SUBSCRIBE SKY THIS MONTH BLOG COURSES ABOUT CONTACT

# The Five Numbers That Explain a Telescope

MAY 4, 2016 BY BRIAN VENTRUDO FILED UNDER: ASTRONOMY EQUIPMENT

**A 14″ Schmidt-Cassegrain telescope (credit: Celestron).**

Before we launch into the pros and cons of the types of telescopes available to stargazers today, let's have a quick look at 5 key numbers that describe the operation and performance of every telescope, from the junk scopes in a department store to the venerable Hubble Space Telescope. Once you understand these 5 numbers, you will understand the similarities and differences between telescopes, and you will know how to choose the best scope for your own interests and budget.

## 1. Aperture – Buckets Of Light

As mentioned in a previous article, the most important specification of any telescope is the *aperture*, the diameter of the main lens or mirror of the telescope. More aperture makes for a brighter image. Aperture also influences most of the other key specifications of a telescope, including practical (but non-optical) specs like cost and weight. A good backyard telescope for us amateur stargazers has an aperture of 80 mm to 300 mm (3.15" to 12") or more. Some big billion-dollar professional telescopes have mirrors with an aperture of 10 meters (400 inches), about the size of a small trout pond.

The light collecting ability of a telescope is directly proportional to area of the lens or mirror, which is in turn related to the square of the aperture. So a telescope with an objective mirror of 200 mm aperture collects four times as much light as a scope with a 100 mm mirror. The cost and weight of a lens or mirror also go up proportionately, sometimes faster than the square of the aperture. That's the main tradeoff, and it's one of the reasons not everyone has a 25″ Dobsonian reflector sitting in their garage. They are big and heavy and expensive.

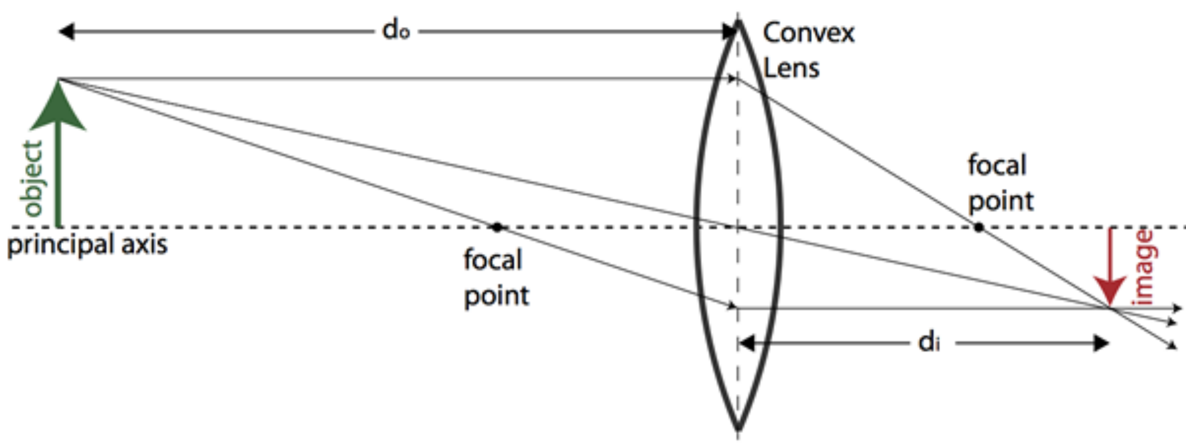

**The aperture of a lens or mirror is the diameter of its light collecting region. The light-collecting ability of an objective lens or mirror is related to the square of the aperture.**

For reference, the aperture of a healthy and dark-adapted human eye is 7 mm. So even a modest telescope with a 100 mm aperture (about 4 inches) has $(100/7)^2$ = 204 times the light-collecting ability of the eye.

## 2. Focal Length – Show Me The Image

Once light falls onto a mirror or through a lens, it's directed by the curvature of the optic to come to a focus at a plane some distance away. The length over which this happens is called the *focal length* of the objective. At the focal plane of a lens or mirror, you can actually see a real image of a distant object. So if a telescope with a lens is aimed at a distant tree, for example, or the Moon, an image of the tree or Moon would be visible on a screen placed at the focal plane of the lens.

The focal length of the objective lens or mirror of a telescope will influence to some degree the overall length of a telescope. This 12″ telescope, which uses a large mirror to collect starlight, has a focal length of about 60″. So the overall length of the scope is quite long and can be unwieldy for some. Some modern scope designs use a clever optical layout to squeeze a long focal length into a small optical tube. This telescope has an 8″ (200 mm) mirror with an 80″ (2000 mm) focal length, but the light folds into a tube less than 20″ (500 mm) long. More about this type of scope in a later article…



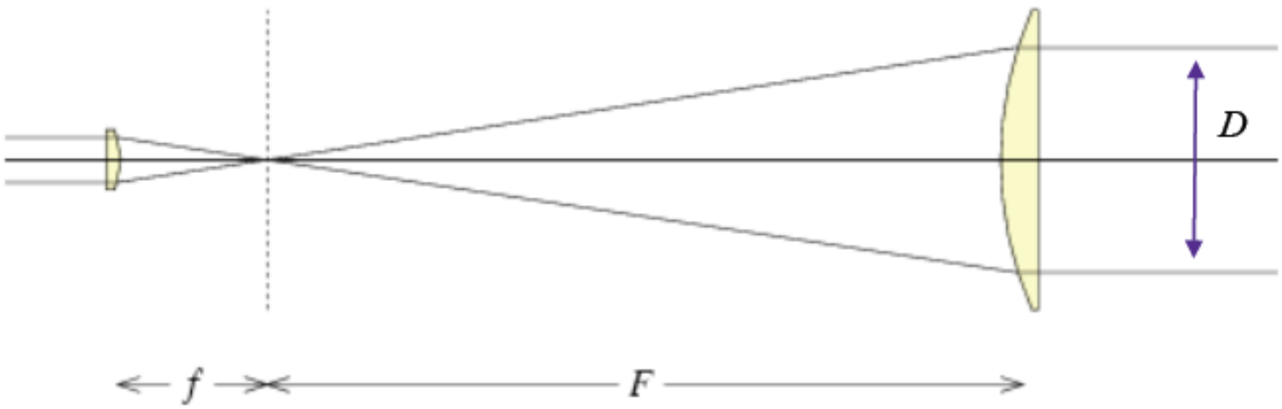

**The production of an image of a distant object by a lens. In astronomy, where the objects are essentially at infinity, the image comes to focus at a plane that passes through the focal point.**

## 3. Magnification – Far And Away, Up Close

To get an image suitable for observing with our eyes, a telescope uses a second lens, or collection of lenses, called an *eyepiece* at the focal plane. The eyepiece magnifies the image from the objective. The eyepiece also has a focal length. The magnification of a telescope and eyepiece is very simple to calculate. If the focal length of the objective is “F” and the focal length of the eyepiece is “f”, then the magnification of the telescope/eyepiece combination is F/f. For example, if a telescope has an objective lens with focal length of 1200 mm (about 48”) and it has an eyepiece of focal length 25 mm (about 1”), then it will have a magnification of 1200/25=48x. Nearly all telescopes allow you to change eyepieces to get different magnifications. If you want to get a magnification of 100x with this example, you use an eyepiece with 12 mm focal length.

**The Moon seen through a telescope at high magnification.**

Another rule of thumb… the maximum useful magnification of a telescope is about 50x the aperture in inches. Any higher and the image gets too dim and fuzzy to be useful. So a 4-inch scope can get you about 200x before the image gets too fuzzy and dim, a 6-inch scope gets you 300x, and so on. This is not a hard-and-fast rule. Sometimes, when the atmosphere is unsteady, you can only get to 20x or 30x per inch of aperture. With high-quality optics and steady seeing, you might get to 70x or even 100x per inch of aperture, so for example, up to 400x with a 4-inch scope. But this is rare.




**The aperture of the objective lens of this simple telescope is D. The focal length of the objective lens if F. The focal length of the eyepiece is f. So the magnification is F/f. The focal ratio is F/D.**

# 4. Focal Ratio – Faster, Brighter, Smaller

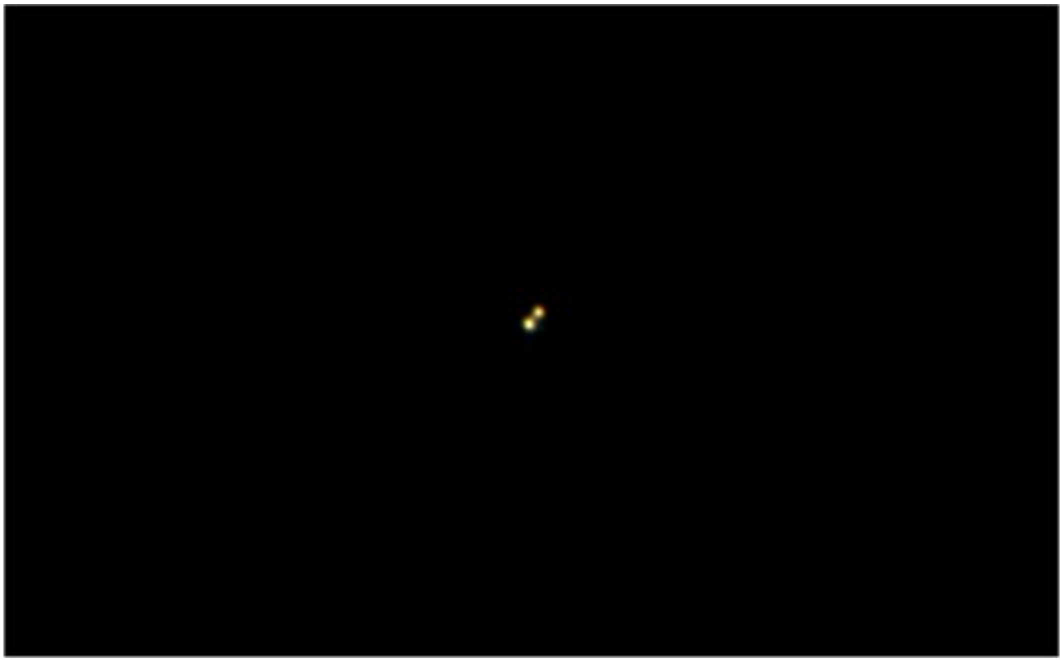
The third key specification of a telescope is the focal ratio, which is the focal length divided by the objective diameter. A long focal ratio implies higher magnification and narrower field of view with a given eyepiece, which is great for observing the moon and planets and double stars. For such objects, a focal ratio of f/10 or more is ideal. But if you want to see wide views of star clusters, galaxies, and the Milky Way, a lower focal ratio is better. You get less magnification, but you see more of the sky. Wide field telescopes have a focal ratio of f/7 or less.

Focal ratio also influences the brightness of extended objects like a nebula or galaxy. For example, a telescope with focal ratio of f/5 will show an image of four times the brightness as a telescope with focal ratio of f/10, all other things being equal. But the image at f/5 will be only half as large. However, the brightness of stars, which are point sources of light, is influenced only by the telescope aperture.

# 5. Resolving Power – Sorting One Star From Another

Finally, the last important number of any telescope: the resolution. The resolution of a telescope is a measure of its ability to distinguish small details of an object or to distinguish two very closely spaced objects from each other. Resolution is important when you're trying to separate two closely-spaced stars, for example, or fine detail on the Moon or a planet. The resolving power of a telescope with an objective of aperture D (in millimeters) is

$$\text{Resolving Power} = 116/D \text{ (in arcseconds)}$$



**The resolution of a telescope is a measure of its ability to separate closely-spaced objects. The components of the double star Porrima are separated by just 1.8″.**

Resolution is directly proportional to the aperture of a telescope. A 200 mm scope can resolve details as close as 0.58 arcseconds, twice as well as a 100 mm scope, all other things being equal. (One arcsecond is 1/3600 of a degree). But the motion and instabilities in the Earth's atmosphere often limit the practical resolution of any telescope to 1″ or more.

**Share This:**