What should I know when I buy an eyepiece?/ Which eyepiece should I buy?

This guide has been prepared by amateur astronomer Andrie van der Linde and owner of Eridanus Optics CC to aid telescope owners in making an informed decision when buying eyepieces.

The eyepiece is a key component in your celestial viewing experience. With a good eyepiece, you will realize the full potential of your telescope while a bad eyepiece will limit what you can see or can spoil your entire viewing session.

Most telescopes in the market for the serious amateur come with an eyepiece of fair/reasonable quality or better. Soon after the initial purchase you will start thinking about expanding your viewing options by buying additional eyepieces. In order to buy the best eyepiece for your requirement, it is important to understand all eyepiece properties, and how it fits in with your priorities. This guide is intended to help you to make the right choice. Some of the reasons why you may be in the market to buy an eyepiece include:

- Need different magnification (typically more magnification)
- Need wider field (typically less magnification)
- Expanding on eyepiece collection
- Looking for better quality
- More eye relief required (e.g. if you wear glasses due to astigmatism)
- Imaging

Referring to the advantages of having a good selection of eyepieces, Paul Hyndman, an amateur astronomer from New Hampshire, wrote: "Not unlike a golfer's clubs, together they form your arsenal. Some may get in more 'play time' than others, but it's the power of their combined versatility that brings fullness to the game!"

Bear in mind that you can use your eyepieces on any telescope (provided it can fit into the focuser). You can truly invest now in your eyepiece collection, even if you own an entry level telescope and plan to buy a serious telescope later on.

It is important that you understand what you want out of the eyepiece. The information provided below is intended for 'beginners' who know nothing or very little about astronomy. Even experienced amateurs with unique requirements may find some guidance.

BOXES

Boxes like this one are used as additional reading for the interested reader and are of a more technical nature.

The topics covered in this guide are:

- **Anatomy:** This part show the various parts that make up an eyepiece.

- **What plays a role?**: This part contains the bulk of the information and include aspects as basic as the barrel size of the eyepiece and as complex as the limiting field of view of the telescope. Other aspect covered include magnification, eye relief, coatings, distortions and more.

- **Special eyepieces:** This part covers non standard (fixed focal length) eyepieces such as Zoom eyepieces; binocular viewers and reticule eyepieces.

- **Recommendations:** Typical applications are considered and eyepieces are recommended that will live up to the demands of these applications.

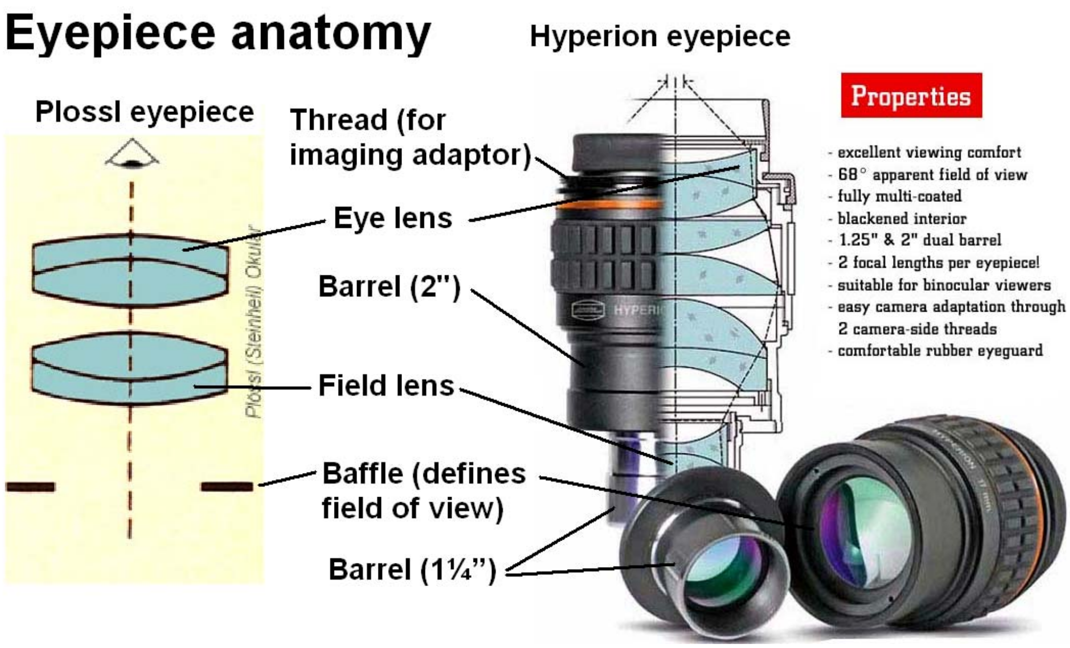
A selection of eyepieces available from Eridanus Optics CC.
(http://eridanusoptics.com/store/index.php?main_page=index&cPath=20_21)

ANATOMY OF AN EYEPIECE

An eyepiece consists of the following:

- Body: This is the housing that keeps the various parts in position.
- Baffle: This circular opening is positioned at the eyepiece's focal point to define a sharp edge for the viewable field. The baffle may be external (Plossl) or internal (Hyperion).
- Barrel: The part that fits into the telescope focuser. Also referred to as 'nose piece'. Most eyepieces has either a 1¼" or a 2" barrel. Some eyepieces such as the Hyperion series can fit into both 1¼" and 2" focusers.
- Eye lens: The lens closest to the eye.

- Field lens: The lens closest to the telescope (or the field that you want to view.
- Lenses: This refers to the total number of lenses that make up the eyepiece. A lens group refers to a single lens or a number of lenses that have been cemented (glued together). A lens design is described by the number of lenses and lens groups. The Plossl eyepiece consists of four lenses in two groups. The Hyperion (a more complex design) consists of eight lenses in five groups.
- Thread: When



WHAT PLAYS A ROLE?

Various factors play a role in selecting an eyepiece for your telescope. Below the most common factors that you should consider are discussed:

Barrel size: Most quality telescopes are fitted with 1¼" focusers. These focusers will accept any 1¼" eyepiece from any manufacturer. Larger telescopes (typically 8" and larger) are fitted with a 2" focuser and a 2" to 1¼" adaptor. This means that you can use 1¼" eyepieces (with adaptor) as well as 2" eyepieces (without adaptor). Lesser known brands sometimes come with a 0.965" focuser. Eyepieces to fit into these telescopes are not freely available. Rather avoid these telescopes.

Most barrels contain thread that can be used to fit filters. The thread should be blackened to avoid reflections. Avoid eyepieces without blackened thread o r without thread.

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The GSO SuperView series utilises both 1¼" (15mm and 20mm) and 2" barrels (30mm; 42mm and 50mm
(http://eridanusoptics.com/store/index.php?main_page=product_info&products_id=232&zenid=0eebb0e60dee803febabc1bce34c92a1)

Magnification Your telescope's magnification is determined by the focal length of the eyepiece. The following equation applies:

Magnification = (Telescope focal length)/(Eyepiece focal length)

E.g.: The magnification when a 10mm eyepiece is used on a 6" (150mm) f/8 telescope (focal length = 150 x 8 = 1200mm) is:

Magnification = 1200/10 = 120x.

NOTE: See Appendix A for notes on 'USEFULL MAGNIFICATION

Field of view (FOV): This is a parameter that defines the angular diameter of a circle. Three different 'Fields of view' should be considered. These are:

- **Apparent field of view** (visible diameter of the eyepiece)
- **True field of view** (actual diameter of the sky visible in the eyepiece)
- **Telescope field of view** (maximum field of view for the telescope)

These FOV's are discussed below:

Apparent Field of view : When looking into an eyepiece, you see a circle within which the celestial objects are visible. The angle that this circle spans is referred to as the apparent field of view (what the field of view seems to be). The typical apparent FOV for a Plössl eyepiece is around 50°. (See Appendix B on how to determine an eyepiece's apparent field of view)

There are various approaches related to an eyepiece's apparent FOV:

- **Narrow:** Fields of view smaller than 45° will fall in this group. The emphasis is most likely to provide a cheap eyepiece. It is unlikely that you will get good anti-reflex coatings. Rather avoid these unless you are sure about the quality.
- **Standard:** Eyepieces with 45° to 55° field of view fall in this group. Plössl eyepieces are typical of this group. This is approximately the field of view that one can interpret directly. Quality will vary between different manufacturers, but the mainstream producers (such as Baader Planetarium, Celestron, GSO, Orion, TeleVue and William Optics) supply consistent quality.
- **Wide:** The field of view of this group of eyepieces is around 60° to 72°. This is the maximum field of view that you can perceive (you know it is there but you cannot interpret all directly). Eyepieces from the mainstream manufacturers can be trusted. Be wary of unknown brands.

The Baader Planetarium Hyperion eyepiece series has an apparent field of view of 68°.
(http://eridanusoptics.com/store/index.php?main_page=product_info&products_id=701)

- **Extreme:** The field of view of this group of eyepieces range from around 80° to 100°. The idea is to provide you with a 'space walk' feeling. You cannot recognise the edge of the field and you can 'explore' the outer regions. The extreme range of eyepieces is very complex and only a few manufacturers attempt to produce these, mostly mainstream producers. The price on these eyepieces is often also 'extreme' for good reason.

The Ethos 13mm eyepiece from TeleVue is an example of and eyepiece with an extreme field of view (http://eridanusoptics.com/store/index.php?main_page=product_info&cPath=167_20_21_23&products_id=534)

NOTE: The eyepiece need not be in the telescope to evaluate an eyepiece's apparent field of view. Simply hold it close enough in front of your eye until you see the edge of the field. It should be a well defined circle. To compare the fields of view of two eyepieces, hold one in front of each eye.

True field of view can be determined by dividing the apparent field of view by the magnification, i.e.

True FOV = (Apparent FOV)/Magnification

A Plössl eyepiece will therefore have a true FOV of 1° at 50x magnification. Note that the true field of view is very small at very high magnifications.

The true field of view is important because several objects span large areas of space. The Andromeda galaxy for instance spans almost 3°. This means that it can only be fully appreciated at around 17x magnification in a Plössl eyepiece with a 50° field of view.

Telescope field of view: Your telescope's focal length and the size of its focuser determine the largest true field of view achievable with your telescope.

The de facto standard for most telescopes on the market is to use a 1¼" focuser. If your telescope is thus fitted with a 1¼" focuser, you can only fit 1¼" eyepieces. These have a 28mm clear aperture through which the light must pass. Any quality 1¼" eyepiece will fit snugly into this focuser (if of reasonable quality). Many large telescopes (e.g. 8" and larger) are actually fitted with a 2" focuser with a 2" to 1¼" adaptor. In these focusers you can use both 2" and 1¼" eyepieces. See the box below for a discussion on how it affects your telescopes maximum field of view.

CALCULATING YOUR TELESCOPE'S MAXIMUM FIELD OF VIEW

FOV_{Max} = arctan(28mm/(Telescope's focal length))

or it can be approximated by:

FOV_{Max} = (180/π) x (28mm/(Telescope's focal length)) and simplified to

FOV_{Max} = 1600mm/(Telescope's focal length))

E.g.: A telescope with a focal length of 1200mm and a 1¼" focuser will have a maximum field of view of 1600 / 1200 = 1.33°.

If your telescope has a 2" focuser and you use 1¼" eyepieces, the same limitations are in force. However, 2" eyepieces have clear apertures of 47mm. You can therefore substitute the 1600mm in the simplified formula above with 2700mm. A telescope with a 1200mm focal length and a 2" focuser will therefore have a maximum field of view of

2700/1200 = 2.25°

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NOTE: Some older telescopes and other lesser known telescope manufacturers use 0.965" focusers and eyepieces. Sleeves to convert an 0.965" eyepiece to fit into a 1.25" focuser are available and can be used without concern. Adaptors to increase a 0.965" focuser's size to accept 1.25" eyepieces are available, but you should expect a reduction in your telescope's back focus, and you may find that you cannot focus your telescope with all (1.25") eyepieces. Note that the telescope's true field of view is also affected due to the smaller diameter through which the image/light must pass.

Eye relief: Eye relief is the distance from the last surface of the lens of an eyepiece to the plane behind the eyepiece where all the light rays of the exit pupil come to a focus and a circular image (also called the "Ramsden Disk") is formed. This is where your eye should be positioned to see the full field of view of the eyepiece. If you wear glasses because of astigmatism, you'll usually need at least 15mm of eye relief if you want to see the full field of view with your glasses on. Eye relief is a crude indication if viewing comfort. It is more comfortable to use eyepieces with long eye relief. With short eye relief eyepieces on the other hand, you stand the risk of leaving an imprint of your eyeball on the lens surface. The amount of glass you see in an eyepiece is a rough indication of the eye relief. Lots of glass means 'lots of eye relief'.

Comparing the visible glass of a 4mm Plossl eyepiece with a 32mm Plossl eyepiece. The 32mm eyepiece has much better eyerelief.

Coatings: This property does not receive a lot of attention, but it is a big contributor to the eyepiece's performance. Because the effect is hidden, you may be fooled into believing that it is not very important. An eyepiece with good coatings on a small telescope can easily outperform a larger telescope with an eyepiece with mediocre coatings. See the box below for a short technical discussion on coatings.

NOTE: You should also be aware that the reflected light are primarily scattered inside the telescope and eyepiece and manifests as light pollution inside the eyepiece and

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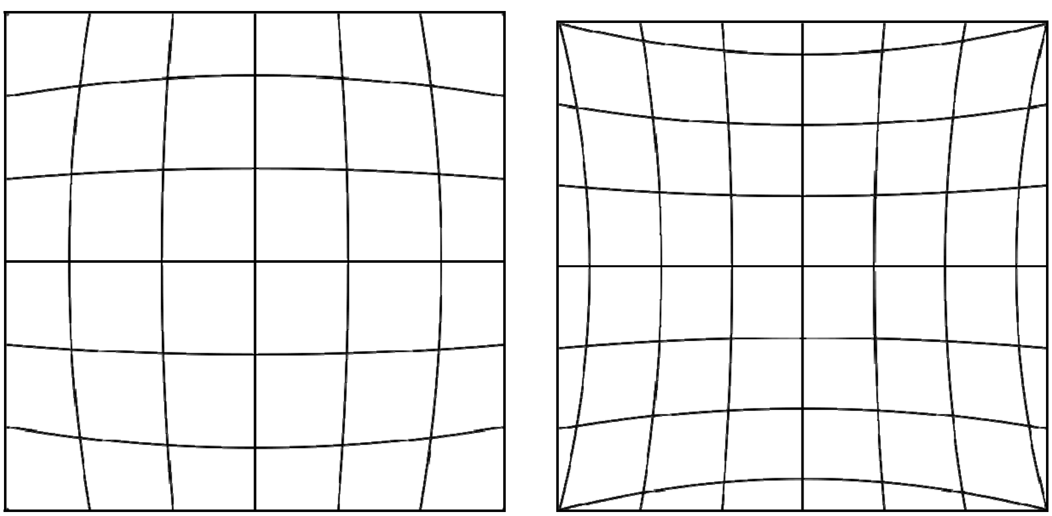
telescope. That is, it reduces image contrast and may create ghost images. A more extensive FAQ on coatings is planned. Look out for it on the website.

The ‘supercoated’ lens (right) reflects much less light than the ‘Fully multicoated’ lens (left)

Distortions: Some eyepiece designs suffer form distortion. The distortion can either be ‘barrel’ or ‘pincushion’ (see images below). Good eyepieces are specifically designed to eliminate or reduce these distortions. Cheap eyepieces are likely to suffer from these distortions. Moderate distortions should not be too serious for visual observations. However, if you plan to use the eyepiece for imaging, this parameter becomes more important, especially when you plan to take multi-exposures (eg with different color filters) of the same object.


Barrel distortion (left) and pincushion distortion (right) of a grid.

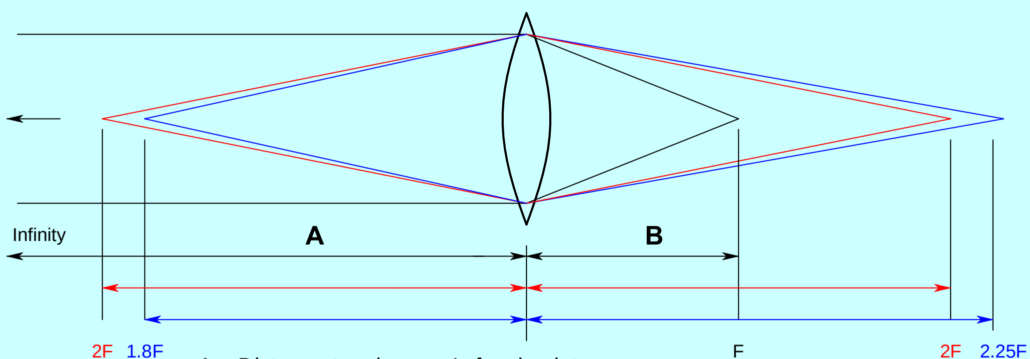
Note that in the centre of the field, there is almost no distortion. Eyepieces with small apparent fields of view will therefore suffer less from distortion than eyepieces with wide apparent fields of view. It is therefore important to select a well designed wide field eyepiece. This is one of the reasons why wide field eyepieces are so costly when compared to eyepieces with small fields of view.

Imaging: The output (eye lens) side of some eyepieces is threaded to accept camera adaptors to make the imaging of celestial object easier. The eyepiece can also be used to add some magnification (see box below). The idea is to have the imaging plane further away than 2x the eyepiece's focal length to achieve the required magnification.

HINT: It is useful to use a long focal length eyepiece with large field for view for imaging. Such an eyepiece has a large field stop and reduces vignetting (a circular darkening around the edges of the image).

A wide range of eyepieces and related accessories are available from Eridanus Optics to support imaging.

HOW EYEPIECES AFFECT IMAGING MAGNIFICATION'



A = Distance to telescope's focal point
B = Distance to camera/imaging device
F = Eyepiece focal length (illustrated in black)
M = B/A (Imaging magnification)

IMAGING MAGNIFICATION
M = 2F/2F = 1
M = 2.25F/1.8F = 1.25

Corrections: Some eyepiece designs compensate for deficiencies inherent in some telescope designs. Fast Newtonian telescopes are prone to coma (stars near the edge of the field look comet like), but due to the popularity of these telescopes, some manufacturers have designed eyepieces to reduce or eliminate the effect. It is seldom claimed outright, but is provided in 'between the line' comments like 'designed with fast telescopes in mind', 'flat field', etc.

Because eyepieces are refractive in nature, some designs will suffer from chromatic aberrations (coloring around bright objects), while others correct for this.

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The highlighted areas shows coma – stars looking coma-like towards the edge of the field.

Exit pupil: This is the size of the bundle of light that leaves the eyepiece. Where the bundle of light is larger than the observer's pupil, light is cut off and the image is darker than what the telescope is capable of. If the telescope has a central obstruction (such as a Newtonian or Cassegrainian telescope), then the observer may see a central darkening. This is particularly true for daytime viewing where the observer's pupil is very small. To calculate the exit pupil, use the following formula:

Exit pupil = (Telescope aperture)/Magnification

THE HUMAN PUPIL

The maximum size of a young person's pupil is 7mm. At age 40 it is about 5mm and gets progressively smaller with age. Using a telescope at a magnification that results in a larger 'exit pupil' than your own pupil, means that you are loosing available light. This is not a big problem; it merely means that you could have got the same viewing quality with a smaller telescope. In the example above, it means that at 20x magnification, a young person with an 8" (200mm) telescope will see exactly the same as another young person viewing at 20x magnification through a 140mm telescope.

E.g.: The exit pupil for an 8" (200mm) telescope operating with a 50x magnification is 200/50 = 4mm. At a magnification of 20, the exit pupil will be 10mm.

While deciding to buy an eyepiece it is good to keep the above 'forces' in mind. I often get customers who are looking for a longer focal length eyepiece to see a wider true field. However, they fail to note that the apparent field of view is smaller (because their existing eyepiece is already designed at the limit). The end result will be to view the same field at lower magnification.

Special eyepieces:

- **Zoom eyepieces:** These eyepieces have the potential to reduce the number of eyepieces in your accessory box to only one. There is a general negative sentiment towards zoom eyepieces among amateur astronomers. Most of them bought a useless cheap zoom eyepiece. Beware of this trap. Fortunately however, there are exceptional quality eyepieces available such as the Baader Planetarium Hyperion Zoom eyepiece or the TeleVue Zoom eyepieces. These eyepieces are ideally suited for group viewing events. You can look at the Moon and zoom in onto a crater or other lunar feature in an instant. The long eye relief associated with these eyepieces also means easy and comfortable viewing.

The Baader Planetarium Hyperion Zoom eyepiece (8mm to 24mm) has quality coatings and has a 50° (24mm) to 68° apparent field of view.
(http://eridanusoptics.com/store/index.php?main_page=product_info&products_id=208)

- **Binocular viewers:** Binocular viewers allow you to view with both eyes through your telescope. The light path is split in two and both eyes see exactly the same image. This can create a three dimensional experience, especially when viewing solar system objects. It also creates a more comfortable viewing experience because there is no need to keep one eye closed while viewing.

  These eyepieces add to the telescopes light path and reduce the back focus. Newtonian telescopes often have a limited back focus and you will be unable to focus on celestial objects. Barlow elements that fit in front of the binocular viewer are used to reduce the effective optical path and the amount of back focus needed. It does increase the magnification of the telescope/eyepiece magnification with the Barlow lens' magnification factor.

  You will need two eyepieces to fit into the binocular viewer receptacles. Quality binocular viewers are available from Baader Planetarium, Celestron, TeleVue and William Optics.

  HINT: To determine your telescope's available back focus (for a particular eyepiece), insert the eyepiece and focus on a distant object. Measure a feature on the focuser tube. Then crank the focuser tube fully in and measure the distance to the same feature. Subtract the two values. This cannot be done with Cassegrainian telescopes, but these normally have sufficient backfocus. Most binocular viewers require around 100mm back focus.

The William Optics Binocular viewer comes complete with two 20mm SWAN (60° Field of view) eyepieces and a 1.6x Barlow lens.
(http://eridanusoptics.com/store/index.php?main_page=product_info&cPath=167_20_21_72&products_id=319)

- **Reticule eyepieces**

  It is sometimes required to have markings in the field of view of an eyepiece. The crosshair found in finder scopes is an excellent example where the centre of the finder scope is aligned with the telescope's optical axis. These markings are referred to as reticules. Reticules may be simple (like a cross hair) or complex (a linear scale combined with an angular scale. The reticule pattern can be illuminated to be visible under dark sky conditions. These eyepieces are useful to determine if an object will fall inside a camera's detector before taking images. Celestron and Baader Planetarium supply reticule eyepieces.

The Baader Planetarium Micro Guide eyepiece is an example of a Reticule eyepiece

- **Barlow lenses and focal reducers:** These are not eyepieces, but are used to modify the magnification of eyepieces. An eyepiece that has a 50x magnification on a particular telescope (24mm used on 1200mm telescope) will have a 100x magnification when used in combination with a 2x Barlow lens. Barlow lenses is beneficial in the following ways:

- **Doubling the number of eyepieces:** Adding a single Barlow lens to your toolbox, essentially doubles the number of your eyepieces. If you have three eyepieces in your toolbox (e.g. 32mm, 25mm and 18mm), you will essentially have six eyepieces merely by adding a 2x Barlow lens (32mm; 25mm; 18mm; 15mm; 12.5mm and 9mm).
- **Improving eyerelief:** An 8mm eyepiece used with a 2x Barlow lens will be equivalent to a 4mm eyepiece with the eyerelief of the original 8mm eyepiece.

On the negative side, you add more components in the optical path with more losses due to reflections. You also introduce small errors due to surface errors on the optic components and mechanical errors due to free play between the Barlow lens and eyepiece. Although these losses are small on most Barlow lenses, make sure you buy one of sufficient quality. When using a high performance eyepiece, get a high performance Barlow lens.

Various Barlow lenses are available from Eridanus Optics CC such as this 1¼" 2x Barlow lens from Celestron.
(http://eridanusoptics.com/store/index.php?main_page=index&cPath=167_20_25_26)

Recommendations:

Below, a selection of applications is listed along with a selection of eyepieces recommended for the particular application:

- **High magnification:** Go for a short focal length eyepiece with long eye relief (lots of glass). Unfortunately, this means that you have to select a more complex lens and you will not get away with an 'economy priced' eyepiece. An option to consider is the William Optics 3mm 'Super Planetary long eye relief' (SPL) eyepiece. Due to the small 'True FOV', you may opt for an eyepiece with a wide 'Apparent FOV'. In this case, you may consider:
  - **Baader Planetarium:** 3.5mm or 5mm Hyperion
  - **Orion:** 3.5mm or 5mm Stratus
  - **TeleVue:** 2.5mm, 3.5mm or 5mm Nagler Type 6
  - **TeleVue:** 3mm, 4mm or 5mm Radian
  - **William Optics:** 4mm UWAN

Avoid eyepieces with short eye relief (small glass), rather go for a longer focal length eyepiece in combination with a good Barlow lens.

- **Wide field:** Select long focal length and/or wide apparent FOV eyepieces. Determine the true FOV you want to see (check that your telescope can actually see the desired FOV). Next select an eyepiece where:

  (Eyepiece Focal Length)*(AFOV) > (Telescope Focal length)*(TFOV).

  It is recommended that you choose the eyepiece with the shortest focal length and the widest Apparent FOV that will work. This will ensure that you can see more detail due to the higher magnification. Eyepieces to consider (select lenses with long focal lengths in all cases):
  - **Plössl:** Celestron, GSO, Orion and TeleVue all supply these eyepieces. Select an eyepiece with a long focal length.
  - **Baader Planetarium:** Hyperion series and Scopos series
  - **GSO:** SuperView series
  - **Orion:** 35mm Ultrascopic; Stratus series; Optilux series and Deep View series
  - **TeleVue:**Ethos series; Nagler series and Panoptic series
  - **William Optics:** SWAN and UWAN series.

- **Imaging:** Go for eyepieces with long eye relief (large glass) and wide field of view to reduce the risk of vignetting. Select from the following (any focal length but longer is better):
  - **Plössl:** Celestron, GSO, Orion and TeleVue all supply these eyepieces. Select an eyepiece with a long focal length.
  - **Baader Planetarium:** Hyperion series and Scopos series
  - **Celestron:** X-Cel series, Ultima series and Axiom series
  - **GSO:** SuperView series
  - **Orion:** Ultrascopic series; Stratus series; Optilux series and Deep View series
  - **TeleVue:**Ethos series; Nagler series,Panoptic series and Radian series
  - **William Optics:** SPL series, SWAN and UWAN series.

  NOTE: Not all these eyepieces has a threaded interface to connect to camera adaptors. However, all can be used with universal camera adaptors that clamps onto the eyepiece and keep the camera in position. Imaging will be more challenging in this case.

- **Public viewing:** Get a quality Zoom eyepiece. No need to swop eyepieces to see the entire Moon now (at low magnification) and detail on the terminator (at high magnification) seconds later. These eyepieces also have long eye relief that makes it easier to look into. The Baader Planetarium Zoom eyepiece is highly recommended (also for casual viewing). For high magnification Zoom options, the TeleVue Zoom eyepieces are ideal. The Celestron and Orion Zoom eyepieces are also recommended.

- **General viewing:** All eyepieces on the Eridanus Optics website are suitable for general viewing. The GSO Plossl series is a good affordable option. Keep in mind that in the end, you get what you pay for. A more expensive eyepiece will give you one or more of the following:
  - Wider field of view – you see more
  - Clearer images – due to better design and coatings
  - Easier viewing – due to longer eye relief associated with these.

Please contact the author of this FAQ if you have any questions or suggestions related to this article.

Regards

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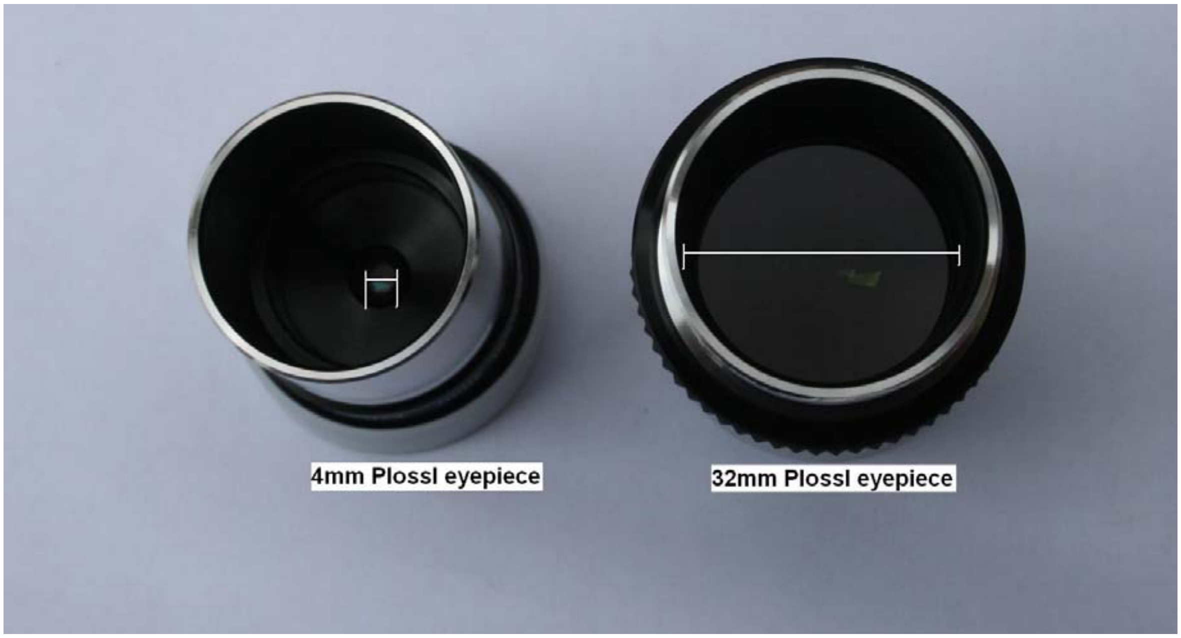
APPENDIX A: USEFUL MAGNIFICATION

People are often 'magnification mad', trying to test the limits of their telescopes with short focal length eyepieces. These eyepieces have very small clear apertures due to the baffle used to define the visible image. (Look into the back of a short focal length eyepiece and see for yourself – see picture below). This reduces the amount of light entering the eyepiece which is then spread over the magnified image. Consequently, highly magnified images appear dimmer than images at lower magnifications. (You can use this feature to reduce the brightness of the Moon if you do not have a Moon filter).



Comparing the field stop of a 4mm and a 32mm eyepiece.

However, there is a practical limit for magnification that your telescope can produce. The rule of thumb is to take 50x the telescope's aperture (in inches). This means you can expect useful magnifications of 300 from a 6" telescope (6x50 = 300). If your telescopes aperture is given in mm's, then you multiply this value with 2. You can thus expect viewable images at magnifications up to 120x for a 60mm telescope (2x60 = 120).

Some sources (notably manufacturers of cheap telescopes) claim higher factors for useful magnification (e.g. 60x aperture in inches is often used, even 74x is sometimes claimed) and, although it is achievable, it will be applicable only under very specific conditions such as:

- You want to split close double stars or for viewing bright objects (more available light) which is
- near the zenith (low absorption due to the short light path through the atmosphere) during
- the late night (after the Earth cooled down and scintillation reduced).

It is my experience that the 50x factor proposed is realistic.

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E.g.: The shortest eyepiece focal length that should be used on an 8" (200mm) telescope with a focal length of 1200mm is 3mm. This is calculated as follows:

- Maximum useful magnification: 8x50 = 400
- Focal length of eyepiece = Focal length of telescope/magnification
  = 1200/400
  = 3mm

What you want to do plays a role in the 'ideal' focal length of an eyepiece. If you need help to work out which focal length to choose, you can try out this handy calculator at: http://www.eridanusoptics.com/store/images/accessories/eyepieces/Eyepiece_guidelines.xls.

This calculator was kindly supplied by Johan Smit of the Pretoria Branch of ASSA.

APPENDIX B: APPARENT FIELD OF VIEW

The cheapest eyepieces have relatively small apparent fields of view. It is easier (and cheaper) to design and manufacture eyepieces with acceptable performance with small fields of view. It often also requires less lens elements. Quality eyepieces with larger fields of view are more complex to design and manufacture, and are consequently more expensive.

The Plössl eyepiece with an apparent field of view of about 50° is currently the de-facto standard. It provides a fairly large field of view and a good flat image. Various other designs such as the TeleVue Ethos and Nagler eyepieces (100° and 82° FOV respectively), the Baader Planetarium Hyperion and Scopos ranges (68° and 70°) and the William Optics SWAN and UWAN (72° and 82°) offer wider fields of view. The wider field of view at the same magnification allows you to see more and is useful in observing extended objects such as nebulae, clusters and close galaxies.

The apparent field of view of an eyepiece can be calculated with the following formula:

AFOV = 2 x arctan(FS/(2x FL) where

AFOV:	Apparent field of view
FS:	Diameter of the field stop (or baffle) opening and
FL:	Focal length of the eyepiece.

E.g.: To calculate the apparent field of view of a 20mm eyepiece with an 18.5mm field stop, follow the steps below:

2x FL = 40
FS/(40) = 18.5/40 = 0.4625
arctan(0.4625) = 24.8°
AFOV = 2x 24.8° = 49.6° (It probably is a 20mm Plössl eyepiece with a 50° field of view).

In the picture below, three eyepieces with comparable focal lengths are compared. Two 15mm and one 16mm eyepieces with apparent fields of view of 52°; 62° and 82° respectively. It is clear that the field stop/baffle for the 52° eyepiece is much smaller than is the case for the 82° eyepiece.

The image brightness will not be affected. Although you allow more light in with the 82° eyepiece, you also spread it over a larger area.

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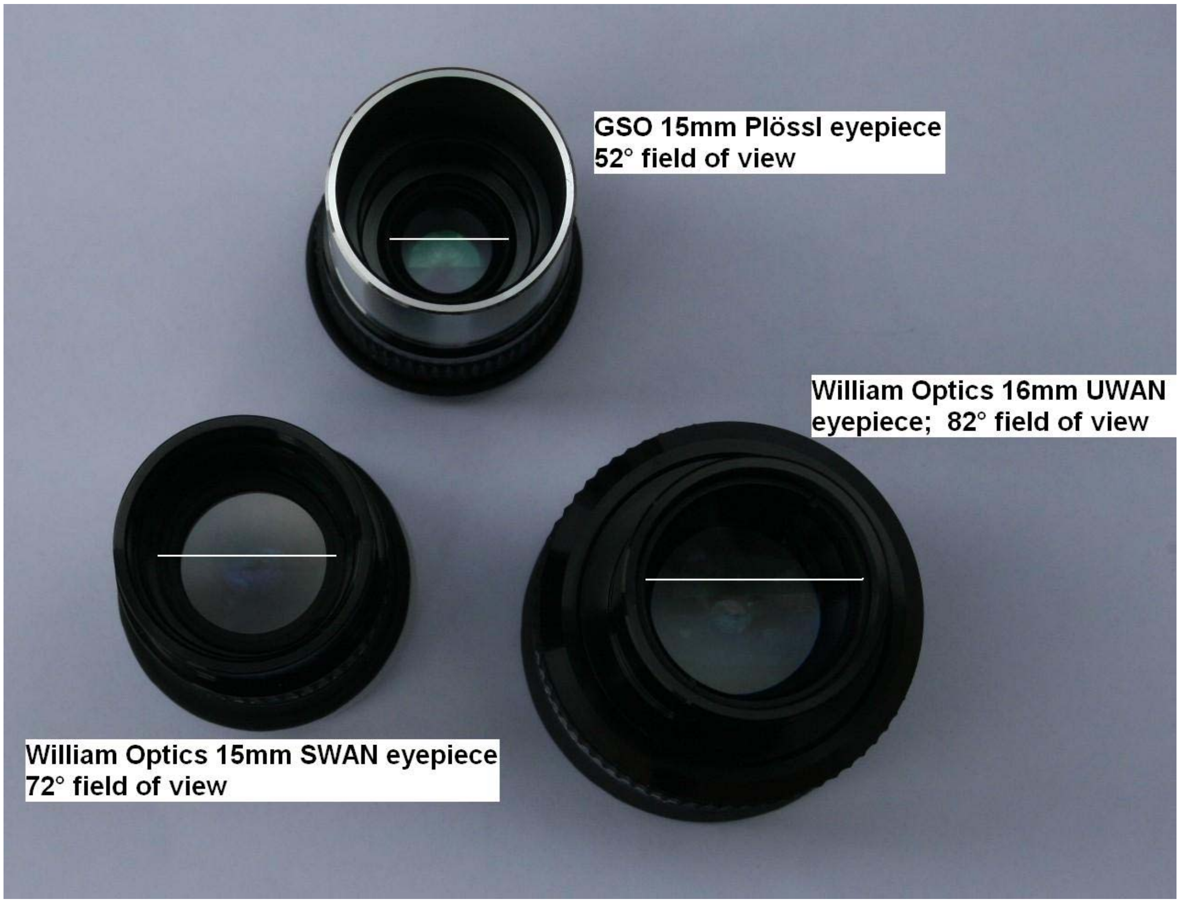

Comparing fieldstops of three eyepieces of comparable focal length and different fields of view.:

GSO 15mm Plössl eyepiece with 52° apparent field of view
William Optics 15mm SWAN eyepiece with 72° apparent field of view
William Optics 16mm UWAN eyepiece with 82° apparent field of view

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APPENDIX B: COATINGS

Eyepiece coatings can be very confusing. But if you carefully analyse the information, you may identify the difference between an eyepiece with inferior and superior coatings. The following types of coatings are commonly found:

Uncoated: No coatings are applied to the eyepiece. The typical loss due to reflections per air/glass surface is about 5%. In a Plössl eyepiece there are four of these surfaces. The total loss of incoming light is:

Total loss = 1 - $(0.95)^4$ = 1 - 0.814 = 0.186 = 18.6%

Note: 100% - 5% = 0.95 - This represents the amount of light transmitted per surface.
$(0.95)^4$ = 0.95 x 0.95 x 0.95 x 0.95 (because of the four surfaces)

- **Coated:** A single layer of anti-reflex coating is applied. This reduces the reflections to about 2% per glass/air surface. The impact on the losses for a Plössl eyepiece is now only 7.8% provided all surfaces are coated.

- **Multi-coated:** Multiple layers (typically four) are applied to glass/air surfaces. The coating reduces the losses to about 1% per surface. The losses in a Plössl eyepiece now reduces to only 4%.

- **Super-coated:** Numerous layers of anti-reflex coatings are applied to the glass/air surfaces. Losses per surface can be as low as 0.2%, reducing the losses for a Plössl to a mere 0.8%. On more complex eyepieces such as the Baader Planetarium Hyperion series with ten air/glass surfaces, the losses are still as low as 2%.

- **Mixed:** The above calculations assumed all surfaces were coated. It is common to find eyepieces where some surfaces are left uncoated. When all surfaces are coated, the pre-fix ‘Fully’ is used. A ‘fully coated’ eyepiece is one where all air/glass surfaces are (single layer) coated. An eyepiece that is ‘multi-coated’ has only some surfaces that are multi-coated. For a Plössl eyepiece these will typically be the outer surfaces. You thus have two multi-coated and two uncoated surfaces. The losses in this case will be:

Total loss $= 1 – ((0.95)^2 \times (0.99)^2)$
$= 1 – (0.9025 \times 0.98) = 1 - 0.885 = 0.115 = 11.5\%$

This means a ‘fully coated’ Plössl are transmitting more light than a ‘multi-coated Plössl. Generally you can assume that if ‘Fully’ is not printed on the eyepiece, then it is not.

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