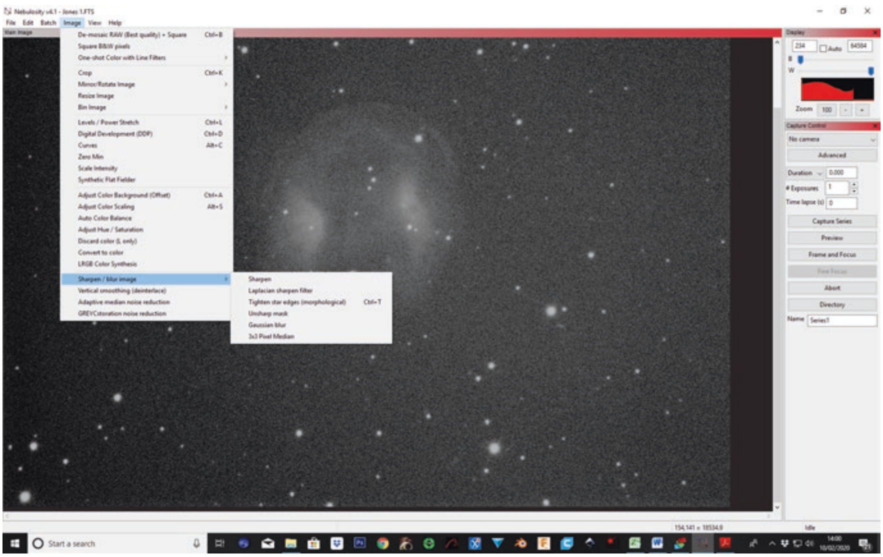

Fig. 9.17 Sharpening tools in Nebulosity. (Screenshot by permission of Stark-Labs)

Other Tools that Nebulosity Has that Are Worthy of a Mention Are

Synthetic flat field tool	this tool is a useful alternative where flat frames are not available for calibrating an image as it will extract an approximation of a flat frame from the image and apply appropriately. This is not as good as using a real set of flat frames but is useful if needed.
LRG Color Synthesis	This is the tool mentioned to combine mono images taken through filters to produce color images.
Sharpen Blur Image	This submenu contains powerful tools to enable you to sharpen and blur images. Use the sharpening tools with care though as they can easily start to introduce noise into your image and unwanted artifacts like dark halos around stars.

Pixel Stats

This is a very useful dialogue box which enables you to see the pixel intensities min, max and mean ADU values for either the whole image or under the cursor. This is useful if you are producing flat frames and do not want to use one of the tools available in other programs, enabling you to achieve the correct pixel value for your camera so that the flats work effectively.

Saving Your Images

It makes sense to keep images somewhere secure as you may wish to refer to them in the future.

Saving Old Calibration Frames

It is a good idea to save processed image files and also the original image files and the calibration frames used to process them. Saving image files like this means that as you revisit some of the same objects again and again you will be able add more and more data to them. This will develop images that are the results of many hours work and very long total exposure times, so the images will record more and more faint detail. This can only be done successfully if the calibration images are saved as well as the actual images.

By now you should have a basic understanding of what image processing is, why the process is necessary and the basic steps involved. Please use this as a very basic starting point as this is a huge subject and needs the investment of considerable time and effort in order to produce the best images.

Chapter 10

Troubleshooting

What to Do When Things Go Wrong?

Gather All the Information on the Problem That You Can

Due to the nature and complexity of an imaging system things will at some point go wrong, but happily most things that go wrong can be sorted out quickly and easily if you think things through carefully. The clues to finding the problem are always in the symptoms.

Think very logically and methodically, one of the best tips in resolving a problem is to ONLY CHANGE ONE THING AT A TIME! And then check to see if the problem has been resolved.

If you change more than one thing at a time you will not know which if any of the things you have changed cured or made the problem worse.

The Following Are some of the Questions That You Should Consider When You Have Problems

Was the usual setup procedure followed including opening all the pieces of software in the same order or was something done differently. Until the set up and running procedures are totally familiar, use a check list. This can be either printed or on your tablet computer or mobile phone.

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_10

If you use APT you can setup checklists which appear when you start the program. This is also useful to leave reminders from one imaging session to another.

If something was done differently; could it be related to the problem? If so go back and do things in the usual order.

Is this a new problem? or has it occurred before? If it has happened before, what was the cause and how was it solved last time.

It can be useful to keep a notebook and write down any problems and the steps you take to correct them. This can help if they crop up again by which time the correction might have been forgotten.

The Basic Steps in Solving Any Problem Are

- Understanding what the symptoms are.
- Deducing what can produce those symptoms
- Working out a possible solution
- Applying the solution
- Test to see if the problem has been resolved.
- Repeating as necessary until the problem has been solved.

Understanding What the Problem Is, and How It Presents Itself

The problem with your imaging system will usually become apparent quite quickly and you should make a note of what the problem is and what is affected. Is it just a software problem? Or is it something physical such as the mechanics or optics of the setup?

What Problems Can Produce the Symptoms You Are Seeing?

This might require a bit of detective work and may or may not be easily apparent at first glance. The problem will probably fall in one or more of the following categories. If you can discover which category or categories it falls into you are then in a better position to narrow it down and correct it.

Ask yourself the following questions; they should give you a starting point for finding the problem.

Power Problems

- A good tip with power problems is to check that all the devices equipped with power LEDs are properly illuminated. Also check that any fans are running such as those on cooled cameras. Is the power light on the telescope drive steady, or flashing especially when it is slewing? A flashing power light on Sky watcher telescope drives can indicate a low voltage problem.
- If only one device is affected try disconnecting the device and reconnecting it following the correct procedure for that device.
- If all the devices are affected check the main power supply is working. Are they on the same power circuit?
- Try resetting all devices on the circuit by disconnecting the USB connectors, then the power connectors. Finally restore the power, and then reconnect the USB cables.

Safety first!
Do You have a GFCI (known as an RCD breaker in the UK) fitted to Your equipment?

Using a GFCI or RCD breaker is an important safety consideration when using mains voltages outside where there may be damp conditions. Make sure your power supply or supplies if using more than one are adequately protected from the damp but at the same time are well ventilated in order not to overheat and cause a risk of fire.

Power Supplies

Make sure that any power supplies used are suitable for the job required by checking the requirements of the equipment. This means that they are capable of supplying the correct voltage and current and also the output plugs are set to the correct polarity.

Voltage Drop

Please also be aware that 12 volt DC power as used by most astronomy cameras and telescope drives and accessories is subject to voltage drops if the cables are long. So keep all 12volt cables as short as possible to avoid this.

Testing Power

If the problem is related to power and you do not have access to test equipment such as a multimeter and the knowledge of how to correctly use it, you might try substituting the suspected items for known good ones. This can apply to cables and power adapters and can be a very fast way of diagnosing problem equipment.

If all of this fails then the only option you have is to seek help from someone that has experience in fault finding.

USB or Com Port Problems

- Are all the device drivers loaded and up to date?
- Can you see the affected device or devices in the Windows Devices and Printers window?
- Are devices that use a Com port correctly configured, and is COM port number correctly set in the software that accesses it?
- Has the Com port number allocated to a device changed following a computer crash or restart?

USB drivers can be a source of problems, which can present themselves in all sorts of ways. One of the things to do is make sure that the most up to date drivers for your devices are being used. Sometimes you may need to uninstall a device driver and re install it again to clear a niggling problem with a device.

Configuration of Com Ports and USB Ports

USB or COM port problems are quite often solved by checking the configuration is correct and then disconnecting and reconnecting the effected device. If this doesn't solve the problem check the cables and try substituting known good cables If this still doesn't work try connecting the device to another computer to see if the problem is with the device or original computer. If this doesn't help you can try uninstalling it in device manager and reboot the computer then reinstall it to see if that helps.

COM Port Changes

Com ports are notorious for changing their port number following computer crashes or restarts. Check that the port number is set correctly if you are having problems connecting to a device that uses one following a crash or restart.

Mechanical Problems

- Is the telescope drive making any unusual noises and if so are they when it is tracking or when it is slewing?
- Is the telescope slewing normally to a target?
- Is the telescope tracking normally once it locates a target?
- Is the telescope tracking as accurately as it usually does?
- Is the telescope parking in the correct position?
- Is the telescope carrying out a Goto into the correct area of the sky?
- Is the autoguiding graph normal? Remember that the seeing conditions can have an effect on this as can wind.

Mechanical problems once identified may require basic adjustments to be made; but before going any further check if the mount is still in warranty as that might cover the work needing to be done. It could be that the mount is in need of a service. In more extreme cases it may be that the mount needs the worm drive requires replacement parts to be fitted such as the small bearings on the ends of the worm gear bearings replacing. This sort of work can be carried out yourself if you have the necessary knowledge and skills otherwise is best left to professionals as it will invalidate any warranty.

The aim should be to get the mount to track unguided producing images with pinpoint stars for 1–2 min. However, due to the polar alignment accuracy and condition of the mount, and how well the system is balanced, this may not be possible.

Clutches Too Tight

Are the axis clutches locked but not too tight? In a mount like the AZEQ6GT this can cause the axis movement to become a little stiff affecting the tracking. Most other mounts don't sufferer from this peculiarity.

Level the Mount

Whilst this is not strictly a mechanical problem and the software will try to compensate for errors, it is better practice to make sure the mount is leveled properly.

Bad Tracking

This could be a sign of poor polar alignment. Polar align the mount to the best of your ability; there are many software tools to help with this. Some are more complex and time consuming than others. Bad tracking can also be an indication that the telescope needs balancing or that cables are dragging.

Trailing Stars

If an image has trailing stars and the length of the trail is roughly proportional to the length of the exposure then the problem may be caused by one of the following:

- **Balance Problems**

The telescope may be out of balance which will put unnecessary strain on the drive system reducing the chances of it tracking accurately.

- **Cables Dragging or Snagging**

If the tracking problem is erratic and only happens from time to time it could be a result of dragging or snagging cables when the telescope is in a particular position.

- **Differential flexure**

This is a very common problem, especially with new setups and is the movement or flexing between two telescopes i.e. the guide telescope and main imaging telescope causing imprecise guide corrections. This can cause trailing that can change depending on the area of sky being imaged. In order for the autoguiding to work the two telescopes have to be connected together rigidly and without any possible movement between them.

- **Windy weather**

This can cause troublesome buffeting of the telescope see point 5, atmospherics.

- **Backlash**

The telescope drive may be suffering from slight backlash which can cause star trailing. PHD2 has the ability to measure the backlash and compensate for it as long as it isn't too severe.

If the backlash is excessive, it can make stars look like dumbbells. This can appear as all the stars in the field appearing to be double stars connected by a trail.

If the backlash is severe enough, there is no option but to find the cause of it and rectify it. This is usually done by adjusting the distance between the worm gear and the main gear that. The adjustment of these gears, whilst simple, can be quite tricky and time consuming to get right. If the mount is suffering from this sort of problem it is probably worth sending it to one of the available service centers to have it checked and adjusted professionally.

- **Correct tracking rate**

It may seem obvious but make sure the tracking rate is set correctly; in the case of deep sky imaging this will be sidereal time.

Optical Problems

- Is there an image from the camera?
- Are all the covers removed?
- Is the image in focus?
- Are the stars suffering from coma in the image?
- Do the stars have trails, if so do the trails follow the movement of one or both axes of the telescope drive?
- Are the clutches locked securely, but in the case of an AZEQ6gt mount do not lock them too tightly as this can cause movement of the axis to become stiff affecting the tracking.
- Is there a background brightness or color gradient across the image? Is it due to light pollution or in the case of some cameras it can be caused by an electrically noisy power supply?
- Is the image noisier than usual, has the camera cooler (where one is fitted) been turned on?

Optical problems can be a result of many things and are more common when using a reflecting telescope such as a Newtonian reflector.

Telescope Cooling Time

Has the telescope had sufficient time to fully cool to the ambient temperature? If this isn't done the telescope will not perform to its full capabilities and the focus is likely to change as it equalizes to its surrounding temperature.

Collimation

Newtonian reflecting telescopes need regular collimation to make sure that the optical elements are correctly lined up. Collimating a Newtonian telescope is a relatively easy task once mastered, and one that can be carried out quickly when required. See the section later in this chapter titled Collimation.

Coma Corrector

To ensure that the telescope produces sharp star images right across the field of view check if it is necessary to fit a Coma corrector (Fig. 10.1).

Coma is produced by the focal plane of the optics not being flat enough for the imaging sensor. This is not necessarily a fault but just a characteristic of come optical configurations (Fig. 10.2).

A coma corrector is a simple solution for a reflecting telescope or a field flattener for a refractor; it is an additional lens unit placed between the camera and the telescope and it corrects the field curvature, and ensures pinpoint stars across the full field of view of the imaging sensor. Sometimes these also act as a focal reducer, due to their design characteristics reducing the magnification of an imaging system by 0.8X.

Pinched Optics

A less common but easily introduced optical problem is pinched optics, where the retaining clamps or screws are too tight resulting in distortion of the optics. Severe pinching on the Primary mirror of a Newtonian reflector can result in triangular shaped stars.

Fig. 10.1 Coma visible in stars at the edge of the FOV

Fig. 10.2 Typical Coma corrector

Software

- Did the computer behave normally on start-up or were there any warning messages that need attention?
- Did the software start normally?
- Did all the USB devices connect to the computer correctly?
- Has the software correctly connected to the devices that it controls?
- Have any device Com port numbers changed? This can happen after a power interruption or computer crash especially in the case of old or cheap EQMOD adapters, which used an older CH340 chipset. A common problem with the cheap versions of these is that they only work with very a specific windows driver.
- Sometimes it is necessary to shut down the software and computer and restart it all again or reinstall the affected software.

Correct Detail Entry

Check that you have you entered the site location details longitude, latitude, altitude and time accurately, ensuring that the software is set to daylight saving time where appropriate.

The details text entry boxes do not always give the complete picture, there can be details after the data entered that are not visible. For example, the author used a GPS device to set the latitude, longitude, latitude and time for a few years with no problems. Using it again after a gap of a couple of years the telescope moved to all the park positions correctly but when told to go to an object in the South it moved North East and this level of error was repeated across the whole sky. This was eventually tracked down to corruption in the latitude and longitude boxes which could only be cleared by deleting the observing site definition and re-entering it. Just re-entering the coordinates did not help resolve the problem.

Collimating a Newtonian Reflecting Telescope

Collimating a telescope is the process of aligning the telescope optics with each other to produce the best quality image.

How to Collimate a Newtonian Reflecting Telescope

Once familiar with the performance of the telescope you will know when it needs collimating by looking at the images that it is producing. It is recommended that when purchasing a telescope new or second hand that the collimation is tested. The collimation may not have been carried out accurately in the factory or it could have altered during transit.

There are a number of ways to collimate a Newtonian telescope depending on the required accuracy. In the case of a visual observer this does not need to be done to the same accuracy as that required for imaging.

There are many ways to do this and the following is the recommended method.

Center "Spot"

The first step, if it hasn't already been done by the manufacturer, is to place a small ring exactly in the center of the primary mirror. The center spot targets on the center of the primary mirror to use as a reference for aligning it. Many people who have telescopes that are not equipped with a center spot use one of the reinforcing rings meant for use with ring binder pages. This is a small plastic self-adhesive ring which is perfect for the job. The ring needs to be placed in the center of the mirror; this can be achieved by measuring the diameter of the mirror and making a paper template to match then folding it in quarters to locate the center. A hole is then cut in the center of the template slightly larger than the center spot being used. Once this has been done the template can be placed over the mirror, making sure that it is carefully lined up with the edges of the mirror. The center spot can then be applied carefully to the mirror through the hole in the center of the template.

Checking the Secondary Mirror for Rotational Error

This is an important step which if missed can result in an apparently correctly collimated telescope that doesn't produce optimum images. The quickest and easiest way of doing this is to take the eyepiece out of the telescope, and move the focuser tube in or out until looking through the focuser you can see the whole of the secondary mirror, which should appear circular. The secondary mirror can be compared to the inside of the focuser tube to check it is circular. If it is, you can move to the next step. If it isn't circular, slacken the center screw holding the secondary mirror in its spider, and rotate the secondary mirror until it does appear circular. Then tighten the central screw to secure the secondary mirror again.

It is also possible to put a camera in the focuser tube and use its live view overlaid with a suitable circular reticule to check and adjust the secondary mirror to a higher accuracy if required.

Aligning the Secondary Mirror with the Primary Mirror

This can be done with a laser, as long as the rotational error mentioned previously is not present. This comprises of placing a laser collimator in the eyepiece holder and turning it on. Look to see where the laser dot falls on the primary mirror. The laser dot should be in the center of the mirror, as defined by the center spot (Figs. 10.3 and 10.4).

If the laser dot is not in the center of the center spot, loosen the center screw on the secondary mirror holder by a small turn, this will loosen it and allow the three surrounding screws to move the laser dot to the center point by loosening or tightening them as required. When this has been done, being careful not to rotate the secondary mirror, tighten the center screw again to lock it in place. Take another look to check the laser dot is still centered in the Primary mirror.

Fig. 10.3 laser Collimator

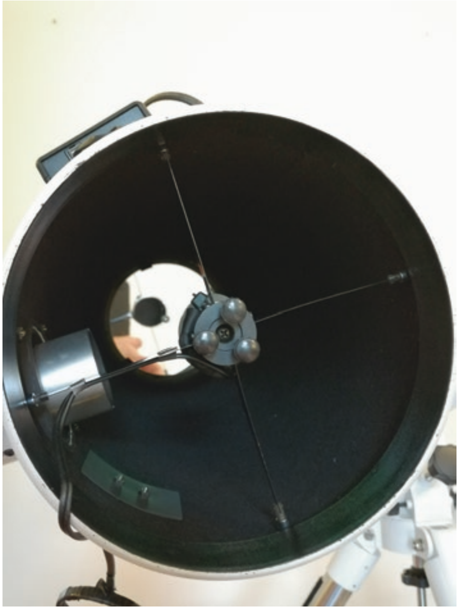

Fig. 10.4 Secondary Mirror Adjustment screws

Collimating the Primary Mirror

The primary mirror now needs adjusting so that it sends the laser dot straight back up the optical axis of the optics and, after striking the secondary mirror, it is centered on the laser collimator target.

The laser collimator usually has a target which is angled at 45° to make it easier to see. You should also see the laser dot reflected from the primary mirror via the secondary mirror shining onto this target. Next adjust the tilt of the primary mirror so that the laser dot disappears into the hole in the center of the laser collimator target (Fig. 10.5).

To collimate the primary mirror: look at the back of the primary mirror cell, you will see six screws they will be grouped in pairs. Of each pair one will be the adjustment screw and one will be a lock screw. The lock screws tend to be smaller long knurled screws and the adjustment screws tend to be knurled with a larger diameter. Slacken the lock screws and rotate the adjustment screws to bring the laser dot into the center of the target on the laser collimator itself. Once this has been done, retighten the lock screws checking that in doing so it hasn't moved the laser dot from the center of the collimator target as sometimes happens.

Fig. 10.5 Rear of an 8″ Sky watcher Newtonian telescope mirror cell

Finally, check that the laser dot is still shining in the center of the primary mirror and also central in the collimator target. If so the telescope is now collimated.

Camera Sensor Tilt

If your stars are elongated across the field of view when taking images, it may be due to the fact that the camera sensor is slightly tilted in relation to the optical axis of the camera. Some manufacturers, QHY for one, supply a special tilt ring that can be used to correct this if necessary.

Another cause can be if the focuser isn't true to the optical axis of the telescope. Most modern focusers have adjustment screws that you can use to correct any tilt.

If you have a heavy camera or camera and filter wheel, it may be that the weight of this equipment is causing the focuser to sag and distort. If the telescope is of good quality, this shouldn't be a problem. If the problem is that the focuser is flexing and adjusting it has not solved the problem, it might be worth upgrading to a better focuser which is capable of being used for astrophotography.

Atmospherics

It is important to remember that the earth's atmosphere is a turbulent place and the movements and temperature differences within it will have a huge influence on the quality of the images that the telescope is able to produce (Fig. 10.6).

This image shows a star being allowed to drift across the field of view by turning the telescope tracking off while the camera is exposing which, under ideal conditions, should produce a very slightly curved but clean line depending on the focal length and declination of the star chosen. The image here shows a very turbulent atmosphere and one that is going to prove problematic if not impossible to produce high quality images under.

Pinched Optics Caused by Over Tightening of the Main Mirror Clips

Pinched optics is caused by the primary mirror retaining clips being fastened too tightly, resulting in pressure on the primary mirror. This produces distortion of the mirror and results in the triangular stars as you can see in the images below of the galaxy NGC 4565. This was caused by overzealous tightening of the primary mirror clips following cleaning of the mirror. This is one of my first CCD images ever taken and was processed as a single image without any calibration frames (Fig. 10.7).

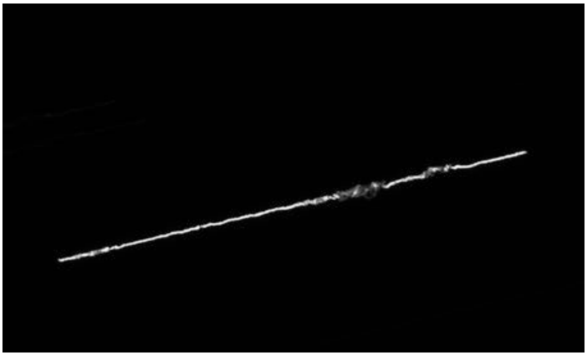

Fig. 10.6 Atmospheric turbulence on a star image

Fig. 10.7 Triangular stars galaxy NGC4565

Star Trails Caused by Loose Mirror Clips

The reverse of mirror clips being too tight is that they can be too loose resulting in star trails in your images, despite having a good auto guiding graph. From a finder guider.

Adjusting the Primary Mirror Clips

- The way to judge if the mirror clips are at the correct tension on the mirror is to very carefully place piece of paper between the face of the clip and the mirror surface.
- The clip is then tightened to the point where you can still just slide the paper out from the gap between the mirror and the clips; this will hold the mirror securely but will not place stress on it producing optical problems.
- The side retaining screws should just be touching, but not exerting pressure on the sides of the primary mirror (Figs. 10.8 and 10.9).

I hope that this chapter will never be needed but is helpful if it is.

Fig. 10.8 Primary mirror cell removed showing mirror clips and center spot

Fig. 10.9 Primary mirror clips and retaining side screws; these must not be over tightened

Chapter 11

Where Do You Go from Here?

Now that you are able to setup and run an imaging system it requires a lot of practice to become fully familiar with it, and even more time to perfect your techniques, tweaking your imaging system until you are getting consistently good results. Once you have achieved this you can think about what sort of imaging you really want to do. It may be that just going from object to object is sufficient or further learning is necessary for more advanced work.

Sooner or later many proficient imagers decide to carry out some sort of project to give their work a focus and add meaning to what they are doing. Long term projects are a great way of doing this and you may undertake these as an individual or a group of like-minded amateurs.

The following are a few ideas for projects that may be give you some ideas:

Short Term Projects

- Image all the messier objects.
- Image all the chosen deep sky objects in a particular constellation.
- An overview mosaic of a large area, inserting close up images of the objects within it.
- Look for variable stars in open or globular clusters.

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_11

Long Term Projects

- Image all the chosen deep sky objects in a particular constellation.
- Produce your own photographic catalogue of deep sky objects.
- Produce your own deep field shots by taking images of a particular area every time you have your equipment running, with the intention of stacking them when you have many hours of images.
- Produce a detailed mosaic of a large object.
- Taking long term images of the Crab Nebula M1 to capture its expansion over time.

Supernova Searches

A supernova search is a fascinating long term project in which you take regular images of a list of chosen galaxies. It is possible that you may be the first to image a star in that galaxy going supernova. Depending on your equipment, the exposure times need not be as long as taking an image of the galaxy as the supernova will appear as a point source, and will show up on much shorter exposures then those required to take an image of the galaxy itself. The aim is in the first place, to detect the brightening of a star going supernova; this is best done by having a reference image of the galaxy, preferably taken with your own equipment, which you can then use the blink function in software to compare the images. Any changes between the reference image and one being checked will be very quickly spotted.

In order to do this effectively it is necessary to identify the most likely galaxy candidates for the search as some are much more active in this respect than others, take for instance NGC5468 which has had 5 supernovas in the last 20 years and as a result is subject to monitoring by the Hubble Space telescope.

To search for a supernova, it is necessary to pick the galaxies you intend to monitor very carefully. It is most effective if you can image them all year around, but this is not always possible if they are not circumpolar.

Your search may be done manually, or if you use software like Nina which is capable of full robotic operation of a telescope it can be done without intervention and can even be fitted in around other imaging.

Supernova may belong to 2 types:

Type 1 supernova happen when one of a pair of binary stars has already gone supernova, resulting in it becoming a black hole or neutron star. When its companion then reaches the end of its life and departs from the main sequence to become a red giant, it starts to have its material siphoned by the black hole or neutron star. This material forms into an accretion disk. This eventually causes the red giant to reach a tipping point and it too then turns supernova.

Type 2 supernova result from a star reaching the end of its life and becoming unstable as a result of depleting all its hydrogen and helium

Monitoring Variable Stars

This can be carried out by having a list of variable stars that you wish to monitor in a similar way to a supernova search list, but in this case you know that the stars to be imaged are variable and it is a case of imaging them, and then carrying out photometry using software in order to take very accurate brightness measurements. These measurements can then be plotted to show the light curve of the star. Depending on your local sky conditions, this could be a very long term project.

Collaborative Projects

The following are a few collaborative projects:

Osiris Rex – Target Asteroids

https://www.asteroidmission.org/get-involved/target-asteroids/

This is a citizen science project which is contributing to our knowledge of near-Earth asteroids.

Zooniverse

https://www.zooniverse.org/

This is a list of research projects, open to amateur involvement, encompassing all areas of the sciences.

The PACA Project

https://www.facebook.com/ThePACAProject/

This is a pro-am collaboration to study comets

American Association of Variable Star Observers

https://www.aavso.org/

This is a very active group of amateur astronomers carrying out detailed studies of variable stars.

Center for Backyard Astrophysics

https://cbastro.org/

This is a citizen science project studying cataclysmic variable stars

Chapter 12

DIY Projects

The following projects vary in difficulty but all require that you have some skills in DIY cutting and drilling and also soldering. If you feel that these projects are beyond your capabilities or the tools that you have are not adequate I would recommend that you buy commercial versions to avoid disappointment frustration and potential accidents and damage.

If you do have the tools and skills it is very satisfying to complete the projects and can also save you quite a lot of money. If you do attempt to build any of them I would stress that you should thoroughly check your work and test it before use as mistakes can prove costly and cause damage to other equipment.

No doubt you will identify the projects that will be of use for your equipment and you may already have built or bought some of these depending on how advanced you are in astrophotography.

I started by building the USB and power distribution box which is mounted on the telescope tube and reduced my cabling to one 12 v power cable and one USB cable running up to the tube from the mount. Trailing cables can cause problems by snagging or even dragging as the telescope is tracking, so this arrangement is an improvement. This type of setup also means that all the devices on the telescope tube are permanently fixed and wired onto it reducing the time taken to setup the equipment ready for use.

M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2_12

Project 1 Heater Controller

Warning; as with all heaters, if it is used carelessly or incorrectly, this controller is capable of supplying enough power to cause a fire or damage. It is very important to fully test the heater controller before using it, and do not leave it unattended when in use.

This is a very simple, inexpensive and effective project which enables you to use most commercially available heater bands on your telescope in order to prevent dew causing problems whilst imaging in high humidity environments. The basis of the controller is the use of an LED strip dimmer module; these are fully adjustable and capable of supplying 12 Volts at 8 amps output, which is more than enough to power your heater straps.

The dimmer modules used may be found on EBay.

One of these modules is also used in the main mirror fan project to control the speed of the fan.

1X DC 12 V/24 V 8 A LED switch dimmer module for LED strip single color VQ V LED.

The dimmer module may be used as it is by fitting a coaxial phono plug directly to the output cable (Fig. 12.1).

If you are just using the dimmer module to control one heater strap, you simply need to connect to the power supply as shown in the photograph and solder an inline audio socket to the end of the cable going to the heater strap. In this case it makes sense to keep the controller in its existing case and simply attach it to the telescope in the required location by either using the case screw holes to fasten it, or by using Velcro strips. Velcro has the advantage of not requiring any holes to be made and the device can be removed and repositioned as needed (Fig. 12.2).

It is suggested that when testing it, always connect it with the power dial turned to the minimum setting, and then slowly increase it very gradually over a few minutes so as not to cause the heater straps to get warmer than is required.

Or removing the controller module from its box and putting it in a suitable project box and using chassis mount phone sockets as seen here remembering to connect the positive wire to the center connector and the 0 volts or ground to the tab that can be seen sticking out at the side of the picture.

It is very simple to connect the controller modules and only requires four wires. Two wires supply the 12 volt power to the controller and the other two wires are the output from the control module. The convention is that the

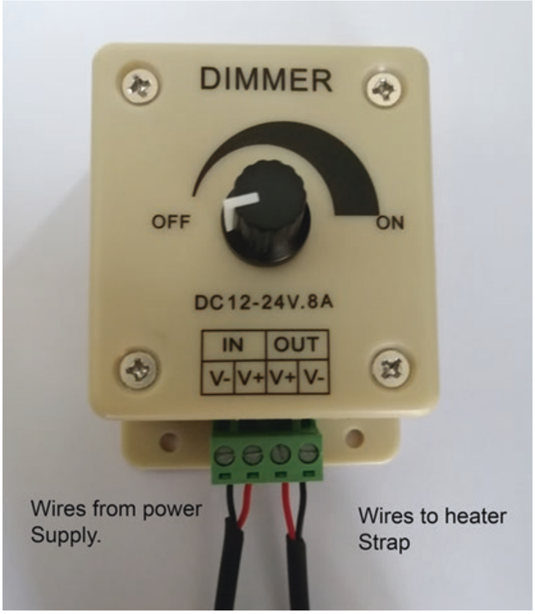

Fig. 12.1 LED controller used as a Heater Controller

Fig. 12.2 inline Phono socket connector used to connect the controller to the heater strap

+V output from the controller is connected to the center terminal of the phono socket and the negative output is connected to the tag on the side of the phono socket. This is then wired correctly to use with commercial heater straps or you can even make your own.

Putting It All Together

If you plan on using more than one heater strap it is still possible to keep the dimmers in the original cases and place them side by side using hook and loop tape. It is neater if you are confident enough however to re-case the required number of controllers in a single project box as follows.

Pull the control knob cover off, these do tend to be on very tightly and might require levering the knob off with a flat bladed screwdriver. When this has been done undo the four screws at the top of the dimmer module box being careful not to damage the cable that goes to the control knob. Undo the locking nut that is around the control knob stem potentiometer. Remove the potentiometer assembly carefully again so as not to damage the fragile wires that connect it to the circuit board. Pull the choc strip connector plug off and set it to one side. Undo the screws securing the circuit board to the case and remove it.

Drill the required holes in suitable positions for the chassis mount phono sockets to fit into and a hole suitable for a 12 v power lead to enter the case. You will also need to make holes suitable for the potentiometers to fit into so that you can control the heater output levels.

Mount the circuit board in the bottom of the case either by screwing it in or using a dab of glue to hold it place. I don’t recommend using a hot glue gun as this has a tendency to overheat the circuit board and case it to fail. Once the circuit board has been mounted you need to mount the chassis mount audio sockets in their respective holes in the case. You can then proceed to wire it up by simply duplicating the wiring for as many controllers as you intend to use and wiring them to their respective output sockets. In this case you may wish to use a panel mounted set of audio sockets as this will give a neater finish and is easier to install requiring only two screws (Fig. 12.3).

When the wiring has been completed and the pull off connectors have been plugged back into the module circuit board the potentiometers can be fitted in the holes cut for them and they can be secured with the locking nuts. It just remains to replace the knob back on the potentiometer having first turned it to ensure it is set at the minimum setting which is fully anticlockwise.

Have one last check of the wiring to make sure you haven’t made any mistakes it can be very useful to get someone else to look it for you just as a final check.

Fig. 12.3 Bank of 4 Phono sockets

First Use

I suggest when testing the controller that you always turn the power knob to its minimum setting before you connect the power then slowly increase it very gradually over a few minutes noting how warm your heater gets. Be very careful so as not to cause the heater straps to get warmer than is expected or required and cause damage.

It is a good idea to use an Infrared thermometer to check the temperature that the heater straps are achieving periodically to avoid any damage or risk of fire.

The idea is to raise the temperature of the mirror or lens being protected just a couple of degrees above the ambient temperature as this will prevent any dew forming which would spoil your images.

Project 2 Power Distribution and USB Box (Fig. 12.4)

Description

The power distribution and USB box is an essential tool in keeping your imaging system organized and neat which will also help reduce the setting up time. This is a very simple project but will save time setting up the imaging system.

The distribution box is designed to supply the imaging system with the power that all the devices need along with a USB hub so that the USB wiring

Fig. 12.4 USB and Power Control Box

to the telescope system is kept to a minimum. In order to do this effectively, the positioning of the distribution box is important as with the correct positioning it makes the system very quick and easy to setup and break down. It also reduces the number of moving cables which can be a source of tracking errors. It may be said that it is better to keep the 12 v power cables separate from the USB cables, but in practice this has not caused any problems.

Requirements

You will need to be able to carry out basic soldering to complete this project; you will also need to be able to use a test meter.

Parts Needed

Project box large enough to hold everything
12 v Power socket and plug connectors suitable for use with the case. These are used to supply 12 v to all the devices on your imaging system.
Aircraft power socket and plug for 12 volt power into the distribution box.

USB hub, preferably one that can be powered and has a switch for each USB outlet even though it may be necessary to unplug some devices to reset them as the switches seem to only switch the power from the hub and not the transmit and receive data lines.
Screws as required for your particular build.
Wire of a suitable gauge for the power of your equipment
Switch
Fuse holder
12 v to 5 v Dc to Dc converter or LM7805 Voltage regulator
Solder
Shrink Sleeve

Assembly

Begin construction by deciding how many devices are to be catered for. It is suggested that allowance is made for at least 2 extra devices for future additions if required. Depending on the physical size of the telescope you may want to mount the finished distribution box on either the telescope tube or the dovetail, unless space is at a real premium in which case it can be mounted on the telescope tripod or pillar mount. Give some thought to the way that the cables will be routed so that they do not foul other distributions or parts of the system.

Begin by marking out the position of the USB hub, followed by the power socket. This can be done easily by putting white masking tape on the box and then using a pencil to draw out the correct positions for mounting the parts. The tape is then removed when no longer required (Fig. 12.5).

Drill mounting holes for the sockets switches and fuse holder taking care to follow your tools safety and operating instructions. Always wear eye protection when using power tools (Fig. 12.6).

Mount the sockets fuse holder and switches in the holes you have made for them making sure that they are nice and secure (Fig. 12.7).

The distribution box is wired as the following picture shows, in this case an inline fuse is used (not shown) (Fig. 12.8).

When the distribution box has been wired up as in the above picture, check with a test meter that the polarity of all the power sockets is correct otherwise there is a risk of causing some expensive damage to the equipment and it would be wise to get somebody competent in electronics and wiring to check the work before attempting to connect it to a 12 v power source.

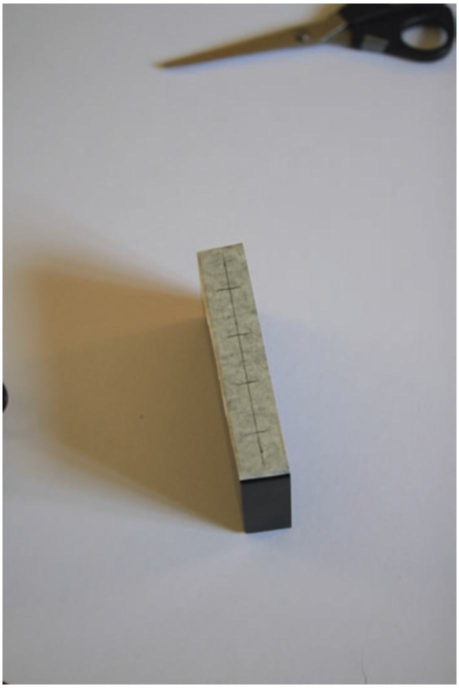

Fig. 12.5 Mark out the project box for drilling the socket holes

Fig. 12.6 Holes Drilled for all the Plugs and sockets

Fig. 12.7 Sockets mounted in project box

Fig. 12.8 Connect the Wiring as per this picture

To complete the project, simply mount a 4 port USB hub on top of the box as seen in the main picture. This now provides a power and USB hub that can be used to reduce and simplify the wiring on the telescope.

Mounting the Distribution Box

The best position for mounting the distribution box depends on the telescope system.

- A small refractor may need the distribution box to be mounted on the dovetail due to the small diameter of most optical tube assemblies.
- A Newtonian reflector telescope may have space on the side of the tube to fit it with Velcro sticky pads.
- The distribution box may also be fitted on the side of the telescope drive if there isn't anywhere on the telescope tube that is suitable.

The wiring between the distribution box and the devices can be held firmly in place without damaging or altering the telescope tube by using self-adhesive two way pads and tie wraps.

If confident enough, it is possible to make your own USB cables for your devices that are the exact length required, resulting in a very neat and durable setup. If you are not comfortable with making custom length cables just buy the closest to the length that you need and make sure that they are well secured and neat.

Once this distribution box has been fitted, you only require one USB cable from the computer to its Hub and one power cable to feed all the devices on the telescope.

Project 3 Primary Mirror Fan (Fig. 12.9)

Description

The Primary mirror fan is designed to fit to the rear of a Newtonian reflecting telescope, and has two main purposes.

1. Help cool the primary mirror quickly to match the ambient temperature so that high quality imaging may be started without long cooldown times.
2. Helps remove the primary mirror boundary layer of air, this is a thin layer of air that hugs the surface of the primary mirror and reduces the image quality.

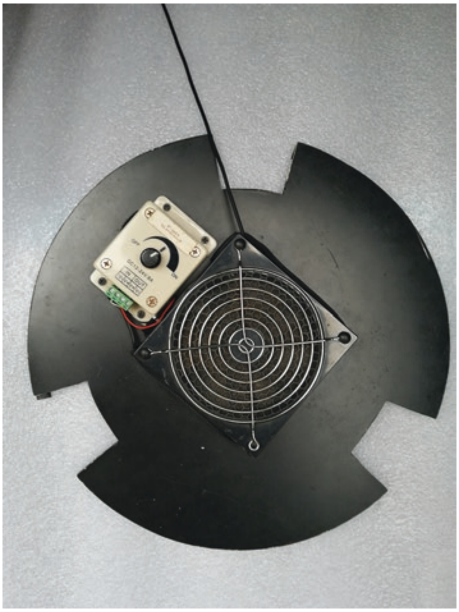

Fig. 12.9 Primary Mirror Fan

The fan is made to operate at two speeds a fast speed to ensure the rapid cooling that is required and a slow speed which is just enough to remove the boundary layer of air from the surface of the mirror. If it is left at full speed this is likely to have two undesirable effects.

1. The fan may cause excessive vibration.
2. The fan will cause the telescope tube to be full of turbulent air which may affect the image quality,

Requirements

- You will need to have a basic understanding of electricity.
- Basic hand tools will be needed to fabricate the fan unit.
- Always observe relevant safety rules when using hand tools and dealing with electricity.

Parts Needed

- **3 mm Plastic sheet**
- A sheet of stiff plastic, approximately 3 mm thick and large enough to cut a disk the size of the inside of the telescope tube at the mirror cell end.
- **Computer Fan**
- A good quality computer fan, of a size suitable for the telescope mirror size, or use more than one fan as long as you try to ensure that the resulting airflow over the back of the primary mirror is relatively even. Using a good quality fan will reduce the chances of vibration affecting the images. Pay attention to the type of bearings the fan has, as cheap sleeve bearings tend to get noisy and cause vibration as they age and can perform poorly in the orientations that they will be subjected to whilst mounted on a telescope.
- **Fan Guard (optional but recommended)**
- The fan guard is a small wire grill that mounts over the exposed side of the fan and prevents fingers or other objects touching the rotating fan. This can cause cuts to fingers and the loss of fan blades which will render the fan useless due to excessive vibration.
- **PWM control box**
- LED dimmer controller, these are sold on websites such as eBay. This must be capable of operating at 12 v and capable of supplying the current as required by the fan used.
- **Wire**
- Standard automotive wire
- **Power socket with tail**
- These can be purchased online and are easy to use as the plug already has a short length of wire attached which can be stripped and secured in the screw connectors on the LED controller without any soldering being required.
- **Screws to mount the control box**
- The screws need to be of a size and length suitable to mount the LED controller on the fan unit.
- **Velcro**
- **Screws to mount the fan**
- The fans will quite often come with screws, but these may not be suitable for mounting it for this application.
- **Hook and Loop pads or tape**
- These are used to secure the fan unit to the rear of the telescope and also facilitate the fan's quick and easy removal.

Construction Details

Start by measuring the inside of the telescope tube behind the main mirror cell. Cut the plastic sheet into a round disk so that it fits snugly in this space, making sure to make cut outs to go around the collimation screws and lock screws (Fig. 12.10).

Cut a hole in the center of the plastic disk suitable for the fan to blow through, and drill holes for the fan mounting points around this hole.

Drill holes suitable for the control box mounting screws in a position suitable for the set up. Fasten both the fan and control box to the same side of the round plastic base.

Wiring the Unit Up

Connect the fan the fan control module and the power supply as per the following diagram (Fig. 12.11).

Use the Velcro pads to attach the assembly to the rear of the telescope.

Using the Fan

The fan may be used at full speed to quickly cool the main mirror before using the telescope and is then turned down until it is spinning quite slowly during the imaging session. This will still remove the boundary layer of air

Fig. 12.10 Show cutouts

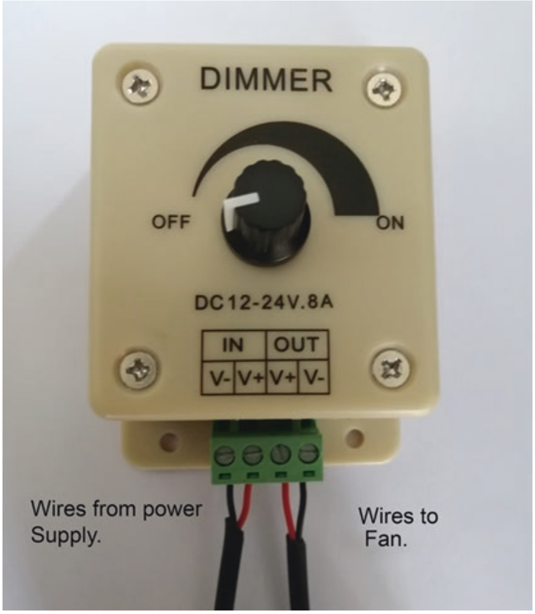

Fig. 12.11 Picture of how to wire the controller

from the main mirror and keep it from coming back. It is useful to mark the normal slow position of the fan control knob so that you can set it to its standard speed quickly.

Note

If you turn the fan on or off or change its speed during an imaging session you will probably need to refocus your telescope.

Heater

A small solid state, fixed temperature heater module may be added to the unit behind the fan but the airflow will need to be well diffused for it to work properly. This will provide a gentle heat to the main mirror to prevent it from getting covered in dew on really wet nights; this will also provide a very gentle stream of air going up the telescope tube and may reduce the need to have a heater on the secondary mirror.

Warning

As the fan is mounted to the rear of the telescope, it may have to be removed before you take the telescope tube off the mount and stand it on end as it may get damaged. It may also prevent the telescope from standing up on the fan end due to the control knobs standing out.

Project 4 DSLR Cooler (Fig. 12.12)

When an electronic imaging camera operates its circuits produce heat and some of the effect of this heat is to produce electrical noise, particularly in the imaging chip and its amplifiers.

Dedicated deep sky astrophotography cameras do this by using circuitry that has been optimized to produce very low noise levels and very careful choice of the imaging chips that they are designed around. They also cool the imaging chip to a low temperature, which results in a much cleaner

Fig. 12.12 DSLR Cooler

noise free image; this is a huge advantage when dealing with very faint objects and hence low signal levels.

A DSLR cooler is an electronic device that aims to enhance the use of a DSLR camera for astrophotography by reducing the electrical noise by cooling the imaging sensor.

Adding this form of cooling to a standard DSLR enhances its image signal to noise ratio considerably, resulting in the production of cleaner less noisy images compared to one that isn't cooled. This in turn enables the photographer to take images of fainter objects, as they are not hidden in as much noise.

How Is a Dedicated Astronomy Imaging Camera Cooled?

Dedicated astrophotography imaging cameras are usually cooled by the use of an electronic device called a Peltier device which is a solid state heat pump. The imaging chip is usually mounted on a cold finger, which is a small pillar of metal mounted on the cold side of the Peltier device. There is also a temperature sensor and control circuit to enable the imaging chip to be cooled down and held at precise temperatures. This repeatable temperature also enables more accurate calibration frames to be taken, and this further improves the possible images produced (Fig. 12.13).

As can be seen from the picture it comprises of two conductive ceramic plates with dissimilar metal junctions between them. The property of which is that once supplied with a DC voltage to the device, one side of it will cool

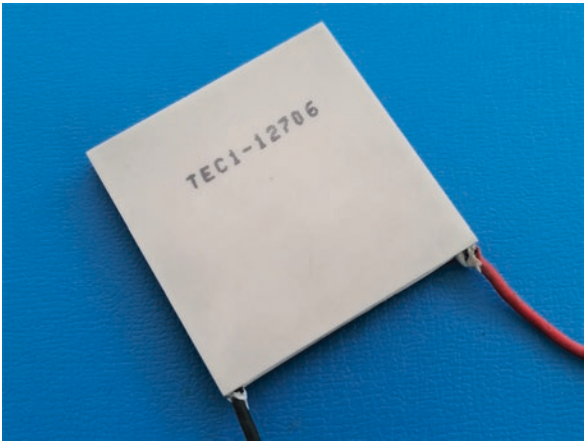

Fig. 12.13 Picture of a Peltier Device

down and the heat from it will be transferred to the other side making it warm up. This continues until the cold side reaches its minimum temperature. This can only happen as long as the heat from the warm side is dissipated usually by a heatsink and fan. If the warm side fails to dissipate enough heat the cooling reduces or even stops as heat bleeds back into the cold side.

The Peltier device therefore, needs to have a good heatsink and fan to remove the transferred heat and allow the cooling to continue.

Cooling a DSLR

There are many ways to cool a DSLR camera; the following are some of the methods of cooling a DSLR camera to try to reduce the noise produced by the electronics.

Cold Box

This method simply puts the whole DSLR camera in a cooled and insulated box and therefore cools the entire camera.

Re Case

Otis possible to disassemble the camera and put the electronics and imaging chip in a new case that then gives direct access to cool the imaging chip. This is a tricky and potentially risky way to cool the camera.

Cold Finger

This method still requires a certain amount of disassembly of the camera but keeps it in its original case, albeit modified to take a cooling system on the outside and a cold finger which reaches the back of the imaging chip to facilitate heat removal. This is usually done by opening and widening one of the camera case seams, allowing a thin piece of metal (the cold finger) to reach the back of the imaging chip. This does require disassembly and modification of the camera with the possible risk of damage. For this reason it is not a recommended method of cooling as it can still be done effectively enough to see a difference in the results without any modification to the camera.

Indirectly Cooled the Method Used in This Project

Warnings

1. This method must not be used on cameras that do not have a flip out screen due to the probability of permanently damaging the screen if the cooler is placed directly on it.
2. Do not leave this cooler set on full or there is a risk of ice forming inside the camera where it cannot be seen. This may also cause permanent camera damage.
3. If you do not have the knowledge or skills to build this safely ask someone who is suitably qualified to avoid possible damage to your camera and telescope or buy a commercial cooler.

This is the simplest method and allows the cooler to be removed and the camera used as normal. This is best achieved with a camera that has a flip out screen. Basically the screen, which tends to be positioned roughly behind where the imaging chip is positioned inside the case, is flipped out. Once the screen has been flipped out, the cooler is positioned in the recess where the screen would normally reside. The cooler is then fastened in place using the tripod screw fitting in the camera base. The cooler then cools the imaging chip through the rear of the camera case, and whilst this doesn't tend to achieve the same levels of cooling, it still achieves very worthwhile results. Remember that the effect of cooling gives diminishing returns, in other words, after the first few degrees of cooling, the benefits get smaller and smaller. This means that even just a small amount of cooling the camera chip reaps large benefits.

DSLR Cooler Parts Needed

- Computer CPU heatsink and fan
- Thermostat module
- Peltier device
- Piece of 5 mm thick Aluminum cut to be a snug fit in the LCD screen aperture
- Piece of aluminum 5 mm thick 30 mm × 100 mm

- DC Power socket
- Tap and Dye set
- Heat transfer pad cut to fit aluminum plate
- Nylon screws
- Thermal paste

Construction of the DSLR Cooler

The first step in constructing the cooler is to cut the aluminum heat transfer plate so that it is a snug fit in the LCD screen recess of the camera (Fig. 12.14).

Once this has been done, mark the positions for the holes that will clamp it to the back of the CPU heatsink, this is done allowing space for the Peltier module to sit in-between them as shown (Fig. 12.15).

Drill holes through aluminum heat transfer plate, and also holes in the rear of the heatsink, which also needs to be tapped. Take care tapping these holes slowly and use plenty of lubricant as it is very easy to break the tap whilst threading the holes.

Make sure that both sides of the Peltier device and the heat transfer plate are very clean; you also need to clean the rear of the heatsink. Spread some thermal paste on the back of the heatsink where it will be in contact with the Peltier device and carefully position the Peltier device onto it.

Spread some more heat transfer paste on the Peltier device and place the heat transfer plate in position and screw it on using the nylon screws making

Fig. 12.14 Heat transfer plate

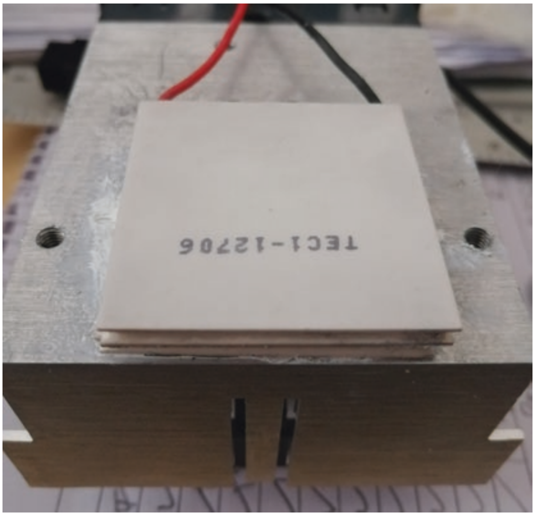

Fig. 12.15 Peltier module positioned in between mounting screw holes

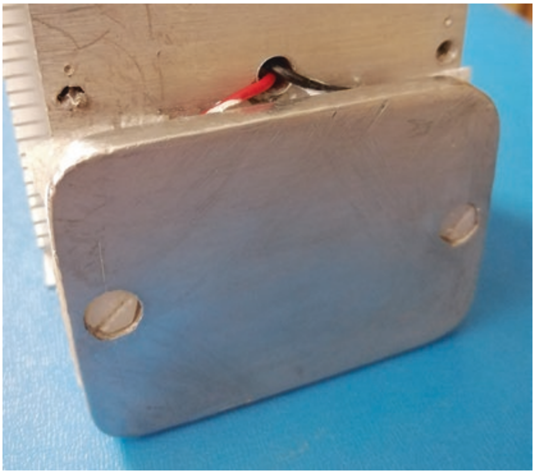

Fig. 12.16 Heat transfer plate attached to cooler

sure that it is secure but not so tight as to strip the threads off the screws. The screw heads do need to be flush with the surface of the heat transfer plate so that it makes good contact with the back of the camera (Fig. 12.16).

The thermostat module needs to be mounted on one of the solid sides of the heatsink so as not to obstruct the airflow and reduce the efficiency of the device. This can be done by screwing it or using glue whichever is easiest.

Make sure that the display and buttons are accessible when the cooler is attached to the camera.

Depending on which thermostat module you use, it may require mounting in a project box or already be cased whichever is easier.

You may now mount the temperature sensor in a suitable place on the heat transfer plate; this will vary from camera to camera, but the idea is to get it to read the temperature of the transfer plate so the cooling can be regulated. This temperature reading isn't the actual imaging chip temperature but is good enough to ensure that the cooling is consistent from session to session when using the cooler.

The location of the power socket will have to be chosen to suit your particular build; once this has been done use the following diagram to connect the Peltier device to the thermostat and the power socket (Fig. 12.17).

Mounting the Cooler on the Camera

This will depend on the camera and CPU cooler you are using but can be done by screwing the long strip of aluminum to the heatsink and cutting a hole to line up with the tripod bush on the camera then using a ¼ Whitworth screw to secure it as shown (Fig. 12.18).

At the top of the camera you can also use a hot shoe adapter such as this which will allow you to fit another strap to secure the cooler at the top (Fig. 12.19).

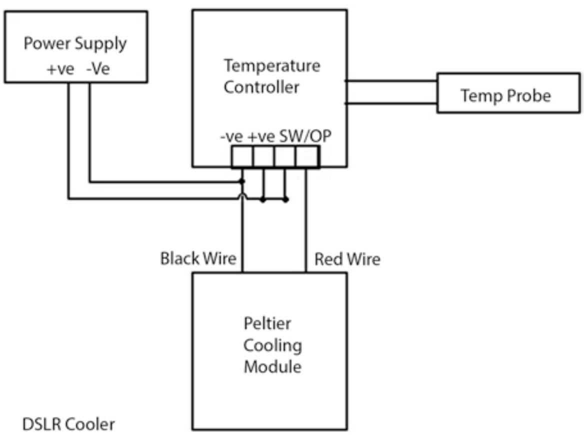

Fig. 12.17 Picture of Wiring Diagram

Fig. 12.18 Cooler mounted on camera

Fig. 12.19 Hot Shoe Adapter

Testing the Cooler

Do not try to run this cooler at very low temperatures or you may freeze any moisture inside your camera and cause permanent damage.

Once the cooler has been wired up as per the diagram and checked for mistakes (especially that you have the correct polarity) you may connect it to a 12 volt D.C. adapter or battery which should be capable of providing 3 amps.

There can be some variation in the setup of the thermostat modules but basically you need to set it to cooling and set the temperature to a few degrees below what the module is showing the ambient temperature to be. Once the cooler has reached the temperature that you have set, the Peltier module will turn on and off automatically to keep it steady.

It may take a few minutes to see the temperature start to drop but this is normal. You will find that if you set the temperature too low you run a risk of ice forming inside the camera. It is best to see what the ambient temperature is and aim to lower it by a few degrees. In winter you will be able to run it at lower temperatures than in the summer due to the variations in the ambient temperature. You will soon get the feel for what is a suitable temperature to reduce the noise in your images. Typically, it should be possible to cool the camera chip by about 7 °C below the air temperature.

Project 5 DIY All Sky Camera Housing (Fig. 12.20)

An all sky camera is typically used by astronomers to capture meteor showers and monitor the sky for clear nights and the approach of clouds and even rain especially when imaging. This can be important if you are operating the telescope from another location as in the in the case of a remote observatory or even from within the house when the weather is very cold.

An all sky camera usually points straight up with a very wide angle lens so that most of the sky is captured in the lens. Due to the fact that all sky cameras are intended to be kept outside, out in all types of weather they need to be totally water and weather proof so that the camera is well protected and able to function reliably in such a harsh and demanding environment.

The details given here are for a camera case that is suitable for small cameras such as the Altair GPCAM or Qhy 5II camera, but with suitable modification could be easily adapted to suit any other camera that you may have available. The main driving force for this project was the need for a camera of this type and the high cost of those available on the commercial market.

Fig. 12.20 All Sky Camera Housing

Choice of Camera

I had a spare Altair GPCAM which was only being used occasionally so the design was actually built around it. However, any reasonable quality guide camera capable of exposures in the order of a few seconds should suffice as long as it is capable of accepting a wide angle lens. The choice of mono or color is up to your own preference or what you have available at the time.

Choice of Lens

There is a vast choice of lenses available ranging from very cheap ones purchased online, to very high quality branded lenses. If you only intend to use it for sky monitoring and catching the odd meteor, then the cheaper lenses available online will do. These cheap lenses can suffer from a lot of coma away from the center of the field of view, but if this isn't a concern they can be a good choice.

If you are using a GPCAM or QHY 5II, I would suggest a focal length of between 1.8 and 2.1 mm. A 1.8 mm lens will give a horizon to horizon view whilst a 2.1 mm lens will give slightly less but usually tend to be both easier to obtain for a reasonable cost and easier to source. A 2.1 mm lens usually covers the main area of the sky that is visible to most people in suburban settings. The best lens to fit will also have a lock screw on the focus so that you can set it up and lock it knowing it won't move and avoiding the need for the camera to be opened up and refocused. You may want to fit an infrared blocking filter although this isn't absolutely essential.

Component Parts

All sky cameras are usually composed of the following parts.

- **A glass or acrylic clear dome** that the camera can look through whilst being protected from moisture rain and dust.
- **A main body** or case, which with the dome, has to provide a dry safe environment for both the camera optics and electronics.
- A method of **sealing the dome** to the body or case a rubber seal or silicon sealant will work fine.
- A method of heating the dome, to avoid dew forming and obscuring the view. The ZWO anti-dew heating strip works well and only requires 12 v at 0.3 of an amp, so is very economical to run.
- A method of **supporting the camera**; quite often it is simply a post with the camera housing mounted at the top.
- **An inline heater controller**; one of the Led controllers shown below works well, as long as it is of the correct voltage 12 v and current rating. The ones that I suggest are available on EBay and are capable of delivering 2 A which is more than enough. To avoid having to house the controller in the camera case it is better to place it at the mains supply end where it can be kept dry and adjusted without having to climb up to where the camera is mounted.
- **A 12 volt power supply for the heater**.
- **Power cables** are available ready made with plugs fitted from EBay.

Description of Parts Needed

Main Body (Fig. 12.21)

Drain Blanking off plug; these may be obtained from a home improvement store and are used to block open drains that are not required.

These blocking plugs are made of a very tough and durable P.V.C. and are designed for an outside environment, so are perfect.

Fig. 12.21 Drain Blanking Plug

If these are not available you could use a Charlotte Pipe 4-in dia PVC Schedule 40 Spigot Test Fitting and 4″ length of 4″ diameter pipe Bonded to it with solvent or similar to make the main housing.

The purpose of the case is to offer both mechanical strength and weather protection to the camera and lens used, so any appropriate case or even project box could be used.

Support Post Coupling (Fig. 12.22)

This coupling is used to provide the mechanical connection between the camera case and its support post.

2-in dia ABS pipe Coupling Fitting.

Support Post

This 2″ pipe will need a hole cutting in it just below the level of the coupling, in order for the heater cable to be fed down through the pipe to give a neat finish to the camera.

2-in ABS DWV Pipe length to suit your intended location.

Solvent for bonding parts together.

Fig. 12.22 Support post Coupling

Acrylic Dome 4″ (Fig. 12.23)

The acrylic domes are readily available online in a range of qualities to suit your budget but beware of buying a dome made for a dummy camera as this will not be optically suitable. These domes usually come with a protective plastic film covering. It is best to leave this in place until you are ready to fit the dome. Only remove the outer protective cover once it is in place.

Rubber Seal for Dome (Fig. 12.24)

The rubber seal for the dome can be cut from a small flat sheet of plain rubber to suit the dome purchased.

Screws

The screws are to suit the dome purchased and are best sourced after the dome has been obtained in order to get the exact size.

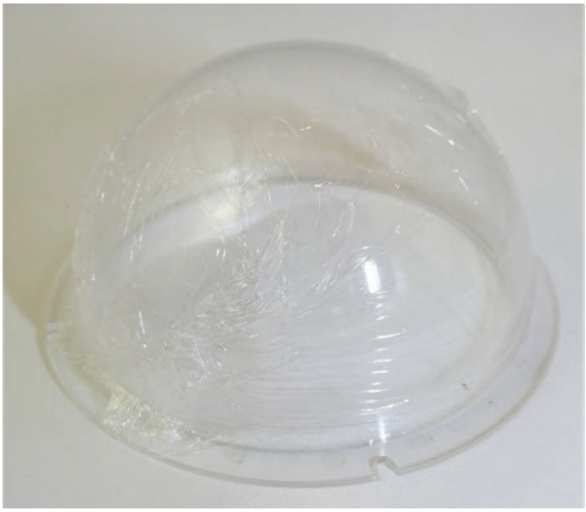

Fig. 12.23 Acrylic Dome

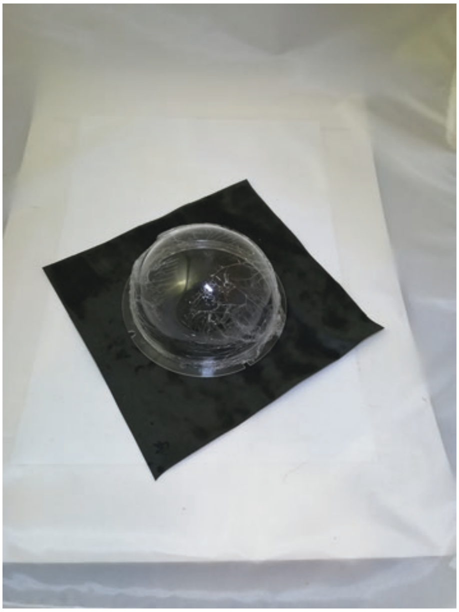

Fig. 12.24 Rubber seal

Heater (Optional But Advised)

In the prototype shown, the heater used is 3 × 5 Watt resistors; however an all sky heater module is available from ZWO. This is supplied complete with a short cable and connectors already fitted ready to use. It can have its heat output regulated through the use of an inline LED light controller connected near to the 12 volt power supply that you use to feed it avoiding any waterproofing requirements.

Alternative Heater Module

An all sky camera heater made by Dewcontrol.com and may be used if preferred and is supplied with a cable of up to 30 ft and a variety of plugs.

Wall Brackets (Fig. 12.25)

2″ pipe straps may be used to permanently mount the camera on an outside wall or shed.

Fig. 12.25 Wall mounting brackets

Long USB Cable

This is used to feed the camera and needs to reach the computer that it will be connected to. You may need to purchase an active cable which has amplifiers and filters, so that it can reach the distance to your camera and still provide a reliable connection.

12 Volt Power Cable

The power cable needs to be of a suitable gauge to supply 12 v; at least 2 amps are needed to run both the heater strip and the controller. These cables can be found on EBay.

1 M–10 M 12 V/24 V DC POWER EXTENSION CABLE 5.5 × 2.1 mm for CCTV CAMERA/LED/PSU LEAD.

Power Supply

A power supply suitable to run the camera heater; the power supply is for indoor use only and can't be mounted outside. These are readily available on EBay in a form suitable for your mains supply.

DC 12 V 5 A Power Supply Adapter for CCTV Security Camera DVR LED Strips.

Construction

This is very easy and only needs very modest tools. It is best to spray paint all the parts with a matt black paint before construction which results in a professional looking finish. You will first need to drill a hole in the top center of the housing suitable for the camera to be a snug push fit (Fig. 12.26).

The 2″ pipe coupling is then fixed using the solvent to the underside of the case and allowed to set (Fig. 12.27).

The heater strip needs to be fitted next, and this needs a hole drilling for its cable and plug to fit through the top of the case. The rubber seal is then cut to the diameter of the flange on the dome and a hole is cut into it to allow for the camera lens to protrude through it.

The rubber seal is then put in place with the acrylic dome on top, which is then secured with the screws being careful not to tighten them so much

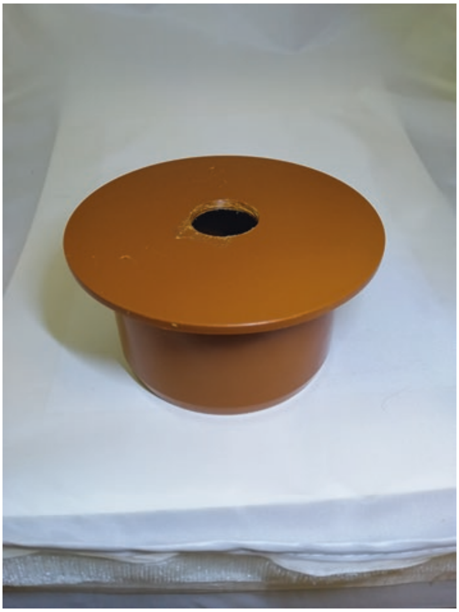

Fig. 12.26 Hole drilled for Camera

Fig. 12.27 Pipe Coupling Glued into place

as to crack the dome, but sufficiently to provide a good seal against the rubber. If you are concerned about the ingress of water through the dome seal it can be improved by using silicone sealer below the rubber at the inner and outer edges. Then finally, apply the silicon sealer around the bottom of the dome before putting it in place and securing it with the screws, and putting it aside for the silicone to dry if it has been used.

The heater is then fastened in place using its adhesive backing so that it is fitted directly on the case cutting out the rubber seal to accommodate the chosen heater (Fig. 12.28).

The camera housing can now be tested, and it is suggested that a watering can or hose pipe is used to test it without the camera in place to check for leaks. When you are satisfied that it is leak proof and functioning satisfactorily, it is safe to mount the camera in place and feed its USB cable down through the support pipe. The heater cable will need to be fed through the hole in the side of the support pipe below the coupling so that it runs alongside the camera USB cable within the support pipe, for a neat and well protected finish.

Test the camera and heater are both functioning properly, and when this has been done you may mount your new all sky camera in its intended location.

The heater should be kept at the lowest setting that works in order to keep the camera dome clear of dew, and should be carefully monitored until you are happy that it is functioning satisfactorily. As the heater controller close

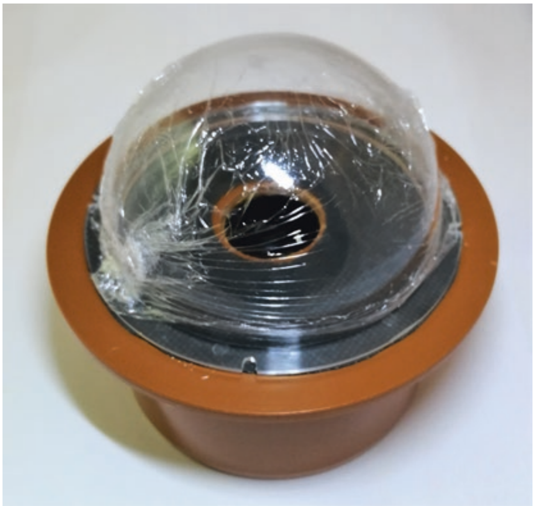

Fig. 12.28 Acrylic dome Ready to be screwed in place

is fitted close to the power supply indoors, it is very easy to adjust. Care must be taken so that children are not able to reach it and change the setting.

Rain repellent sprays do work very well at keeping the dome clear but try spraying a small amount on part of the base of the dome first to make sure it doesn't cause any problems with the acrylic dome.

It is suggested that for safety the heater is only used when you are able to monitor the camera.

Choosing a Suitable Location for the Camera

The main considerations in siting the camera are as follows:

1. The camera should have a clear view of as much of the sky as possible.
2. Choose a site that is away from street lights if possible, as reflections from the acrylic dome can cause problems.
3. The site chosen must be accessible to mount the camera safely, easily install the necessary cables and also for any maintenance that may be required at a later date.

Software for Use with the Camera

AllSkEye

Free to use Windows software
https://www.allskeye.com

- AllSkEye seems to be the widely used software program for all sky cameras and is a very capable package here is a list of some of its features:
- Capable of running autonomously and is capable of taking pictures at predetermined times which can be based on sunrise and sunset times.
- Supports Automatic exposure times.
- Has a Save or FTP Image function.
- Capable of doing basic image processing such as clip, stretch, debayering and mirroring.
- It is possible to add overlays in AllSkEye such as a compass rose or text and logos.
- Will produce AVI or MP4 movie files from saved images.

- Will run a basic meteor or line detection.
- It is possible to set automatic deletion of old files, to avoid unrestricted growth, when used continuously.
- Capable of sending an email alert in case of errors which cause it to close.
- Once it was only available for Starlight Xpress and ZWO cameras but now supports cameras that have an ASCOM driver.

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M. O'Brien, *A Deep Sky Astrophotography Primer*, The Patrick Moore Practical Astronomy Series, https://doi.org/10.1007/978-3-031-15762-2