Eyepieces+

by Ken Graun

The FOCAL LENGTHS OF EYEPIECES are alway etched on their barrels and are always expressed in millimeters (mm). This number varies from about 3 to 55 mm. The lower the number, the HIGHER the magnification.

Eyepiece overview

Eyepieces are used to change the magnification of your telescope. Some people call an eyepiece a lens, which they are, but nobody in astronomy calls them that. Normally, one has a few eyepieces to change the magnification of the telescope.

A little history, the first telescopes, from the early 1600s and into the 1700s, had one non-removable permanent eyepiece—these telescopes could only be used at one magnification.

There are a lot of variations in eyepiece design, both mechanical and optical with prices that vary from about $15 to $500+ each.

Magnification craziness

There is a general misconception or hype about telescope magnification. The highest useful magnification is around 400x and this can be achieved only for telescope diameters of 6-inches or greater and with good atmospheric "seeing" conditions. **Useful magnifications for Deep Sky Objects range from 50x to 200x. For the planets and Moon, the range is 50x to 400x**. Usually, the atmosphere limits the hightest useful magnification. There are nights when going above 100x or so is not practical because of atmospheric turbulence.

Focal length of an Eyepiece . . .

. . . is always expressed in millimeters and is the distance from the field lens (very bottom lens) to the focus point. An eyepiece acts exactly as a magnifying lens and could be used as a magnifying lens except that the barrel gets in the way. The focal length of eyepieces are almost always etched somewhere on the eyepiece. The smaller focal length numbers give you the *highest* telescope magnifications while the larger focal length numbers give you the *lowest* telescope magnifications. The lowest/smallest eyepiece focal length is around 3mm while the longest/highest is around 55mm. Usually, eyepieces with the shortest/smaller focal lengths are physically smaller than those with larger/longer focal lengths. Common focal lengths for eyepieces are 3, 6mm, 10mm, 12mm, 15mm, 20mm, 25mm, 30mm but they can take on any value.

1 inch = EXACTLY 25.4 mm
mm = millimeters

Telescope Magnification = Telescope Focal Length ÷ Eyepiece Focal Length

Example: If, your telescope has a focal length of **780mm** and your eyepieces have focal lengths of **6, 15 and 20 mm**, what are your magnifications?

6mm ➡ 780 ÷ 6 = **130x**
15mm ➡ 780 ÷ 15 = **52x**
20mm ➡ 780 ÷ 20 = **39x**

Eyepiece optical design

Traditionally, the most common eyepiece designs, that is, the internal arrangement of the lens elements, are called **Huygens, Ramsden, Kellner, Orthoscopic, Plössl and Erfle**. The Orthoscopic was considered the premier eyepiece. The design of the Orthoscopic and Plossl are similar. Erfle was the wide-field eyepiece. Today the Plössl is the standard "inexpensive" eyepiece. There are now many specialty eyepieces usually sporting very wide fields-of-view (see back). The Plössl is an excellent eyepiece design even though it is given somewhat of a bad rap.

The lens next to your eye is called the Eye Lens and the last one at the bottom of the barrel is the Field Lens.

There are special illuminated Reticle Eyepieces that have crosshairs and/or other etchings for specialized use.

What is bad about the Plössl Eyepieces? *Absolutely nothing!*

They are good eyepieces and because of modern manufacturing techniques, they can be inexpensive (for as little as $15 each). The complaints people have about Plössls are their "small" apparent field-of-view (see back) of around 50° and shorter eye relief for shorter focal lengths (see back). Amateurs have gotten snobbish about eyepieces—why pay $200 or more for an eyepiece when you can get excellent results for $15!

Sets (family) of Eyepieces

Most eyepieces belong to a set but you can usually buy them individually. A series of eyepieces in a set span a range of focal lengths and all have similar characteristic like mechanical and optical design, parfocal, eye relief, field-of-view, etc.

Focusing differences

EYES. Your eyes are optical systems. If everyone had 20/20 vision, there would be only "one" focus for any eyepiece. Normally, each observer, especially when in groups, has to turn a knob to refocus using the eyepiece focuser or focuser for their eyes—usually it is just a small adjustment.

EYEPIECES. Unless your eyepieces are parfocal (see back), you will have to refocus each time you change eyepieces.

Positioning your eye correctly

To get the best view through an eyepiece, you have to set/place/position/orientate your eye "just right" over the eyepiece. So, you may have to move your eye about the eyepiece and/or change the distance of your eye from the eyepiece to get a good/clear/total view without any "blackout" areas. This takes a little practice and can be annoying until you get use to the process. Each eyepiece has its own characteristics.

1.25 & 2-inch diameter Eyepieces

There are two standard eyepiece barrel diameters, and they are 1.25-inch and 2-inch. It is interesting that these measurements are not in millimeters and they *are* the world's standard! The 1.25-inch diameter is the most popular size—most eyepieces are this diameter. The 2-inch diameter eyepieces can offer wider fields-of-view (see back) for a given focal length. I do not recommend the 2-inch eyepieces because they are big, heavy and usually expensive. And, not all telescopes can accept 2-inch eyepieces into the focuser. Plus, if you are using 1.25 and 2-inch eyepieces at the same time, you will have to constantly take out/insert an eyepiece adapter for the 1.25 inch eyepieces. 1.25 inch eyepieces also fit nicely into pockets.

Oh, there is an old 0.975 inch diameter barrel that was used on some scopes years ago. It was mainly found on cheaper scopes.

Barlow

The barlow is an "eyepiece" that usually doubles (but any multiplier from 2 to 5 times) the magnification of any eyepiece inserted into it. It looks like a long eyepiece that is inserted into the focuser and then a regular eyepiece is inserted in the barlow. In the past, barlows degraded the image quality but that is not the case with a quality barlow today. Barlows come in 1.25 and 2 inch barrel diameters.

Using a Barlow does not change any optical characteristics of the inserted eyepiece. For example, eye relief stays the same even though you double+ the magnification.

Eye Relief & Eyeglasses

Eye Relief is the distance in millimeters that you must place your eye behind the eye lens in order to see the entire field-of-view. Usually, you have to place your eye closer to the eyepiece for shorter focal length eyepieces. Eye relief can be an issue for eyeglass wearers. Generally, an eye relief around 15 to 20mm is sufficient for individual who must wear eyeglasses when looking through an eyepiece, and around 20mm is often refered to as long eye relief. If possible, try to observe without eyeglasses. Eye relief can get down to 3mm or so, usually for short focal length eyepieces and one really has to cram their eye close to these eyepieces to see out of them—these short eye relief won't work for eyeglass wearers. There are series/sets of eyepieces with long eye relief, often around 20mm for every focal length in the series but these eyepieces are usually expensive. Some eyepieces have rubber guards and/or adjustable collars to make viewing with or without eyeglasses more comfortable.

A barlow lens can be used to double+ magnification and it will keep the eye-relief of the inserted eyepiece, which is one way for eyeglass wearers to avoid using short focal length eyepieces that have short eye relief.

How do you know the eye relief of an eyepiece? The eye relief usually has to be looked up on the internet—it is specific to the manufacturer. Most eyepieces do not come with written specifications.

Rubber Eyeguards

Rubber eyeguards around the eyepiece help to keep stray light from entering the eye and provide a softer/warmer surface to rest your eye or eyeglasses against. The only drawback is that they can degrade/split from use or age and it may be difficult to get a replacement.

Astigmatism

Many say that if you have astigmatism, you will need to wear your eyeglasses when observing, that is, looking through an eyepiece. Well, I do and I don't. This does cause some stars in the eyepiece to be out of focus but I don't mind it because it is so much nicer/easer to observe without glasses. So, give it a try to determine what works for you.

Eyepiece filters

Most eyepieces, both 1.25 and 2 inch have internal threads at their bottom ends to accept or screw in filters. Read more....

Do I need a Moon filter? Yes! Moon filters, which are often 2 polarizers or neutral density filters (like sunglasses), will dramatically decrease the Moon's brightness in your eyepiece and greatly lessen eye fatigue. Through a telescope, the Moon can be exceedingly bright for that eye!

Do I need those colored filters? The simple answer is **NO**. The colored filters are sometimes used to enhance subtleties on the planets but the enhancement are themselves subtile. And, you can see these subtilities with your eyes alone. I have a complete set of colored filters and I NEVER use them.

What about other filters? There are speciality, "deep sky" filters that can improve contrast by filtering out light pollution but I would put off buying any of these until you get some experience behind the eyepiece.

Zoom Eyepiece

A zoom eyepiece is a single eyepiece that can be turned by hand, while in the focuser/eyepiece holder, to change the magnification—so you don't need to change eyepieces to change the magnification. Zoom eyepieces have had problems with image quality but there are excellent zoom eyepieces, like the Tele Vue 3mm to 6mm which is one of my favorite eyepieces, especially when I view the planets or try to split very close double stars.

Parfocal Eyepieces

Parfocal is a mechanical design feature of a *set of eyepieces* that are made to provide no or minimum refocusing when changing eyepieces. The eyepieces are designed to come to the same "place" for the focusing point. Many of Tele Vue eyepieces are parfocal even though they are from different sets. Parfocal eyepieces are nice—I use a set of them!

How many Eyepieces should I get?

To start, a good number to get or work up to is 3 or 4. Of course, that count can go much higher. A good barlow can double (multiple) the range of magnifications so two eyepieces with a barlow can potentially provide four different magnifications. So, if you initial get a barlow, try to get eyepiece focal lengths that don't duplicate any of the other magnifications.

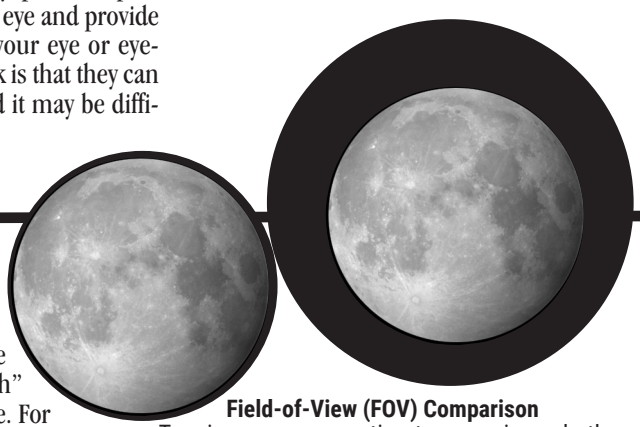
Eyepiece 1 ➡ 3 to 5 mm
Eyepiece 2 ➡ 8 to 12 mm
Eyepiece 3 ➡ 15 to 20
Eyepiece 4 ➡ 25 to 32mm

Keeping Eyepieces

Most amateurs who stay with the hobby keep their eyepieces even as they sell their telescopes (most go through several scopes). One develops favorites and eyepieces can be a considerable investment.

Field of View

There are, in essence, two types of field-of-view. True Field-of-View (FOV or TFOV) is the "size" of the window that you "see through" when looking through an eyepiece. For example, one eyepiece allows you to see the whole Moon—nothing less or more. However, another eyepiece allows you to not only see the whole Moon but there will also be a lot of night sky around it. For any set of eyepieces, as the magnification increases, your field-of-view decreases. Apparent Field-of-View (AFOV) is an optical characteristic of an eyepiece and defines your True Field-of-View. Plössls have an Apparent Field-of-View of about 50° and Tele Vue's Nagler eyepieces have Apparent Field-of-Views of 82°. If both types of eyepieces have 20mm focal lengths, then the Nagler will be able to see a True Field-of-View that will be 60% wider than the diameter of the Plossl FOV. Note: the Apparent Field-of-View for most eyepieces has to be obtained from descriptions or information on the internet—AFOV is rarely engraved/printed on eyepieces.



Field-of-View (FOV) Comparison
Two images representing two eyepieces both magnifying at 100x but with one having a 50° FOV (left image of Moon) and the other a 68° FOV (right image). So, the larger an eyepiece's apparent-field-of-view (AFOV), the bigger the window you get to see through. FOV always decreases with higher magnifications.

Calculating the True Field-of-View

First, you need to know the magnification that an eyepiece gives for your telescope. Let's say you are using a telescope that has a focal length of 2000mm and with a 18mm Plössl eyepiece. This yields a magnification (2000÷18) of 111x. All Plössl eyepieces have an Apparent Field-of-View of about 50°. The True Field-of-View is 50°÷111x=0.45° which is a little less than the diameter of the Full Moon*. Remember, as the magnification goes up, your TFOV always gets smaller.

True Field-of-View = **Eyepiece's Apparent** Field-of-View ÷ **Eyepiece's Magnification**

*Remember, the diameter of the Moon is 1/2 (0.5) of 1 arc degree (a compass degree) or 30 arc minutes.