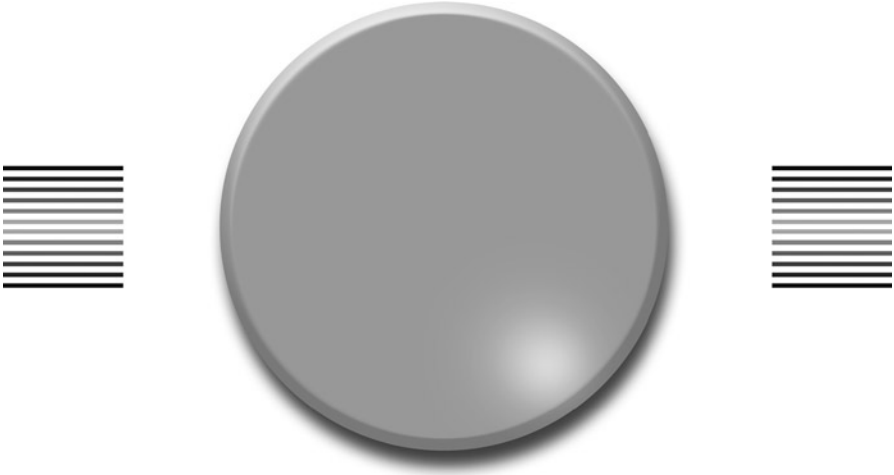
CHAPTER TWO



# Know Thy Dob

Since the vast majority of Dobsonians on the market use Newtonian reflectors, it is fitting to begin this survey of this rapidly changing market with a discussion concerning the ins and outs of the reflecting telescope, so that you can get the most out of it and maintain it in tiptop condition. This chapter will discuss everything you need to know about how your Newtonian works. On our road to understanding, we'll be dipping in and out of history to record the key events that shaped the evolution of the Newtonian into its quintessentially modern form.

The basic design of the Newtonian reflector – so named because of its invention by Sir Isaac Newton – has hardly changed since it was first conceived by the great scientist in 1668. Instead of using a convex lens to focus light, Newton used a finely polished spherical mirror. Astronomers had known about the possibilities of parabolic mirrors since 1663, when James Gregory, an English mathematician, envisioned a reflecting telescope that would bounce light between two mirrors, one with a hole in it to allow light to reach the eyepiece. Of course, being one of Europe's finest mathematicians, Newton was well aware of the properties of parabolic mirrors that would in theory produce even better images, but methods to "carve out" a parabolic surface presented a practical problem beyond him at the time. That's why he settled on the less than perfect spherical

N. English, *Choosing and Using a Dobsonian Telescope*, Patrick Moore's Practical Astronomy Series 1, DOI 10.1007/978-1-4419-8786-0_2,
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**Fig. 2.1.** A replica of Newton's reflecting telescope (Image credit: Pulsar Optical).

geometry for his metal mirror. The reflected light was sent back up the tube to a tiny flat mirror, mounted centrally and at a 45 degree angle, delivering the light cone to the eyepiece, where it reached focus. Newton was apparently very fond of pointing out that his little telescope – which delivered a power of about 40× – performed as well as refracting (lens-based) telescopes many times longer (Fig. 2.1).

Spherical mirrors are easier to make, but they have one minor flaw; light from the edges of a spherical mirror do not come to focus at the same point as rays from the center. In other words, the spherical mirror exhibits *spherical aberration,* which smears out the image so that it is difficult to get a razor-sharp view. That said, you can still obtain good results with spherical mirrors so long as the focal length of the 'scope satisfies the following formula:

$$\text{Focal length} = 4.46 \times (\text{Aperture})^{4/3}$$

This formula gives the minimum focal length a spherical mirror needs to be in order to meet the Rayleigh criterion, which is the lowest quality level that will produce an acceptably sharp image. For example, if you construct a 6-inch (15-cm) spherical mirror, it would need to have a minimum focal length of $4.46 \times (6)^{4/3}$. Plugging these numbers into a calculator gives a value of 48.6 inches (1,245 mm). There are commercially available Dobs that have spherical mirrors, but they are usually confined to apertures less than 6 inches for practical reasons.

When you take a mirror that has a nice spherical shape and deepen its curvature at the center a little bit, you will eventually arrive at a parabolic shape. It can be proven mathematically that only a parabolic surface has the attractive property of bringing to a single focus all rays parallel to its axis. In other words, a perfect parabolic mirror would have no spherical aberration. John Hadley, together with his two brothers, George and Henry, built the first reflector with a parabolic mirror, a 6-inch (15-cm) instrument of 62-inch focal length which he presented to the Royal Society in 1721.

For nearly two centuries after the invention of the Newtonian, the mirrors were made from a special alloy of mainly copper and tin. These "speculum" mirrors (practically 62 percent copper and 32 percent tin) gave a golden cast to the image and had a reflectivity of about 70 percent (actually a 1947 study suggested that its reflectivity varied from about 63 percent for blue light and 75 percent for red). After 6 months of exposure in a damp climate, its reflectivity drops by 10 percent, necessitating frequent polishing. Coupled to this, metal mirrors are exceedingly difficult to grind and are unduly heavy for their size. These deleterious aspects of speculum mirrors forced astronomers to look for better ways to build mirrors.

## From Speculum to Glass

The next evolutionary step came in 1856, when the German astronomer Karl Steinheil, borrowing a technology developed by the chemist Justus von Liebig around 1840, hit upon a way of coating a 4-inch (10-cm) glass mirror with a thin veneer of silver. The telescope, by all accounts, gave excellent images but, remarkably, received little attention from the scientific cognoscenti. The following year, the physicist Jean Foucault made his own silver-on-glass mirror, and the resulting telescope – as well as the tests he singlehandedly developed to test its quality – received unanimous praise from the French Academy of Sciences.

These innovations set the scene for the rapid elevation of the reflecting telescopes in both the amateur and professional astronomy circuits that began in the middle of the nineteenth century and has continued unabated ever since. Glass mirrors could be made lighter and so more easily mounted inside their tubes. What's more, because parabolic mirrors work well, even at short focal ratios, they could be made much smaller than the standard instruments of the day – the long focus classical achromatic refractor – and thus were often more convenient to use in the field. But silver, despite its significantly greater reflectivity than speculum metal, was also subject to tarnishing over time. It was only after a series of influential experiments conducted in the 1920s that astronomers settled on the current reflecting material, aluminum. Although not nearly as reflective as silver, aluminum is far more durable and holds its shine for longer. All economically priced Dobs on the market have aluminized mirrors that reflect between 85 and 89 percent of the light striking them. With enhanced coatings however, reflectivities as high as 99 percent can be achieved (but, you guessed it, at extra cost).

Aluminum coating is done by depositing an ultra-thin layer of gaseous aluminum in a high vacuum tank. The aluminum metal is evaporated from a wire near the bottom of a purposefully built tank and coats the mirror which is rotated at the top of the tank. Then, a very thin silicon dioxide transparent coating is coated over the aluminum. During this process, the mirror never becomes hot.

## Support Your Mirror

In order to perform well in the field, the mirror must be supported in its correct relative positions and orientations within the telescope tube. The earliest Dobs had their primary mirrors mounted inside simple sling-like devices that were OK but certainly not up to the task of holding collimation well after being lugged about in the back of a car. It goes without saying that the support must be firm enough to hold the mirror securely, but not so robustly as to stress the carefully figured shape of the mirror. The weight of the mirror is taken with supports on the bottom and sides. The mirror cell itself is housed inside a protective cell and held in situ by small clips (top supports), although smaller cells can be adequately supported using between 9 and 18 pads that provide structural support to the rear of the mirror. Lateral movement is kept in check by means of either a web-like sling or a teeter-totter post arrangement called a waffle tree (Fig. 2.2).

**Fig. 2.2.** A basic 9-point primary mirror cell (Image credit: John Heath).

The usual collimation arrangement for primary mirror cells is to have three adjustable spring tensioned bolts spaced 120 degrees apart. The primary mirror is aimed at the secondary mirror by adjusting these bolts up and down independently. There are a great number of primary mirror cells on the market, and they range from the barely functional to the highly elaborate. The most important function of this cell is to keep the position and orientation of the primary mirror securely fixed relative to the other optical components of the Newtonian.

## The Secondary Mirror

The role of the secondary mirror, as previously mentioned, is to pick off the light gathered by the primary mirror and redirect into the drawtube, where an eyepiece can focus it. The secondary is usually mounted on spiderlike vanes attached to the side of the tube. The secondary is either a flat, elliptically shaped (because that's the geometry that minimizes the amount of light obstructed) mirror or a prism (Fig. 2.3).

**Fig. 2.3.** A typical secondary flat mirror attached to spiderlike vanes (Image by the author).

The latter are rarely used these days because they are only practical for smaller sized 'scopes less than 6 inches (15 cm). The elliptical mirror, which projects a circular geometry when viewed at the required angle, is carefully sized so as to minimize the amount of light cut off to the primary mirror but not so small so as to reduce the amount of light reaching the eyepiece (that would result in a darkening of the corners of the field of view and vignetting). Typically, central obstructions are expressed as a percentage of the diameter of the primary mirror. Short focal length Dobs usually have central obstructions of the order of 25 percent or greater, whereas longer focal length instruments (f/8 or above) can have central obstructions as low as 15 percent. Newtonian reflectors even of f/6 design can easily accommodate secondary mirrors less than 20 percent of the diameter of the primary mirror and still give full illumination to a reasonable field of view. (Indeed, this author has often entertained the idea of making a dedicated 6-inch f/6 planetary 'scope with 20 percent central obstruction. It might not fully illuminate wide field eyepieces, but that's not what this 'scope would be used for).

For focal ratios of f/8 and higher, secondary obstructions of 15 percent and smaller can be used productively. Compare that to compound reflectors of the Cassegrain and Gregorian types, either in classical or Schmidt Cassegrain or Maksutov configurations, which require

secondary obstructions between 25 and 35 percent of the diameter of the primary mirror. In general, only the Maksutov Newtonian has smaller obstructions than the Newtonian.

A large central obstruction will make it more difficult to see subtle low-contrast detail, such as Jupiter's wispy equatorial festoons, or the delicate surface markings on Mars. The point at which this loss of image contrast becomes noticeable is a matter of heated debate, but most experienced observers agree that as long as the secondary mirror's diameter is less than 20 percent that of the primary mirror, its effects should be all but impossible to see. For binary star work some have claimed that a large secondary obstruction actually enhances performance, since it slightly shrinks the apparent size of the Airy disk, throwing the light into the first order diffraction ring and thereby somewhat increasing the apparent resolving power of the instrument. That one possible case aside, telescopes having central obstructions in excess of 25 percent begin to degrade the image noticeably in the arena of low-contrast resolution. When the size of the secondary reaches 30–35 percent, as it does in many commercial Schmidt Cassegrain telescopes, the drop in the ability to resolve fine detail becomes extremely noticeable. No matter how good your optical system may be, the mere presence of such a large secondary mirror may degrade the final wavefront to an effective quarter wave, PV, or less (Fig. 2.4).

**Fig. 2.4.** A typical secondary mirror housing for a small Dob (Image by the author).

Equally important is the quality of the secondary mirror itself. How flat is it? And how much light does it reflect? Standard "flats" come with a surface accuracy of about 1/10th wave, that is, they do not depart from perfect flatness by no more than about 50–60 billionths of a meter. With standard coatings they typically reflect about 96 percent of the light incident upon them. Of course, you can get flats that are considerably better than this, but at additional cost.

Some observers find the diffraction spikes (caused by the vanes of the secondary mirror) a distraction. Typically, four vanes are used, but some cut that down to three or have designed their own ingenious ways of mounting their secondary. Curved vane secondary spiders, which were first introduced back in 1931, virtually eliminate the diffraction spikes common to Dobs and Newts with straight vane spiders. But do curved spiders really lessen the diffraction at the eyepiece? No, they actually create more diffraction. Why? Well, for one thing, a straight vane causes diffraction over a 2 percent area. But a curved vane actually intercepts about 66 percent more area than straight vanes, so it will introduce more diffraction into the image.

Besides, if curved spiders were of any real advantage at all, professional observatories would be using them. Indeed, if your forte is teasing out the faint companion of a bright double star, the curved diffraction pattern will often bury it. In contrast, with a straight vane spider, you can always nudge the faint companion star out from under the diffraction spike and observe. Nor is there only one good way of doing this. Any departure from the straight four-vane design will give noticeably different results. Some companies, such as 'scopetronics and Protostar, even sell retrofit units that accommodate a wide variety of commercially made Dobs. Are they worth the extra expenditure (a $100–$200 venture)? If you've spent a lot of time around refractors, you may be tempted to do this. If you were weaned on reflectors, chances are you'll likely be sticking with convention. It's up to you and your tastes.

## Image Quality

In the end, what really matters is the quality of the images your Dob serves up on celestial objects. The mirror, being freed from the nuisance of chromatic aberration (the main drawback in inexpensive achromatic refractors), serves up color pure images each and every time. But there's more to image quality than lack of false color. Here's a list of the aberrations that can degrade a telescope image.

| Aberration | How They Scale |
|---|---|
| Spherical | $1/F^3$ |
| Astigmatism | $1/F$ |
| Coma | $1/F^2$ |
| Distortion | $1/F$ |
| Field curvature | $1/F$ |
| Defocus | $1/F^2$ |

Let's tackle spherical aberration first. A perfect mirror focuses all incoming light to a sharp point on the optical axis, which is usually along the center of the telescope tube. However, a real mirror focuses rays more tightly if they enter it far from the optical axis than if they enter it close to the optical axis. This defect is called spherical aberration.

How does spherical aberration impair the image in the reflecting telescope? At low magnifications, little or no effects can be seen, but as you crank up the power an instrument displaying significant spherical aberration will be very hard to focus sharply. As a result, high power views of planets and the Moon take on a slightly "soft," drowned-out appearance.

Coma is an off-axis aberration. By that, we mean that stars in the center of the field are not affected, but the distortion grows stronger toward the edge of the field. Stars affected by pure coma are shaped like little comets (hence the name) pointed toward the center of the field. The effect is particularly common in reflecting telescopes, especially those that have fast focal ratios (f/3.5 to f/5). Fortunately, Al Nagler, founder of TeleVue optics, developed the Paracorr, auxiliary optics that do a great job correcting much of it. You slot the device into the focuser ahead of your eyepiece, much like a Barlow lens. The Paracorr extends the effective focal length of your Dob by 15 percent. Some observers have noted that while certainly correcting for coma it reduced on-axis definition just a little. Baader Planetarium (Germany) has developed another version of the Paracorr. Called the Multi-Purpose Coma Corrector (MPCC), it retains the native focal length of your 'scope. Sky Watcher has also introduced an economically priced coma corrector for their f/5 Dobs. We'll be delving into these magical devices in more detail in a later chapter.

Another aberration to look out for is astigmatism. This occurs when a mirror is not symmetrically ground around its center or, more usually, by misaligned optics. Most of the time, when such a system is misaligned or badly reassembled, slightly out-of-focus stars take on an oblate appearance. What's more, when you flip from one side of focus to another, the oval flips orientation by 90 degrees. In focus, images appear distorted, too.

The last two Seidel errors – distortion and field curvature – are in many ways less important. Field curvature is easy to spot. First, focus the star at the center of the field and slowly move it to the edge of the field of view. If you have to refocus it slightly to get the sharpest image then your 'scope is probably showing some field curvature. Distortion is usually seen when using wide-angle eyepieces on short focal ratio 'scopes. It comes in two flavors; pincushion (positive distortion) and barrel (negative distortion). These distortions are best seen during daylight hours by pointing your 'scope at a flat roof and looking for bending of the image near the edges of the field.

Distortion is very hard to correct completely, and only the best (read most expensive) eyepieces seem to be able to correct for it adequately. The good news, especially if you're a dedicated sky gazer, is that it will have little or no effect on the quality of the night time images your 'scope will throw up and so for the most part can be ignored.

The final aberration featured in the table is the defocus aberration, which you can see scales inversely with the square of focal ratio. This provides a measure of how easy it is to achieve precise focus. In other words, telescopes with greater focal ratios enjoy greater *depth of focus*. Thus an f/8 'scope will be four times $(8/4)^2$ easier to focus than an f/4 'scope of the same optical quality.

Focusing an f/4 Dob can be an exercise in frustration, especially during periods of poor and mediocre seeing, but it is considerably easier in an f/8 Dob under the same conditions. It has been argued elsewhere that depth of focus is strongly linked to image stability (the images will be four times more stable under all conditions of seeing. This author's own research conducted in collaboration with Vladimir Sacek (creator of TelescopeOptics.net) has shown that greater depth of focus is best seen as a tool to achieve best focus position. What's more this research has shown that depth of focus is protective of a telescope's best performance level.

The important general principle to take into account is that when the focal ratio of the mirror is increased all the aberrations fall, so you are more likely to get better images in an f/8 Dob than say an f/4 Dob of the same aperture. That is not to say that high F ratio mirrors are that much easier to make than their low F ratio counterparts. To see why, consider making a 6-inch f/12 spherical mirror and then think about the differences you'd have to introduce to the same mirror to create a parabolic geometry. The difference would be minute! All it takes is just a smidge too much grinding to overshoot the mark! Another problem with high F ratios is that it rapidly increases tube length. Setting up a 10-inch (25-cm) f/5 Dob is a one-person job; but an f/10 'scope of the same aperture is certainly sure to require at least two. That's why the vast majority of commercial Dobs in apertures over 10 inches have very fast focal ratios (f/3.5 to f/5).

How would you rate the image quality in your Dob? OK? Good? Magnificent? A traditional way of measuring optical quality is to specify how well the mirror is figured. Because the differences between a good mirror and bad mirror can be minute, it simply isn't convenient to express errors in everyday units. Instead some opticians prefer to express the error in terms of the fraction of the wavelength of yellow-green light the primary mirror deviates from that of a perfect optic. This color of light has a wavelength of 550 nanometers. One nanometer is one billionth of a meter. An OK mirror will be figured to an accuracy of ¼ of a wave, that is, the microscopic irregularities in the shape of the mirror cannot be more than about 140 nanometers in order for it to operate satisfactorily under most conditions. Such a mirror is said to be *diffraction limited*, which means that the optics are constrained by the wave nature of light itself and not by any flaws in its optical figuring.

Who gave us that idea? That honor goes to the nineteenth-century physicist, Lord Rayleigh, who reckoned that an image distorted by anything more than ¼ wave of yellow-green light would appear *obviously degraded* to the eye. This is called the Rayleigh limit. Of course, it stands to reason that a primary mirror corrected to an accuracy of, say, 1/8 of a wave has an even better figure, but would you notice the difference in the field? Careful observers would definitely say yes. Tests conducted by Peter Ceravolo and published in Sky and Telescope, March 1992 suggest that telescopes with final images of less than ¼ wave P-V wavefront were not as revealing of fine planetary detail as those which were working at 1/8 wave or better. A Newtonian primary mirror that is corrected to an accuracy of ¼ of a wave will show some nice detail on the planets but not nearly as much as an identical reflector corrected to, say, 1/6 or 1/8 of a wave. That said, there is a limit to how much the human eye can discern. In typical tests, most people are not likely to see a difference between an mirror corrected to 1/8 of a wave and one that is corrected to a 1/10 wave accuracy. Dave Bonandrini, a very experienced user of Dobsonians from Ann Arbor, Michigan, in the United States., said this about mirror figure. "I think most astronomers would be fine with a telescope that has a 1/4 wavefront," he said. "If set up side by side, many astronomers can see the difference between a 1/4 and 1/8 wave. I have never seen a mirror test over 1/20 wavefront. Whenever we have tested a 1/30 wave mirror, it usually is well under 1/8 wave."

Surface accuracy is all well and good, but it doesn't tell the whole story. Errors in the figure of the mirror surface making up the objective can lead to increased spherical aberration, coma, distortion, field curvature, and astigmatism (the five Seidel errors). To this end, optical engineers have devised an even better way of expressing optical quality – enter the Strehl ratio.

To understand this quantity better, picture again the image of a tightly focused star seen at high power through the telescope. The star will not be a perfect point but will instead be spread over a tiny disk of light called the Airy disk surrounded, in ideal conditions at least, by of series of diffraction rings. This is what opticians call a diffraction pattern. In 1895, the German mathematician and astronomer Karl Strehl computed what the diffraction pattern of a perfectly corrected lens (or mirror) would look like, with a central peak intensity (representing the Airy disk) surrounded on either side by a series of peaks of progressively less intensity.

A *real* mirror, on the other hand, will have some optical aberrations that will leave their mark on the diffraction pattern observed. For example, a mirror might display some coma and so some of the light never gets focused tightly inside the Airy disk, resulting in a decrease in the peak intensity in its diffraction pattern compared to a perfect lens. Other optical errors, such as spherical aberration and astigmatism, for instance, also leave their mark on the diffraction pattern. And yes – it inevitably reduces the peak intensity of the Airy disk. Put another way, an optically perfect telescope will place about 87 percent of the light inside the Airy disk and the rest is to be found in the surrounding diffraction rings. All real-world telescopes place less than 87 percent of the light inside the Airy disk.

There is a neat way to calculate the Strehl ratio of your 'scope given either your Peak-to-Valley (P-V) error or your Root Mean Square (RMS) error. If ω is the Root Mean Square (RMS) error of your mirror, then its corresponding Strehl is given by:

$$S^{\sim e} - (2\pi\omega)^2$$

For example, if we set $\omega = 1/13.4$ RMS wavefront error, then the corresponding Strehl will be 0.8. Such a Strehl value is considered to be diffraction limited. The best-figured mirrors have Strehl ratios considerably higher than this (>0.98 is possible). Finally, it is the author's opinion that under good conditions, where seeing and localised thermal effects do not degrade the image, observers will likely not see much difference between a mirror figured to an accuracy of a smooth ¼ wave and that delivered by one figured to a higher accuracy.

## Tube Design

The length of a Newtonian reflector is basically governed by the focal length of the primary mirror. Because the instrument is not a compound design, the effective length of the telescope is very close to the focal length

of the primary mirror. Thus, an 8-inch f/6 (20 cm) instrument will have a physical length of at least 1.2 m and a 10-inch (305-mm) f/5 instrument will have a length of the order of 1.5 m. By comparison, compound designs such as Schmidt Cassegrains or Maksutov Cassegrains of equal aperture will have a length less than half that of a Newtonian. The long tube of the Dobsonian (especially closed tube designs) may create some transportation issues. The 10–12 inch (25–30 cm) seems to be the upper limit for solid tubes. That's because a 'scope this size will fit across the back seat of almost any car. Going bigger than this, the advantage is tipped in favor of a segmented design.

Of course, this problem is considerably reduced by making the tube so that it comes apart into two or more sections, creating so-called segmented or truss tube designs. The Newtonian reflector suffers from the fact that whether one uses a solid tube or a truss tube, the optics are left wide open to the effects of dew, air currents, dust, dirt, and whatever else comes along. This is a real disadvantage when compared to the closed system of the refractor, Schmidt Cassegrain or Maksutov design. The advantage of the closed system is that the primary mirror and secondary mirror are kept sealed and remain clean. Added to this is the idea that tube currents cannot form and degrade the final wave-front.

## Focusers

If you look through a variety of 'scopes of different focal ratios you'll soon notice a trend. The higher the F ratio, the easier it is to find the point of best focus. A 6-inch (15-cm) f/8 Dob is a breeze to focus; a 6-inch f/5 is considerably trickier. When you get to f/4; a high quality focuser almost becomes a necessity as the depth of focus (which scales directly as the square of focal ratio) is so shallow that the slightest shift can make all the difference between a sharp and a fuzzy image.

The first commercial Dobs to hit the market back in the 1980s and 1990s came equipped with simple but functional rack and pinion focusers. Lubricated by grease, they were always prone to stiffening during cold snaps. Frequent users had to "relube" them from time to time to keep them working at all. These days, things have definitely changed for the better, with even many budget-priced models – the "Econo-Dobs," to use Phil Harrington's phrase – now sporting silky smooth Crayford-style focusers that are definitely a mark up from their rack and pinion counterparts.

That said, some observers have seen the need to upgrade their standard Crayfords, replacing them with high-quality dual speed focusers made by

third-party companies. These high-end focusers allow Dob users to attain and hold precise focus much more effectively. In addition, an oversized knob on the top of the focuser body can be tightened to lock it in place for photographic applications. We'll be looking at a few nice focusers that you can retrofit onto your existing instrument in a later chapter.

## Mirror Cooling

If you take your Dob out from a warm room to the cool night air and immediately begin to observe, chances are you'll be disappointed by the views it throws up. As soon as you uncap your telescope, the tube begins to fill up with cold ambient air, and the primary mirror starts to acclimate to the cool of the night air. Until it reaches the ambient temperature of the atmosphere around you, the *boundary layer* of warmer air coming off the primary sits just above the mirror surface, causing bad seeing. A quick look at a planet or a star shows it "boiling" in the eyepiece. As you'd expect, the problem gets worse as mirror size increases, and if the temperature continues to drop all night the mirror might never catch up. In that situation, the boundary layer will never disappear.

One excellent solution to this problem is to install a cooling fan behind the primary mirror cell that blows cold air onto the cell, cooling it off to ambient temperature much more quickly while also helping to remove that boundary layer. That said, it still involves a bit of waiting for the mirror (especially for an 8-inch aperture Dobs and larger) to cool to ambient, even with the help of the fan, but nothing like the few hours it takes without one.

The primary advantages of cooling fans are most noticeable when viewing the planets, splitting tight double stars, and other high magnification work. The image is more stable – that is, less prone to degrading – and the images of stars are tighter. In general, you do want to keep the air moving when you are observing; not only will it help the 'scope track a falling temperature, but it will also keep the boundary layer under control. Some observers turn their fans off while actually observing, claiming that it introduces tiny vibrations that can disturb the image.

Mirror cooling can be as simple or as complicated as you want it to be. You can make your own fan for a 6-inch f/8 Dob with a $10 computer fan. It attaches to the rear tube with Velcro and doesn't cause much in the way of vibration issues while observing – even at fairly high powers. If you do see some fan-induced vibrations, you can always experiment by lowering the voltage a little. With a modest set up, a 9 V supply provides effective air flow. Your mileage may vary (Fig. 2.5).

**Fig. 2.5.** A built-in mirror cooling fan (Image credit: Andy Sheen).

## Pause for Thought – The Newtonian Logic

On a cold January day in 1672, the thirty-year old Isaac Newton presented an entirely novel type of telescope to England's Royal Society, where it aroused great interest. He had succeeded in making a mirror with a spherical curvature, slightly less than 1½ inches (3.7 cm) in diameter. The mirror was made of a copper-tin alloy, to which Newton had added

a bit of arsenic to make it easier to polish. Above this primary mirror Newton placed a small, flat secondary mirror at a 45-degree angle, to reflect the light into an eyepiece mounted in the side of the telescope tube. And though he was not the first to suggest the use of mirrors in the design of astronomical telescopes, his little reflector changed the world of astronomy forever. Though it was only 15 centimeters in length, the instrument had a magnification of about 40 and could outperform lens-based instruments more than two meters long.

It is now 450 years on, and Newtonian reflectors have improved beyond measure and still command respect from an army of beginning stargazers and seasoned veterans alike. Their great strength is their affordability, embodied in the fruits of the Dobsonian revolution, provide backyard astronomers with arguably the most "bang for the buck" of all telescopes, serving up images that are sharp, detailed, and free from the false color that plagues refractors of the same size. A Newtonian reflector uses a single parabolic mirror to gather light from distant objects. Light enters the tube, traveling down to the mirror, where it is then reflected forward in the tube to a single point called the focal plane. A flat mirror called a "diagonal" intercepts the light and directs it out the side at right angles to the tube through to the eyepiece for easy viewing.

Newtonian reflector telescopes replace heavy lenses with mirrors to collect and focus the light, providing an impressive amount of light-gathering power for the money. You can have focal lengths up to 1,200 mm and still enjoy a telescope that is relatively compact and portable. Let's look at some of the many advantages connected with Newtonian reflectors that make them superior to virtually all other optical systems as serious, all-around performers.

For one thing, they are usually less expensive for any given aperture than comparable quality telescopes of other types. Since light does not pass through the objective (it only bounces off a mirrored surface), exotic glasses are not needed; the material only needs to be able to hold it to an accurate figure. Because there is only one surface that needs to be figured (as opposed to four in a refractor) it is easier for amateur telescope makers (ATMs) to fashion their own objective. A short focal ratio can be more easily obtained, leading to wider field of view. Long focal length Newtonian telescopes can give excellent planetary views.

Another great utility afforded to Newtonian reflectors is that they can be made in large enough sizes to satisfy the fundamental requirements for the general observer without experiencing extremely high costs. For example, an average 12-inch (250-mm) f/5 Newtonian can be made to sit comfortably within the cradle of a simple Lazy Suzan-style alt-az mount and can be set up for observing within minutes (if properly acclimated).

Such an instrument, once cooled down to ambient temperatures, can detect objects some nine times fainter and can resolve details three times finer than the best 4-inch (10-cm) refractor that usually costs two or three times as much. And although they are certainly not grab 'n go instruments, large Dobsonians – especially those of the truss-tube variety – can be transported long distances in the back of a small car and can be set up within minutes.

In addition, the simplicity of the Dobsonian mount means that very large backyard 'scopes can be acquired for a relatively small financial outlay. This author once had the opportunity to look through a massive 30-inch (75-cm) monster at a star party, and the views were spectacular to say the least, though it took a while to get used to maneuvering the ladder to reach the eyepiece. We spied the Ring Nebula (M57). What were the views like? Well, words such like "spectacular," "huge," "colorful," and "compelling" spring to mind. Of course, Dobsonian-mounted Newtonians have also entered the electronic age. Several manufacturers now sell encoders, for both the right ascension and declination axes, that allow you to quickly locate thousands of galaxies, star clusters, and nebula simply by pushing the 'scope to a particular spot in the sky. What's more, large Dobsonians can now be placed on specially designed, tilted platforms that enable the 'scope to track objects automatically as they move across the sky. And most recently of all, alt-az mounted Dobs have now been empowered with full GoTo capability.

So why doesn't everyone use a large aperture Dob instead of coveting smaller refractors or ultra-compact catadioptric designs? The answer is complex and varied. Some diehards can never get excited about Dobsonians, or even Newtonians in general. Newtonians have issues – there's little doubt about it – that arise both from their complex nature relative to simpler designs (such as refractors), as well as thermal mismanagement. For others, the problem lies in the quality of the mirror. Although they don't suffer from chromatic aberrations, they frequently suffer from miscollimation issues, which creates the wrong impression if the owner isn't careful enough to check the alignment of the optics on a regular basis. Other mirrors are just poorly designed and throw up astigmatism, coma, and modest amounts of spherical aberration. As we've seen, the shorter the focal length of the mirror, the more difficult these aberrations are to control, with the result that top-quality, "fast" mirrors are more expensive to buy, and focal ratios much below f/3 or f/4 are extremely difficult to make with any accuracy. That said, a long focal length (f/8 or slower) Newtonian is hard to beat as a lunar and planetary 'scope, especially in apertures from 6 to 10 inches. because these aberrations are very much reduced.

The Newtonian reflector requires a smaller secondary obstruction than any other reflecting telescope design. Compound reflectors of the Cassegrain and Gregorian types, either in classical or Schmidt Cassegrain or Maksutov configurations, require secondary obstructions having a physical size of at least 25–35 percent of the diameter of the primary mirror. Newtonian reflectors, by contrast, even of f/6 design, can easily accommodate secondary mirrors less than 20 percent of the diameter of the primary mirror and still give full illumination to a reasonable field of view. Better still, for focal ratios of f/8 and higher, secondary obstructions of 15 percent and smaller can be attained. No other reflecting optical system can do this without resulting in extreme proportions.

The impact of the secondary obstruction on observing is most readily noticed in attempting to resolve fine, low-contrast planetary detail. Telescopes having central obstructions in excess of 25 percent begin to degrade the image noticeably in the arena of low contrast resolution. When the size of the secondary reaches 30–35 percent, as it does in many commercial Schmidt Cassegrain telescopes, the reduced ability to resolve fine detail becomes extremely noticeable. This obstruction and the so-called diffraction spikes caused by the support structure (called the spider) of the secondary mirror reduces contrast. Visually, these effects can be reduced by using a two- or three-legged curved spider. This reduces the diffraction intensities by a factor of about four and helps to improve image contrast, with the potential penalty that circular spiders are more prone to wind-induced vibration. Although a four-legged spider causes less diffraction than a three-legged curved spider, the latter often gives a more aesthetically pleasing view.

So there you have it: Dobsonians are serious instruments for lunar, planetary, and deep sky observing. Although not as readily portable as a small refractor or Schmidt Cassegrain or Maksutov instrument, such an instrument will optically match or outperform all other forms of astronomical telescopes inch for inch of aperture in larger sizes. That said, a Newtonian reflector requires slightly more care and consideration in use, but will be significantly less expensive to construct than any of the other telescope types. The point to emphasize here is that the Newtonian reflector is in no way a substandard instrument when compared to other compound reflecting optical systems or refractors. If the gremlins associated with accurate collimation and thermal management are sorted out, then it is every inch the equal of these instruments and, in some ways, superior. If the instrument is designed well and constructed out of quality materials, the views it will serve up will absolutely amaze you.

You will note that we understand the term “Dobsonian” to mean any simply mounted (usually alt-az) reflecting telescope. It need not be a Lazy

Suzan mount, and it may not even be a Newtonian reflector, but it's got to be easy and intuitive to operate. John Dobson himself would undoubtedly be happy with this general description.

All that said, we're now ready to explore the rich milieu of the Dobsonian telescope. In the following chapters, we'll explore the ways in which the Dobsonian revolution has developed over the last decade into an astonishing array of instruments, from tiny hand-held rich-field 'scopes to towering giants that would hold their own or even outperform many observatory class telescopes. To begin with, let's take a look at the most diminutive of the commercial Dobs, the new breed of starter 'scopes that get so many youngsters and older beginners hooked on sky gazing.

http://www.springer.com/978-1-4419-8785-3

Choosing and Using a Dobsonian Telescope
English, N.
2011, XIII, 232p. 118 illus., 105 illus. in color., Softcover
ISBN: 978-1-4419-8785-3