Telescopes and Their Limitations by Dick Suiter

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> Dictionary Definition: *Telescope*, n., A viewing device that makes distant object appear nearer, constructed from an arrangement of lenses or mirrors.

> Optics Definition: *Visual Telescope*, an optical device taking a parallel beam of light and converting it to another parallel beam of smaller diameter, i.e., an afocal magnifier. It is used for gathering light and enhancing resolvable detail.

Of course, optical workers have another definition for *Photographic Telescope*, but when you read that you quickly realize it is just a large photographic lens with limited field-of-view. The true telescope has the eyepiece and eye included in the design.

What is the best type of telescope? None are. It all depends on what you are willing to pay for, lift, and use. All this is said better in the article "What is the best planetary telescope?" by Roland Christen, at www.cloudynights.com, except I would be willing to extend his conclusions to many types of viewing, not just planetary.

If there are any general rules, they are these:

1) Consider buying binoculars of 35 to 50 mm aperture before you buy a telescope. (Come to club observing sessions and use our telescopes before you decide.)
2) Once you do decide, get the largest aperture you can <u>comfortably</u> move, not the biggest aperture you can afford.
3) Make sure it is properly and ergonomically mounted.
4) Make sure that you can find things in it.
5) Don't skimp on eyepieces.
6) Keep photography out of your thinking until just before you're ready to do it.

Note: the first rule is important. Another rule I would follow is

> *If you are not willing to buy a star atlas, don't buy a telescope!*

You would not believe the number of people who have never owned an atlas. The computer programs are okay, I guess, but there is nothing quite like a paper atlas for teaching you the sky.

2) APERTURE

We tend to explain our drive for ever-higher apertures as a simple light-gathering move, especially to the general public. People can comprehend collecting all the light in a bigger circle. What we don't often explain is that there is a much more subtle reason we want a larger aperture. In fact, with some planetary observing we are much more comfortable with less of the dazzling light. The *real* reason we want aperture is that it paints a more detailed picture at the focal plane.

The resolving power of fine detail in the sky is proportional to the number of wavelengths across the diameter of the aperture. In arcseconds, the resolution is about the following number

$$\text{resolution [arcsec]}= 5.4/D[in]=140/D[mm]$$

We can use this formula to prepare a table of resolutions. Detail improves as the resolution number gets smaller. This resolution number should be doubled to derive the size of the smallest low-contrast blob that is visible in an image. Jupiter has a disk that gets to be 45 arcseconds across, when it is conveniently placed. Thus, a little picture on the surface of the planet comprised of 78.5 "resel" blobs is all we could see through a 60-mm refractor.[*] This is easy to calculate. Just take 45 arcseconds and divide it by the 2*res number listed for the 60 mm refractor, 4.5 arcseconds. You get a value of 10, which is then squared to a two-dimensional array of 100. The number is multiplied by $\pi/4 = 0.785$, to account for the fact that planets are mostly round, while this square array is not; hence the corners are dark.

Contrast that with the view possible in a 24-inch telescope, which offers a picture comprised of 7850 resel blobs, and you will see why aperture is so desirable.

Table 1: Resolutions (1 arcsecond = 1/3600th degree)

A [in]	A [mm]	resolution [sec]	2*res
2.4	60	2.3	4.5
3.1	80	1.8	3.5
3.5	90	1.6	3.1
4.25	110	1.3	2.6
4.5	115	1.2	2.4
6	150	0.9	1.8
8	200	0.7	1.4
10	250	0.5	1.1
12.5	320	0.44	0.9
14.25	360	0.38	0.8
16	400	0.34	0.7
18	460	0.30	0.6
20	500	0.27	0.5
24	610	0.23	0.5
36	910	0.15	0.3

Of course, resolution below 1/2 arcsecond is rare (indicated in blue in the table), owing to atmospheric turbulence. We are mostly deriving increased light-gathering power from increases after 10 to 12 inches. Still, the exceedingly rare instances when turbulence is negligible do give spectacular views to those possessed of a large telescope of high quality. Also note that the resolution of very low contrast details (2*res in the table) does not go below 1/2 arcsec until 20 inches (500 mm) is reached. Above that point, I would say that further increases in aperture are all done for simple light gathering.

Perhaps the definition of *f*-number is in order here. If, for example, the ratio between focal length (that is, how long the telescope is) by its diameter is 4 (e.g., 50-inches divided by 12.5-inches = 4), it is said to be an *f*/4 telescope. Working it the other way, if we call an instrument a 6-inch *f*/8, then its focal length is 6 x 8 = 48 inches. It is about 4-feet long. Angular resolution depends only on diameter, not *f*-number. For visual use, *f*-number affects only the range of eyepiece focal lengths; it does not affect image brightness.

3) ERGOMETRIC MOUNTS

I can remember the days when the only mounts that bore the name "alt-azimuth" were nasty little pipe-mounts thrown together by persons too poor or too hurried to make better. The Dobsonian revolution

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[*] "Resel" is defined in analogy with "pixel," meaning a 'resolution element' instead of a picture element. Resels are not confined to a rectangular array.

changed that. Dobsonian altazimuths were originally designed to support massive telescopes, but they were found useful for the ordinary small telescopes too. The advantage of the Dobsonian over the equatorial mount in terms of convenience is that of *eyepiece availability*. Except for minor shifts in height, you can always reach the eyepiece. It is placed up near your standing position. This is especially true of small telescopes where the balance point is higher. My 8-inch, for example, differs only about a foot between horizon-pointing (eyepiece up) and zenith-pointing (eyepiece level).

This eyepiece convenience is an incredible advantage. In the old days of German equatorial mountings (GEMs), you were forever bending way over to peer through the eyepiece of refractors and continually rotating the tube of Newtonians. With modern go-to mountings, you can get most of the advantages of altaz and equatorial drives.

A lot of people say they are going to get the largest Dobsonian reflectors (greater than 20 inches) without realizing that they may be too cumbersome to easily pack, transport, and set up. A telescope that you *do not use* is no telescope at all, even if it is the biggest thing in your club. One person I heard about bought a huge Dobson-mounted reflector, took the pieces that arrived in the mail into his home, put it together, and then couldn't get it out the door.

The lesson is clear. When you are considering acquiring a mounting and telescope, select it with a clear vision of the steps involved in *carrying it and using it*.

4) FINDING THINGS

A lot of low-end telescopes come with a 6 x 30 finder. You look backwards through it and you see that the objective is stopped-down to about 8 mm. This cheap finder is just about useless. It scarcely transmits an image better than a simple eye does. It has images that resolve slightly better than the eye and allows about 7th magnitude stars to be detected. Keep it covered and use it when your red-dot finder dews up.

A lot of people have gone to the unit-power (zero magnification or reflex) finder best known by the lead brand-name of Telrad[TM] or "red dot" finders. If there are sufficient stars in the area to make geometric estimates of the position or if you are trying to point at a bright lunar/planetary target, this works as well (almost) as a good telescopic finder. Unfortunately, not all areas of the sky are replete with marker stars. These reflex finders are particularly hard to use when we give our telescope sessions in town at the schools.

The general rule for telescopic finders is the rule of thirds. Take the aperture of the main instrument, divide it by three, and use a finder at least that big. If you have a 10-inch telescope, you need at least an 80 to 90 mm finder.

This does not scale well, so other strategies and compromises must be used for very large instruments. One trick is to put an excessively low power eyepiece in the main instrument itself (this helps most if the focuser is large). Another is to use go-to systems or digital setting circles exclusively, but if your electric-power sags, you can't find anything.

I was once in favor of straight-through finders only, since you may use the other eye as a form of unit power finder, but as I age, I must admit that right-angle finders are tempting. If one is used, however, get the roof-prism type that does not flip the image right to left. That way you see a magnified view of the real sky and can use atlases.

5) EYEPIECES

Little consumer telescopes would work a lot better if they put decent eyepieces in them. First of all, many small refractors and some 4.5-inch Newtonian reflectors use 24.5 mm (0.965 inch) diameter eyepieces. Although there is no reason they don't work well, these are almost universally of inferior design, poor transmittance, and narrow field.

People think more expensive eyepieces are always better, but that is not always true. Wide-field operation at low focal ratio, and more eye-relief are often goals that are traded against image sharpness. Eyepieces generally work better at longer (higher) f-numbers, so don't expect an f/4-telescope image to look like an f/8-telescope image in an inexpensive eyepiece. What often works fine in the slower telescope fails badly in the f/4.

The eyepiece range is affected by the f-number. You should select eyepieces or eyepiece-Barlow combination only on the basis of *exit-pupil diameter*. I have done this for you in Table 2.

Table 2. Eyepiece focal lengths vs. f-number

exit pupil	f/4	f/5	f/6	f/8	f/10	f/12	f/15
7 mm	28	35	42	56	70	84	105
6 mm	24	30	36	48	60	72	90
5 mm	20	25	30	40	50	60	75
4 mm	16	20	24	32	40	48	60
3 mm	12	15	18	24	30	36	45
2 mm	8	10	12	16	20	24	30
1 mm	4	5	6	8	10	12	15
0.5 mm	2	2.5	3	4	5	6	7.5

This table does not advise you which focal lengths to buy, just what range to select from. For example, it would be a mistake to purchase a 3-mm eyepiece if you have an f/15 refractor. The range there is 7.5 to 105 mm. It is also not advised to buy a 40-mm eyepiece for an f/4 telescope, unless you have some special purpose for it, like using the main telescope as its own finder (mentioned above).

6) AVOID PHOTOGRAPHY CONSIDERATIONS

If you only would "like to do some astrophotography or CCD-imaging someday," be advised that this requirement is harsh with regard to selecting the telescope. My advice is to keep photography out of your thinking until right before you actual want to take images. By that time you'll want a specialized telescope anyway.