Chapter 2

Filters and General Equipment for Astronomical Observing

If you are an avid visual astronomer, it may come as little surprise to find that colored filters make a world of difference to your observing clarity, and their use brings out detail from the subtle shadings found on Solar System objects.

On occasion, a telescope manufacturer will include a set of colored filters along with the telescope you have purchased, although many amateur astronomers tend to ignore their use, and the filters just gather dust as the telescope becomes well used. If the filters are of good quality then they can be used to enhance the view of some objects quite easily after a little patience and trial.

Colored filters with a wide bandpass are a very useful tool and should not be abandoned simply because one has not yet used them or has had a little practice. They can make a great difference between seeing or recording an object or missing it completely in the sky background. Many planetary observers rely on filters commercially available, as they report that they really do make a difference in seeing faint details and also assist with reducing glare, as many of the planets and especially the Moon are very bright and suffer from the enormous contrast between their sunlit surface and the dark background sky.

Filters for Visual Observation

Astronomical filters for visual observing are a specialized piece of the astronomer's armory. They work by blocking a specific part of the color spectrum, usually an "opposite color," which then leaves the remaining wavelengths a little more open to view. The color of the filter lets through wavelengths that correspond to that color while darkening or providing more contrast to wavelengths outside of the filter

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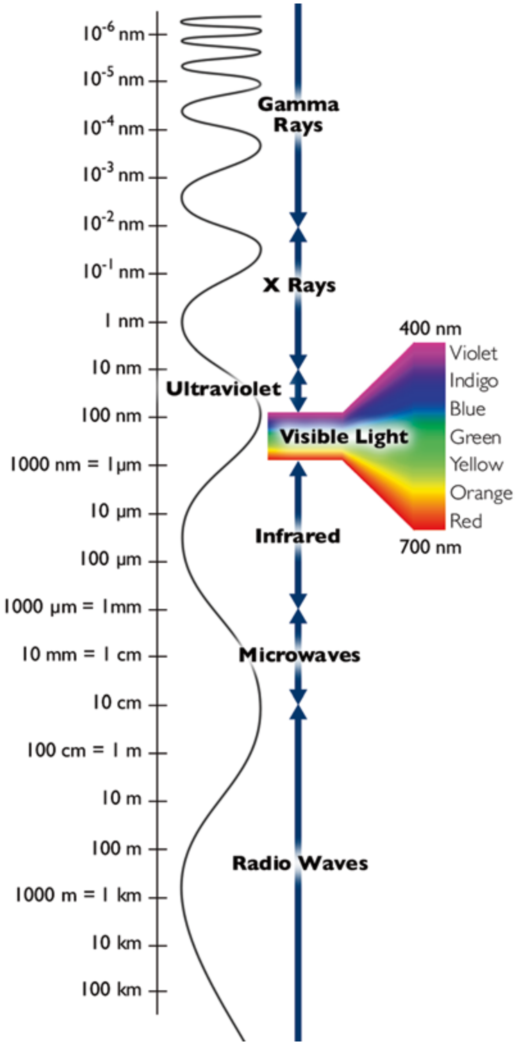

Fig. 2.1 EM spectrum

range or blocking them altogether. The visual element of the electromagnetic spectrum can be seen from the accompanying Fig. 2.1.

As can be seen the visual part of the spectrum lies in a narrow range between 400 and 700 nanometers (nm), with blue at the shorter wavelengths and red at the longer. Using a red filter, for example, with a bandpass longer than 600 nm will block wavelengths of light short of 600 nm and will render such shorter wavelengths as black or at least darker and give increased contrast to details in an astronomical object. One must also remember that many of these details are subtle, and use of filters may enhance some features but render others almost invisible. It's a matter of trial and error.

The colored filters that will be mentioned shortly are best used on Solar System objects via visual observing. They do not necessarily work on CCD imaging systems outside of the BVR (RGB) range, and neither do they work for DSLR cameras unless used with the planets and augmented with skills in image processing. For deep sky work they also have their limitations until you get into the range of narrowband filters where the specific bandpass enables the photographer to build an image based on true color and wavelength rather than relying on color or BVR, as one would in terrestrial photography. Please note that the filters detailed below are largely for visual work only. We shall deal with the use of filters in photography in another chapter.

Wratten Filters for Lunar and Planetary Observing

Although there are several astronomical suppliers that provide these filters with generic names such as Meade, Agena or Orion, all such filters are evident by their color and are usually marked with particular numbers known as Wratten numbers, which allow the observer to choose which parts of the EM spectrum they are going to enhance in order to make planetary and lunar definition and contrast easier to discern through the eyepiece.

The Wratten system was developed in Britain in the early twentieth century by Fredrick Wratten and Kenneth Mees, who founded a company in 1906 that produced gelatin solutions for photography. Mees then developed gelatin filters dyed with tartrazine to produce a yellow filter, but soon developed other colors and a panchromatic process of photography. In 1912 they sold the company to Kodak at Harrow in England, and Mees moved to New York to found the Eastman Kodak laboratories there. In honor of his partner and mentor, Kenneth Mees named the burgeoning number of colored filters "Wratten" and introduced the complex numbering system that is still in use today.

Not all the Wratten filters are suitable for astronomical use, but the main colors are still widely used in visual astronomy and terrestrial photography work and are detailed below.

These colored filters are known as broadband or "longpass" in that they allow a large variety of wavelengths through but block wavelengths above or below a certain range in the EM spectrum. As the spectrum in visible light lies between 390 and 700 nm, with the blue wavelengths being the shortest (~400 nm) and the red being the longest (~700 nm), then anything with a wavelength range above or below a particular filter will be blocked and increased contrast in compensating colors will be noticed.

Most astronomical suppliers sell complete sets of filters for Solar System observing, and naturally such sets are known as lunar and planetary filters.

Fig. 2.2 Meade lunar and planetary filters

They have a range from red to blue across the spectrum and cover the broad bandwidths associated with such colors in addition to covering some of the wavelengths of the Wratten filters that are discussed below. A typical set will include a neutral density filter for lunar observing and a No. 25 red, No.12 yellow and No. 80A blue for as full coverage as possible. A Meade filter set can be seen in Fig. 2.2, although each manufacturer generally follows the same colour set for such work.

In the following section you should note that the Wratten number comes first followed by its color. However, we have grouped the filters under their color rather than put them in number order, as color is their most obvious feature when using them. We will use the spectral sequence from long to short wavelengths as the basis of the description, so we shall follow the standard ROYGBIV spectra that you probably encountered in school. There is also included some brief advice on the usefulness of the filter in visual astronomy before we move on to exploring the use of such filters in greater detail. All of these filters are available to purchase in 37.1 mm (1.25″) or 50 mm (2″) fittings for the observer's eyepiece range and are commonly available from astronomical suppliers (Fig. 2.3).

Fig. 2.3 Wratten colored filters

No. 25A Red

The No. 25A filter reduces blue and green wavelengths, which when used on planets such as Jupiter or Saturn result in well-defined contrast between some cloud formations and the lighter surface features of these gas giants. However, it needs to be used judiciously, as the light transmission is only 15 % and requires quite a large aperture, at least 150 mm+ for visual observation. It is also used to enhance infrared photography on a terrestrial scale, but for astronomical purposes it blocks light shorter than 580 nm wavelength.

No. 23A Light Red

This is a good filter for use on Mars, Jupiter and Saturn and may be useful for daylight observations of Venus as it has a 25 % light transmission through this rather dark filter, and, as it is an "opposite" color to blue, it darkens the sky very effectively in daylight. Some astronomers report that it also works well on Mercury, but this author would not recommend viewing this planet in general during daylight due to its proximity to the Sun, unless one is confident of their observing ability and equipped with a GOTO system. This filter blocks wavelengths of light shorter than 550 nm in the visible EM spectrum.

No. 21 Orange

This orange filter reduces the transmission of blue and green wavelengths and increases contrast between red, yellow and orange areas on planets such as Jupiter, Saturn and Mars. It brings out the glories of the Great Red Spot on Jupiter very well under conditions of good seeing on a modestly sized ‘scope (150-mm aperture) with a median magnification. It also blocks glare and provides a lesser contrast between a bright planet and the background of space, as this filter only transmits about 50 % of the light and blocks wavelengths short of 530 nm.

No. 8 Light Yellow

This filter can be used for enhancing details in red and orange features in the belts of Jupiter. It is also useful in increasing the contrast on the surface of Mars, and can under good sky conditions aid the visual resolution of detail on Uranus and Neptune in telescopes of 250 mm of aperture or larger. The No. 8 is also quite useful in cutting down glare from the Moon during visual sweeps of this object and works much better than the “moon filters” usually included with some cheaper telescopes on the market. The No. 8 filter allows 80 % light transmission and blocks light short of 465 nm.

No. 12 Yellow

This filter works on the principle of opposites described above, blocking the light in the blue and green region and making the red and orange features on Jupiter and Saturn stand out more clearly. Deeper in color than the No. 8 filter, it is the filter most astronomers recommend for visual work on the gas giants. It has a 70 % light transmission and cancels some of the contrasting glare on Jupiter when seen against a dark background sky. It blocks visible wavelengths short of 500 nm.

No. 15 Deep Yellow

This filter can be used again to bring out Martian surface features and the polar caps in addition to bringing out detail in the red areas of Jupiter and Saturn. Some astronomers also have reported some success using this filter to see low-contrast detail on Venus. Other astronomers, including the author, have used this filter on Venus during the day to add more contrast to the image. This filter is particularly useful, as Venus is a very bright object, and the filter has a 65 % light transmission with a longpass blocking light short of 500 nm and can considerably reduce the glare of this very bright planet.

No. 11 Yellow–Green

This darker filter is a good choice to enable the observer to directly see surface details on Jupiter and Saturn. It can also be useful on Mars if you are using a large aperture telescope in the 250 mm+ range and the seeing is steady as it darkens the surface features and makes areas such as Acidalia and Syrtis Major stand out well. The No. 11 filter allows 75 % transmission of light and can be used to darken features on the Moon, too. However, it is more of a color correction filter rather than a longpass filter and will allow all visual wavelengths through.

No. 56 Light Green

This filter has been used by the author for observing the ice caps of Mars during its close encounter in 2003 and found that despite the low altitude of Mars from the UK during that apparition the filter worked well in bringing out these features and even hinted at other rocky features on the planet's surface during periods of clear seeing. True, the orange filter above did work better in rendering color and detail on the Red Planet, but the contrast with this filter was quite good. This will allow most wavelengths through but does have some concentration around a wavelength of 500 nm.

With its 50 % light transmission this filter is a favorite of lunar observers, as it increases the contrast while reducing the glare. It is also a filter that is well tuned to the wavelengths of the human eye, and the greenish cast can almost be ignored during visual observation. This is another color correction filter with all wavelengths equally affected. The effect can be seen on the first quarter Moon in Fig. 2.4, photographed here in ordinary white light and then through the Wratten No. 56 filter. The glare is reduced and features are easier to make out in general, though it can be difficult to get used to seeing a green-colored Moon. Perhaps the ancients had something when they thought it was made of cheese…

No. 58 Green

This filter blocks red and blue wavelengths of light, and many observers find that it slightly increases contrast on the lighter parts of the surface of Jupiter. This author has also used it on Venus, where it does add to the contrast and reduces glare, but it must be admitted that it is not easy to visualize any detail in the clouds. However, because of its 25 % light transmission, this filter requires a larger aperture telescope—probably above 200 mm is best. It is also a color correction filter rather than a longpass.

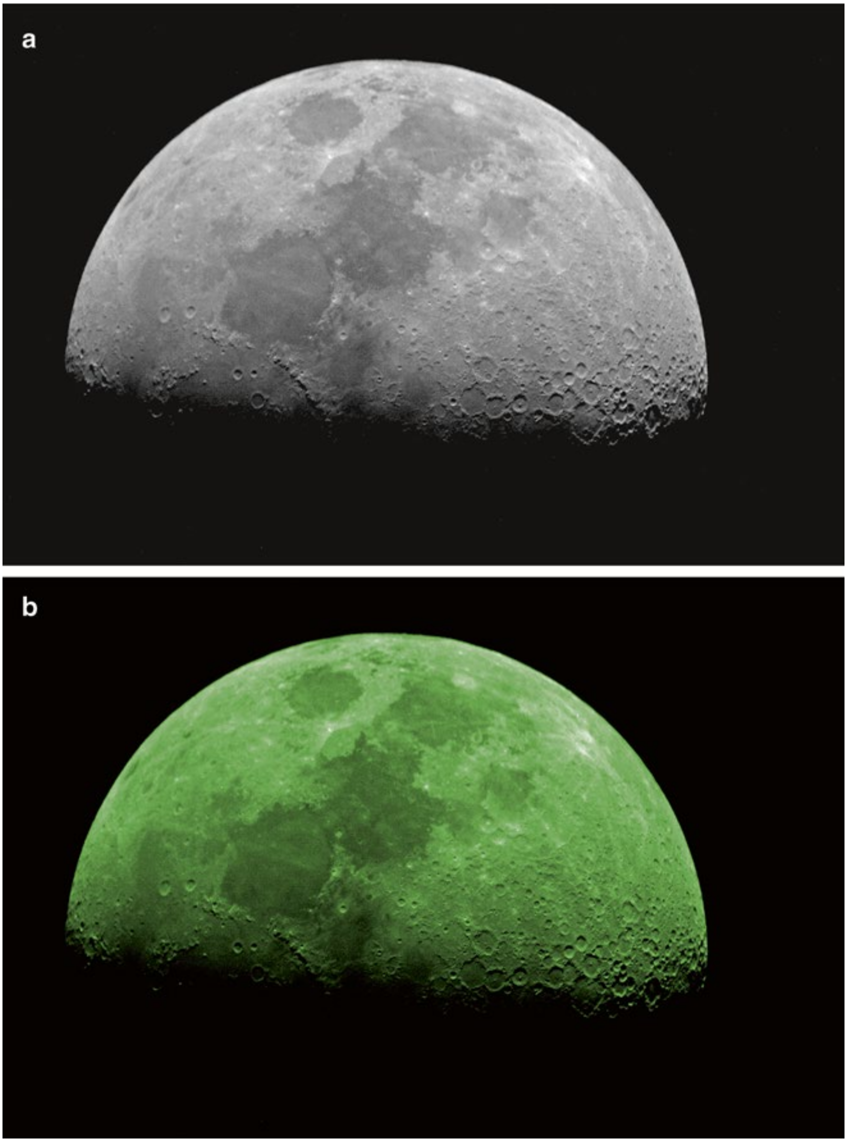

Fig. 2.4 (**a**) First quarter Moon, and (**b**) No. 56 filtered Moon

No. 82A Light Blue

This is almost a multipurpose filter, as it does enhance some features on Jupiter, Mars and Saturn and also works quite well in enhancing some features on the Moon. It is commonly referred to as a "warming" filter that increases the color temperature slightly and allows the red wavelengths through. With a light transmission of 75 % it can be used on any aperture telescope and can even make some difference to deep sky objects such as M42 and M8, though the effects can be quite subtle.

No. 80A Blue

Although this is quite a dark filter, it is as versatile as the No. 82A in that it enhances red features on planets such as Jupiter, Saturn and Mars. It is also good for lunar observation, as it reduces the glare and provides good contrast for some features such as ejecta blankets, ray systems and lava fronts. Some astronomers report success in its use on binary star systems with red components such as Antares and α Herculis as the contrast enables the observer to split the two components well. The No. 80A filter has a 30 % light transmission and so should be used with a larger aperture if possible, though this caveat does not apply to lunar observations. It also acts as a color conversion filter, enhancing wavelengths around 500 nm.

No. 38A Dark Blue

Again, a good filter to use on a planet such as Jupiter because it blocks red and orange wavelengths in such features as the belts and in the Great Red Spot. Some astronomers report that it also adds contrast to Martian surface phenomena, such as dust storms, and makes a better contrast for observing the rings of Saturn, though this author has not observed a dust storm and can see very little effect on the rings of Saturn. However, some astronomers report that using this filter increases the contrast on Venus, leading to the visual observation of some dusky cloud features. This filter again needs a fairly wide aperture, above 150 mm to operate effectively, as it has about a 15 % light transmission. It absorbs red, green and UV light and is commonly referred to as a minus green plus blue filter.

No. 47 Violet

A very dark filter that strongly blocks the red, yellow, and green wavelengths. It is highly recommended for Venus observation due to its low light transmission of about 5 %, providing great contrast and enhancing cloud features. It can be used on

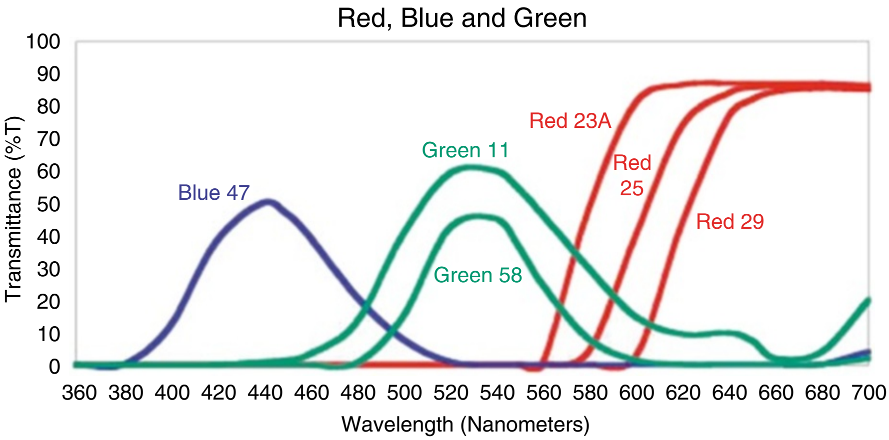

Fig. 2.5 Wratten filter bandwidths (*Source*: Analog Photography Users Group (APUG) at http://www.apug.org/forums/forum45/60828-tiffen-filter-wratten-equivilents.html)

the Moon to decrease the glare when observing features at a 10–12-day-old phase, and some features in the Schroeter Valley and Aristarchus Crater were better seen due to the lack of glare. Recommended for the Moon if you have a large aperture! This is another color separation filter that enhances the blue or shorter wavelengths of the spectrum.

The above filters enhance the astronomer's observations of the planets and our lunar neighbour very well and are highly recommended. Figure 2.5 gives the typical bandwidths of the Wratten filters considered above.

Additional filters that also are helpful in visual observing are the polarizing filter and the neutral density filter. Both are longpass filters that usually transmit all wavelengths of light but can cut down on glare and contrast.

Neutral Density Filters

A neutral density (ND) filter transmits light uniformly across the entire visible spectrum and is an excellent filter to use to reduce glare in objects such as the Moon and planets, especially the Moon. Due to its bright glare many lunar and planetary astronomers keep a permanent ND filter on their favorite eyepiece and add on other filters as necessary. The neutral density filter is quite handy if you're are doing a public observing session where you can switch from a first quarter Moon to deep sky objects, as its reduction in glare assists in maintaining your night vision and doesn't result in customers squinting and half blinded as they stumble away from the bright object in the eyepiece! These filters come in a variety of densities that apply different contrast to the image based upon the amount of light transmission each ND filter allows. Commonly they come in numbers such as 50, 25 and 13 that signify the amount of light they transmit—50, 25 or 13 %, respectively.

Polarizing Filters

Although it does not work at any particular wavelength, the polarizing filter allows light of any wavelength through but blocks those with random scattering patterns, allowing only light waves in a flat "plane" through, which has the effect of increasing the contrast, reducing glare and slightly enhancing the saturation of color in an object. Such filters are very useful on bright objects such as the Moon and planets, and we shall examine their effects in due course.

Why Use Filters for Visual Observing?

The above information should provide the visual observer with a little guidance on using filters to see subtle details on some Solar System objects. Not to be forgotten is the fact that occasionally you can combine filters to produce a better visual view, though be careful that you do not end up with a set of filters that will give you a neutral density! Combining some red green and blue filters will do this—and in doing so the observer may as well remove the filters altogether, as all they have done is cut down on the light transmission through the telescope! This may be fine for viewing the Moon, but for fainter Solar System objects, maximum light transmission and enhance contrast through using a filter is preferable.

Some observers may scorn the use of Wratten filters and can claim to see enough detail in objects without their use. To this argument the author can only say that any optical aid is useful if it achieves the goal of the observer. The experience of many seasoned observers reveals that using colored filters can overcome such problems as image deterioration due to atmospheric effects and allows separation of colors in a planetary atmosphere that may not be attainable by the human eye alone while staring at the glare of a bright Solar System object such as Jupiter or Venus. They provide a welcome contrast between areas of different colors and provide a sharper less "glare-filled" view of a bright object.

Astronomers must remember that the human eye has not evolved to cope well in the dark, and our color perception departs noticeably from the norm once we become dark-adapted. Subtle colors such as reds, browns and greens disappear at night as the human eye becomes adapted to the blue range of the visual spectrum, a phenomenon known as the Purkinje effect after its discoverer the Czech anatomist Jan Purkinje. He noticed that under low illumination the human eye loses the detection of wavelengths longer than 555 nm as the chemical opsins and rhodopsin in our eyes have a peak absorption of around 500 nm. Observers end up with essentially black and white vision, so the addition of a colored filter with a wide wavelength that enables one to make the most of the "missing" wavelengths is going to be an advantage in any observing situation.

In addition to the above, the observer has to contend with problems related to the atmosphere, through which we see any astronomical object. Atmospheric scattering is responsible for an almost luminous veil through which we visually perceive an object and is due to the nature of the particles in the air. Atmospheric scattering is inversely proportional to the fourth power of the wavelength of light, so if we are viewing an object that is primarily blue in color with a peak wavelength of 480 nm, then the light is scattered more than a red object at 750 nm. This is why our sky appears blue during the day. Remember that at night we lose the red end of the EM spectrum due to the Purkinje effect! A filter can add enough contrast to partially overcome the effects of scattering.

Observers are also affected by a phenomenon known as prismatic dispersion, which is most evident when a star or planet is seen near the horizon. It results from refraction in the atmosphere being less for the longer wavelengths, whereas the red appears nearer the horizon and violet toward the zenith. This is why most astronomers prefer to observe an object when it is near or at culmination so that this effect is lessened. Use of red or blue filters on an ascending object may make the difference between seeing details such as the Great Red Spot, for example.

Finally we have to counter the effects of irradiation, which is manifested by areas of unequal brightness, resulting in the brighter zones encroaching on the fainter areas within a planetary atmosphere. This effect is primarily psychological, as it is the interpretation of the brain that evens the illumination out, but results in decreased contrast and a lack of detail between areas of different brightness. Use of a red or orange filter will even out the illumination and allow the eye/brain coordination to distinguish differences.

In the case of bright objects the reduction in light transmission is an advantage. The difference in contrast between the belts and zones on an object such as Jupiter can be so great that the human eye and brain just smear the whole, and it can be difficult to discern details without a filtered system. This is due to the differences in intensity of reflected light from light/dark zones in such planetary systems. To illustrate this let us examine the difference in intensity as viewed through a telescope.

Contrast in any system can be measured using the formula:

$$C = \left(b2 - b1\right) \div b2$$

where C is the contrast and b1 and b2 are different areas of brightness on the surface of a planet. Bright areas on Jupiter have an intensity of 6 Lumens m^{-2}, and the intensity of the darker zones have an intensity of 3 Lumens m^{-2}. This would give:

$$\left(6 - 3\right) \div 6 = 0.5$$

a contrast 50 % lower in the darker zones than in the brighter zones. A filter will even out the contrast by permitting wavelengths representative of the redder or darker zones through while diminishing the contrast on the brighter zones. Surely a filter that would aid in the perception of subtle features is going to be a bonus to any observer?

Therefore the use of filters, despite their decrease in light transmission, is very useful in visual astronomy. The use of filters assists primarily in reducing contrast initially, and though the reduction in light transmission is generally not favored in astronomy, this is one area in which this general rule need not apply.

It takes time and personal training to use a filter effectively and to discern different details in the atmosphere of a planet such as Saturn or Jupiter, let alone fine details on the Martian surface. Nevertheless, filters offer a very convenient and relatively cheap way of seeing these details, so the application of a little effort is well worthwhile.

Observing Hints: Dark Adaptation, Telescopes and Eyepieces

The above filter groups must be used in ways in which their maximum utility can be gained. The most important considerations when using a filter set are not only their effect on the wavelengths of light passing through any optical system but also the types and aperture of the telescope in use, the magnification possible with such an instrument plus the amount of dark adaptation that the observer can achieve. Secondary considerations are the amount of pollution and dust in the atmosphere, atmospheric transparency, the air humidity and the steadiness of the atmosphere at different times of the year.

Dark Adaptation

Most people underestimate the power of the naked eye and how to use it properly to gain the most from astronomy. Telescopes, cameras and CCDs are designed to get the best from any observing or imaging, but the human eye is the centerpiece of any attempt to see the sky, and many are surprised at what the eye can discern. On a dark night, the iris, the diaphragm controlling the amount of light entering the eye, is fully open, and measures on average 6 mm in width. This maximum aperture is most desirable to astronomers, so when you go out into the darkness of an evening, take a little time to allow the iris to open fully, a technique known as dark adaption. This process can take about 5–10 min, but to be fully dark adapted takes up to 30 min.

During this period of time, do not go near any light sources, switch on your flashlight or stare at car headlights, otherwise your adaption will be ruined and you will have to start again. Many observers supplement this process by closing their eyes, thus hoping to speed up the adaptive procedure. A fully dark-adapted eye is obtaining the maximum input from the surroundings and can discriminate between subtle areas of light and shade on most astronomical objects.

Once this has been accomplished, you can begin observing, as your eyes are now a little bit more sensitive to light than they ordinarily are during the day. However, some astronomers have noted that faint objects seem to be a little brighter if they are seen "out of the corner of the eye," as it were, and this phenomena is another important tool of the observer. The process of seeing objects in greater detail simply by not looking directly at them is called *averted vision* and is a bonus when looking for faint objects such as galaxies or planetary nebulae or even faint details on planetary surfaces. This phenomenon arises due to the way that the eye is constructed. At the rear of the eye is a light-sensitive membrane called the retina. The retina is fabricated from two sets of cells, commonly called “rods” and “cones.” The cones lie directly behind the pupil when the iris is fully open and the light sensitive rods lie off to the sides of this aperture. So when not looking directly at an object the more sensitive rods are able to pick up the stray light that the cones are missing, thus making averted vision a good habit to get into as far as astronomers are concerned.

Thus when not looking directly at some object, the more sensitive cones are able to pick up the stray light that the rods are missing, thus making averted vision a good habit to get into as far as we astronomers are concerned. To enable you to maintain your night vision, it is best to examine any star charts or atlas by means of a flashlight with a red beam. This red light will not interfere with a dark-adapted eye and is comfortable and easy to see such charts by Equatorially mounted Reflector telescope.

When observing, make sure that your comfort is the paramount consideration, so always dress warmly, have a hot drink handy and take a break every hour or so if you intend to observe all night. Additionally, if you can stand on a raised board while observing, then the heat of your body will not be sapped through your feet, leaving you cold and miserable. This is simple common sense, you may well say, yet many observing sessions have been ruined by the lack of such preparation.

To enhance your appreciation for nature’s deep sky wonders, and to bring out the best in your optics, it is imperative to find a dark sky site. What is meant by this term is a site where no street light or the pervasive orange glow of streetlights can be seen, and the sky remains dark right down to the horizon without interruption from any light sources through a 360° circle. Granted such sites may have to be found well outside your town or area, especially for urban astronomers, but it is worth the effort to go out of your way to obtain fine observational results. The International Dark Sky association has designated dark sky parks and reserves in many areas of the globe, and it would be useful to locate the closest one to you. If this site is too far away, local astronomical societies have information on local areas that are fit for observation.

To see deep sky objects and faint details at their best, it is best to avoid times of the month when the Moon is shining brightly. Although the Moon is a lovely romantic object shimmering with a silvery light, looking wonderful in a cloudless sky, it is less than romantic to astronomers and astrophotographers interested in digging out remote or obscure clusters, nebulae and galaxies. However, for planetary observing the phase of the Moon is an irrelevance; many observers report that a bright moonlit night is ideal for planetary observing, as the darker sky background is washed out, resulting in less contrast between the bright planet and the deep sky. However, only observe when the air is fairly clear and the atmosphere, or seeing conditions, remain quite steady.

Telescopes

If you own a small telescope, then ensure that it is properly mounted and the mount is as stable and vibration-free as possible. A steady mount cannot be overestimated, as any vibration is going to take time to damp down and render a good clear image. Many small telescopes have alt-azimuth mounts that need constant adjustment to keep up with the rotation of Earth and thus have a lot of unstable vibration to contend with throughout the observing session. Tightening up any bolts and nuts on the axes and making the mount stable by hanging weights from the center of the leg supports can have positive results, as can having good slow motion controls. Better stability can be achieved with an equatorially mounted telescope, even if undriven, as the slow motion controls ensure use of only the right ascension axis while a driven mount that will follow the target is much to be preferred. In addition, the axes on equatorial mounts can usually be locked down, and slow motion controls are a little finer with less vibration.

The market is flooded with good-looking telescopes that perform extremely poorly and are purchased by the unwary with an interest in astronomy but no knowledge of optics. Ask anyone in a local astronomy group for the best advice on what to look for when purchasing a telescope. Good optics are an essential when using filters, as bad quality optics will destroy the fine details that a filter is meant to bring out.

When buying a small telescope, do not believe the claims of the manufacturer that this instrument will magnify up to 400 or 500 times. Such claims are almost always fraudulent, as at such magnifications only a blur will be observed through the eyepiece. As a general rule, a telescope is performing at its optimum when it has a magnification of 25× per 25 mm of aperture. Therefore, if you have a 100-mm telescope, the maximum it should be able to magnify, with resultant clear detail, is 100×. Following this advice will forestall any frustration you will ultimately experience if you have the misfortune to be sucked in by the advertiser's gimmicks. This is just a general rule, however, and depends on the seeing conditions and the quality of the telescope, so experiment with differing magnifications as you see fit.

Another key element in any visual system is the quality and clarity of the optics in the telescope and eyepieces. Image definition depends on sharp focus, resolving power and the contrast that can result from different levels of magnification, so keeping your telescope in top condition is a must. Clean optics with good eye relief to the eyepieces is an essential part of astronomical observing. With the plethora of telescopes flooding the market today amateurs can easily maximize the size of their telescope for a small financial investment. However, this does not always work to the advantage of the observer. Do not sacrifice quality for quantity. A large telescope with a 200-mm aperture may sound ideal to most observers, but the increased resolution may be sacrificed to the increased glare and lack of contrast unless a filter is used on a bright object.

In many cases the small and faint details that are rendered visible by a filter, especially on such planets as Mars, are dependent on the resolving power of the telescope, and naturally the larger the telescope, the greater its resolving power. Tiny details in the sub-arc second range will only be evident under high magnification with an aperture of the correct resolving power. To calculate the resolving power of any telescope the formula is:

$$\alpha = 0.25(D/\lambda)$$

Where α is the resolution in arc seconds (″), λ is the wavelength of light in microns and D is the diameter of the telescope in meters. Using such a formula we can obtain the resolution of any telescope we wish with a simple calculation. If λ is the middle of the optical spectrum at 500 nm, in microns it will be 0.5 and the diameter D of a telescope is 100 mm or 0.1 m, then dividing λ by D we arrive at 5, which now must be multiplied by 0.25, which gives us an angular resolution of 1.25″ or 1.25 arc seconds. A telescope with an aperture of 300 mm will give a resolution of 0.4 arc seconds, so filter use with a larger aperture not only allows the observer to clarify and enhance the detail but also see increased detail at higher resolution than a smaller telescope.

Although it is impossible to recommend a specific type of telescope, as refractors, reflectors and catadioptric all have their uses, it is obvious that size is an important consideration. Nevertheless, a small refractor will generally give good clear views if the optics are of good quality, and for their size and portability they are very hard to beat. Others will rely on reflector telescopes, which may have very large apertures in comparison to the 70–100 mm of small refractors. Obviously the aperture and optical quality of such telescopes ranges widely, but no matter what the system in use, the addition of filters when observing the Solar System are a bonus in terms of the detail, clarity of the image and the ability to discern small features on a planetary disc. Let us examine each type in turn.

Refractors

A good quality refractor in the 100–120-mm range is a very versatile instrument and will provide a good platform for observing most deep sky objects. Refractors of this size give much better images than reflectors and even some Maksutov-Cassegrains or catadioptrics, as the light path is unrestricted and provides a ready platform for an SLR camera or a CCD device.

A point to note with refractors is that their focal ratio (f) can vary between types. Some of the short focus refractors such as the Skywatcher Equinox ED-Pro are superb instruments made with the best quality optics, but some of their 80-mm scopes are a fast f6 ratio, which means that the field of view through the instrument is quite large, spanning more than 2° with a low power eyepiece. Although this is not necessarily a consideration for most observers, should you wish to image or visually observe planetary nebula then this large field of view may lead to some confusion in identifying objects that are only a few arc seconds in size. A refractor with a longer focal length (f10, for example) may be a better requisite for such observations or imaging.

Fig. 2.6 Types of telescopes

The drawback of such an instrument is its limited aperture. A good refractor is a versatile instrument, but the difficulty of making quality objective lenses in sizes larger than 150 mm for commercial sale has always provided the amateur with a financial problem. To see really faint and indistinct objects, a reflector rather than a refractor may become the instrument of choice, as reflectors are very durable, portable, despite their larger size, and the sheer size of the aperture and light grasp plays into the hands of those looking for fainter objects or more detail in the brighter ones. Figure 2.6 shows a typical selection of telescopes available from most suppliers.

In most amateurs' experience, the quality of the optical system is paramount. Refractor telescopes using fluorite or Schott glass lenses are among the best available, as they reduce chromatic aberration and render very clear, well defined color images that can take a relatively high power. The only drawback with such systems is that they generally tend to be relatively limited in size outside of major observatories, and some telescopes, such as the wonderful Televue and Takahashi systems, command high costs, though the resolution, clarity and quality of the resultant image visible through such systems is second to none. A good refractor telescope is a prized possession.

Aperture, stability and quality ensure that refractor systems can be coupled to the whole range of Wratten filters so that the observer will greatly benefit from their use when observing the Moon and planets. DSLR and CCD imaging can be performed quickly and relatively easily with a filter wheel and camera placed accessibly at the main focal point of the telescope, though the observer needs to beware of the tripod legs on some mounts when imaging objects overhead!

Reflectors

Reflectors have become the main telescope of choice for most observers, as large apertures can be purchased for a fraction of the cost of a top-quality refractor. Most reflectors are built according to the Newtonian design, where a parabolic mirror at the base of the telescope reflects light back up the tube to a mirror angled at 45° (a flat) and then out through the side of the tube at a comfortable height for viewing. For the price of a good quality refractor you can buy a 250 or 300 mm reflector or larger on a Dobsonian mount. Despite their size, the instrument is still portable and can be transported relatively easily, though it is incumbent on the observer to check that the optics remain collimated when you set up.

A difference between refractors and reflectors in practice is also that a refractor is "ready to go" virtually right after set up, whereas a reflector may take some time to cool down to the external temperature before it can obtain fine images. Tube currents play a pervasive role in visual astronomy, and it is best to let a reflector settle before attempting to view any fainter objects on a target list. In addition, many of the Newtonian reflectors available commercially are not built for photography but just for visual observing. Although this is not a concern for most observers, it is something to be taken into account if one uses a large reflector. A Dobsonian mount negates the ability to track the sky effectively and so makes astrophotography a moot issue. A reflector on an equatorial mount overcomes such problems, but then the size and weight of the complete system begin to work against it as an easily portable object.

The sheer aperture of some reflectors make the use of filters a priority when viewing Solar System objects, as the large light grasp provides a very bright image that can suffer from glare and lack of contrast. On objects such as Venus, Jupiter, Saturn and especially the Moon, the low light transmission of the Wratten filters Nos. 25, 38, 80A and 56 enable detail to be seen without any loss of resolution.

Catadioptrics

These are almost a compromise optical system between reflectors and refractors in that they use both mirrors and lenses to achieve focus. Most amateurs will be conversant with the typical setup of such telescopes, such as the Schmidt-Cassegrain, wherein a corrector lens at the front of the 'scope adjusts the light path to fall on a spherical mirror, which then bounces light onto the silvered spot on the lens, back down the tube and out through a hole in the primary mirror to a focus outside the rear of the mirror cell. Maksutov-Cassegrains use much the same light path, the principal difference being in the curvature of the front lens or meniscus of the system. In such a manner, the light path is quite long in a relatively small instrument, as the light path makes three trips around the system, resulting in a long path and a larger focal ratio, generally between f10 and f13 or more.

The advantage of such a telescope is its portability, small size and stability coupled to its ability to provide a ready platform for an SLR or a CCD device. The small field of view ensures that any extended object fills the field, which is typically about 0.5° and makes looking for small objects easier. Due to the larger relative size of the longer focal lengths of catadioptric telescopes, Wratten and other filters for DSLR and CCD imaging are very useful and cut down on the glare and light transmission through such 'scopes without losing the resolution or fine detail in the object under observation.

Catadioptrics come in a range of apertures, from small 90-mm 'scopes to giant 40-cm telescopes, which are not really portable objects at all. Several well-known manufacturers make catadioptric telescopes, and they are available at reasonable prices in outlets worldwide. They are easy to set up and maintain, though use of a dew shield is a must, as the primary lens of the system is right at the front of the 'scope and will suffer from dewing if it is not properly shielded. Dew shields, dew zappers and associated equipment can be obtained from all good astronomical suppliers, or can be home-made quite easily and cheaply.

Eyepieces

There is no point in having a quality telescope and then spoiling the ability to see detail by using inferior quality eyepieces. It is often the case that a good telescope and mount can be purchased as a complete item along with eyepieces, only to find that the eyepieces are not the kind of quality that matches the telescope. Over the years, many amateurs have learned this lesson; the supplied eyepieces with any system are not as good as they could otherwise be, and they have invested in a range of eyepieces for use with the variety of 'scopes they may possess. Quality eyepieces are a must no matter what the telescope in use.

In visual observing the Wratten filters are screwed to the eyepiece or gently placed over the front element.

Like a telescope, an eyepiece will come in a choice of focal lengths. These are usually displayed on the barrel as 32, 25, 20 mm and so on. These figures give the user the focal length of the optical elements within the eyepiece. Even if the observer has built up a good standard set of eyepieces, each will perform slightly differently on each different telescope that the observer uses. The main denominator will be the difference in field of view and magnification of the eyepiece on each telescope. Magnification can be obtained with the following equation:

$$M = \left(f_t / f_e\right)$$

where f_t is the focal length of the telescope and f_e is the focal length of the eyepiece. The magnification is simply obtained by dividing the focal length of the telescope by the focal length of the eyepiece For example, a refractor may have a focal length of 1,000 mm. If the eyepiece of choice is a 20-mm then the magnification of such in use with this refractor will be (1,000/20) = 50 times, or a magnification of 50×.

If the 20-mm eyepiece is used with a system having a longer or shorter focal length, then adjustments have to be made accordingly. For example, a 700-mm focal length will now have a magnification of 35× (700/20), while a 1,400-mm focal length will now have a magnification of 70× (1,400/20). This magnification will also impact upon the field of view of each instrument using that eyepiece.

When choosing different focal length eyepieces it is important to remember two things—the size of the exit pupil and the necessary eye relief of each one. The exit pupil is defined by dividing the diameter of the primary lens or mirror of your telescope by the magnification of the eyepiece and is always quite a small number. The exit pupil of a 100-mm f10 refractor telescope using a 20-mm eyepiece is therefore 2 mm (100/50) and provides an adequate exit pupil for most observers. The secondary consideration when choosing an eyepiece is the eye relief given to the observer, especially for those who may wear eyeglasses, but as a general rule the smaller the focal length of the eyepiece, the smaller the exit pupil and therefore the more difficult in practice the eyepiece becomes to use. This can be alleviated choosing eyepieces that have an ultra-wide flat field, making it a little easier to find the image. A good eye cup on the eyepiece may also assist those that wear glasses as some can be either extended or folded back to enable the user to find a comfortable distance.

Most observers use multi-element eyepieces that have weird and wonderful names such as Plossl, Erfle and Orthoscopic; these eyepieces are now the standard for observers and give exceptional views through most instrumentation, giving flat fields with no astigmatism or blooming of images at the edge of the field. They also vary in price, and the super high quality types may cost as much as small telescopes themselves! Nevertheless, a selection of good eyepieces giving a range of magnification is a must for all astronomers and provide a bonus for seeing those small, faint or difficult objects due to variations in FoV, contrast and color rendition.

Most standard eyepieces have fields of view (FoV) that vary from 30° to 50°. Of course, when in use this field is not 30–50° at all. One has to now divide the magnification the eyepiece gives on a particular instrument into the field of view quoted. So, for an eyepiece with a FoV of 50° and a magnification of 50×, the apparent field of view through the eyepiece will be 1° (50/50) or 60 arc minutes, whereas one with a magnification of 50× and a FoV of 30° will give a FoV through the telescope of 0.6° (30/50), or a FoV of 36 arc minutes.

An additional tool for determining the FoV is to put a bright star such as Altair (α Aquilae) or σ Orionis on the edge of your eyepiece field and allow the star to drift through the field until it reaches the other side. Time this event and multiply the time by 15 to obtain the FoV in minutes and seconds. As 60 min make 1°, it will be easy to determine FoV with this method and adjust accordingly.

Observers will have to make all these calculations across the range of their ‘scopes and eyepieces so that they will then understand the FoV through each instrument and will be able to use this information in observing the field for faint objects and making a mental determination of how large an astronomical object would appear in such a combination. This is extremely useful for hunting down faint extended nebulae or compact objects such as some planetary nebulae, as the FoV will enable the observer to gauge the size of the target in the eyepiece more effectively.

One additional accessory that will aid with magnification is the Barlow lens. This negative focus lens effectively doubles or triples the magnification of each eyepiece, and the quality versions have a demountable lens that will fit into the adapter sleeve of a DSLR camera, thus increasing the focal ratio of the optical system and enabling a smaller FoV around the object one wishes to image. These lenses are available from all good suppliers, but the quality can vary.

A technique that is very useful when using colored filters at the eyepiece (or any other for visual observing) is that of “blinking” the field, which involves *not* screwing the filter to the eyepiece barrel but holding it between the eye and eyepiece and moving it in and out of the field. Working like a blink comparator, the use of the filter then turns the details on your chosen object “on and off” as it crosses the field of view and makes the body stand out in sharper relief as some details gain clarity and the brighter ones fade, and the contrast brings out details that would otherwise be lost in the glare. This technique is easy to use and can make a clear difference to the observer’s hunt for faint details, and it also works for some narrowband filters such as the OIII, which shall be the subject of later discussion.

Quality eyepieces married to a good telescope of reasonable aperture can be used to make important observations of Solar System objects, the Moon and some deep sky objects, too. Marrying a CCD camera to such systems can broaden the range of filters used beyond the Wratten system, but that is something we shall cover in a later chapter.

Conclusion

It is hoped that readers are convinced not to ignore the strange colored filters that may accompany their telescopes. If you don’t yet have colored filters then it is recommended getting at least a selection of them from the earlier list, as they do proffer a new experience when gazing at the Moon or planets. The enhancement of detail and the reduction of glare should be ample inducement to own some filters that can be purchased inexpensively from astronomical suppliers. Most offer a selection as part of a lunar and planetary set wherein Wratten numbers 8, 11, 21 and 82A are the most common combinations in a set of filters for this kind of observing activity. Retailers will sometimes offer two sets, a “light” set, as noted with the Wratten numbers above, and a “dark” set, with Wratten numbers 15, 25, 47 and 58 to offer additional contrast and variety in your Solar System observing.

The table below gives a précis of the filters described above and their characteristics. Married to a good quality telescope with an appreciable aperture and good eyepieces the astronomer is well equipped to explore faint and subtle details in many objects.

Wratten no.	Color	Characteristics
25A	Red	Longpass filter blocking light short of 580 nm
23A	Light red	Longpass filter blocking light short of 550 nm
21	Orange	Longpass filter blocking light short of 530 nm
8	Light yellow	Longpass filter blocking light short of 465 nm
12	Yellow	Longpass filter blocking light short of 500 nm
15	Deep yellow	Longpass filter blocking light short of 510 nm
11	Yellow–green	Color correction filter, not a longpass filter
56	Light green	Color separation filter
58	Green	Color separation filter
82A	Light blue	Warming filter. Raises the intensity of long wavelengths
80A	Blue	Color separation and warming filter
38A	Dark blue	Absorbs red, green and UV light
47	Violet	Color separation filter

Colored filters are therefore highly recommended for Solar System objects and coupled with large aperture telescopes can reveal fine detail in the cloud belts and rings of the gas giants. It cannot be stressed enough that Wratten filters are an essential component of the lunar and planetary observer's toolkit. Let us then explore their use further by looking at the Moon and planets in detail.

Further Reading

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