



The Albuquerque
Astronomical Society

Eyepieces

Astronomy 101

Jim Fordice



Eyepiece Characteristics

- Focal Length & Magnification
- Field Stop
- Field of View
 - Apparent Field of View
 - True Field of View
- Eye Relief
- Exit Pupil
- Barrel Size
- Parfocality

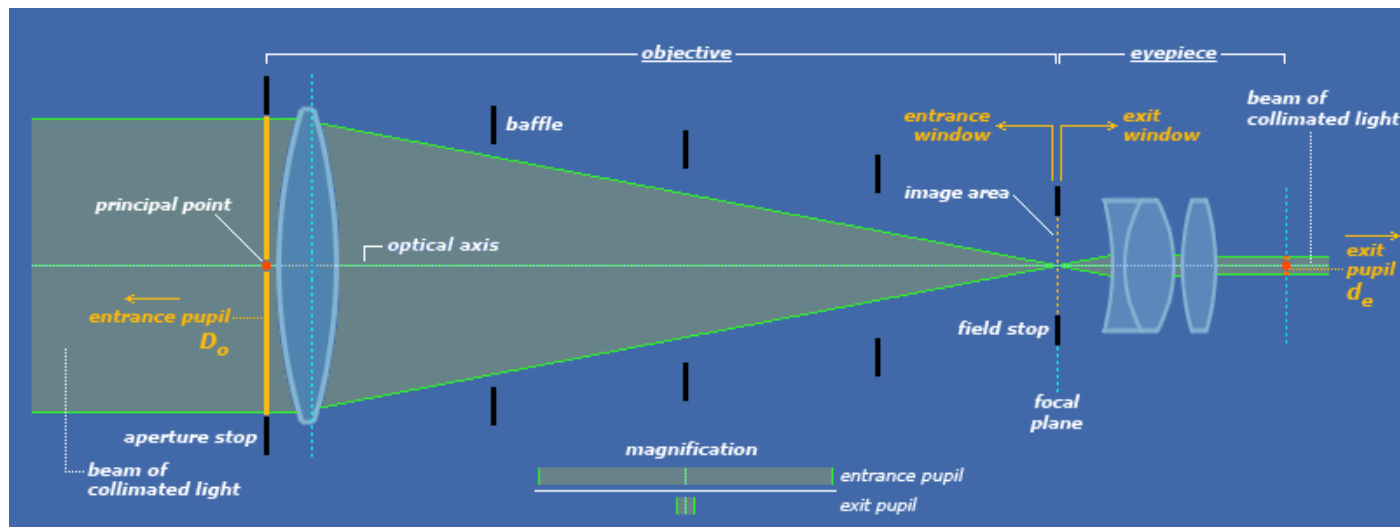
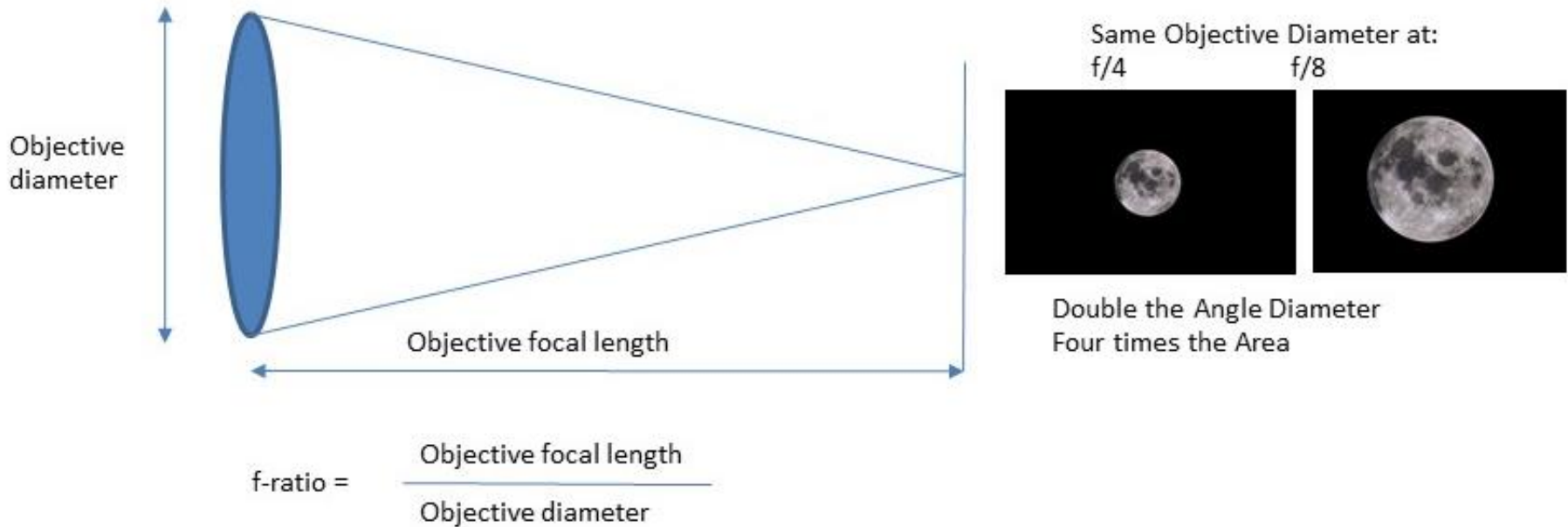




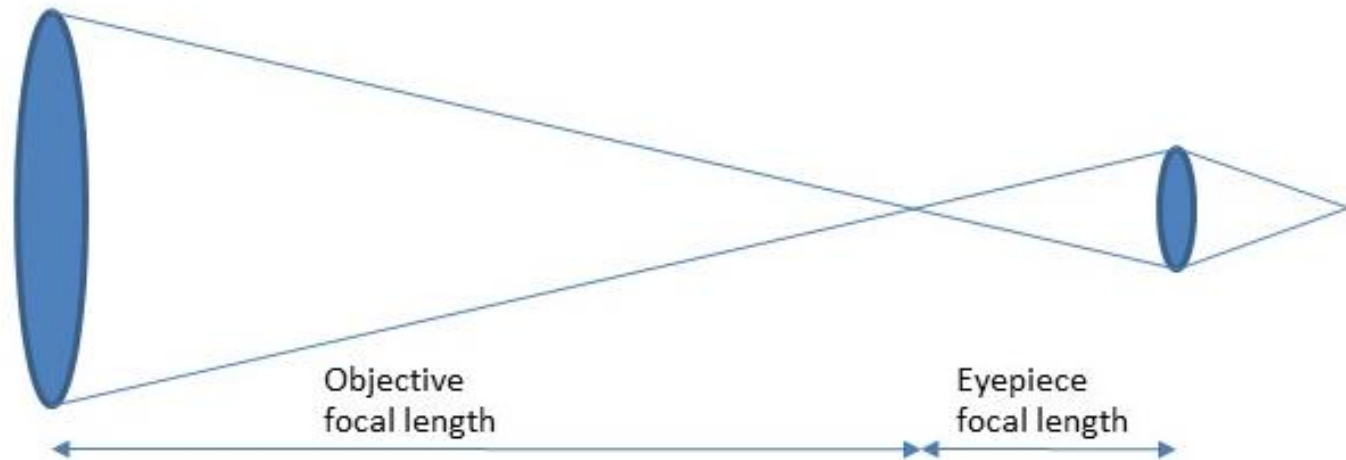
Image Size and F-ratio



<https://telescopemount.org/telescope-eyepieces/>



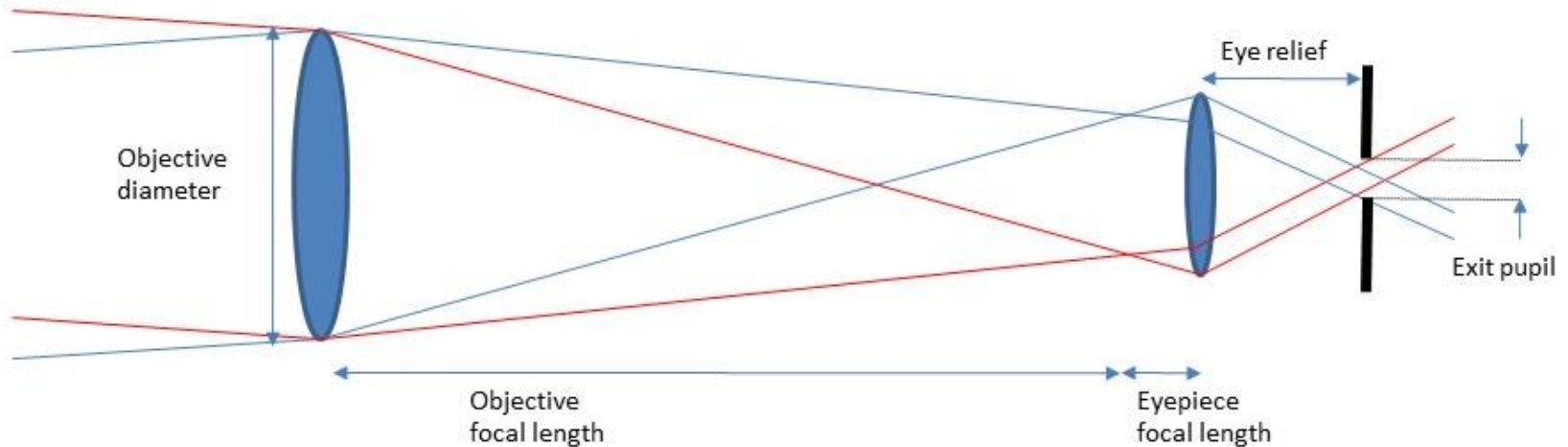
Magnification



$$\text{Magnification} = \frac{\text{Objective focal length}}{\text{Eyepiece focal length}}$$



Exit Pupil & Eye Relief



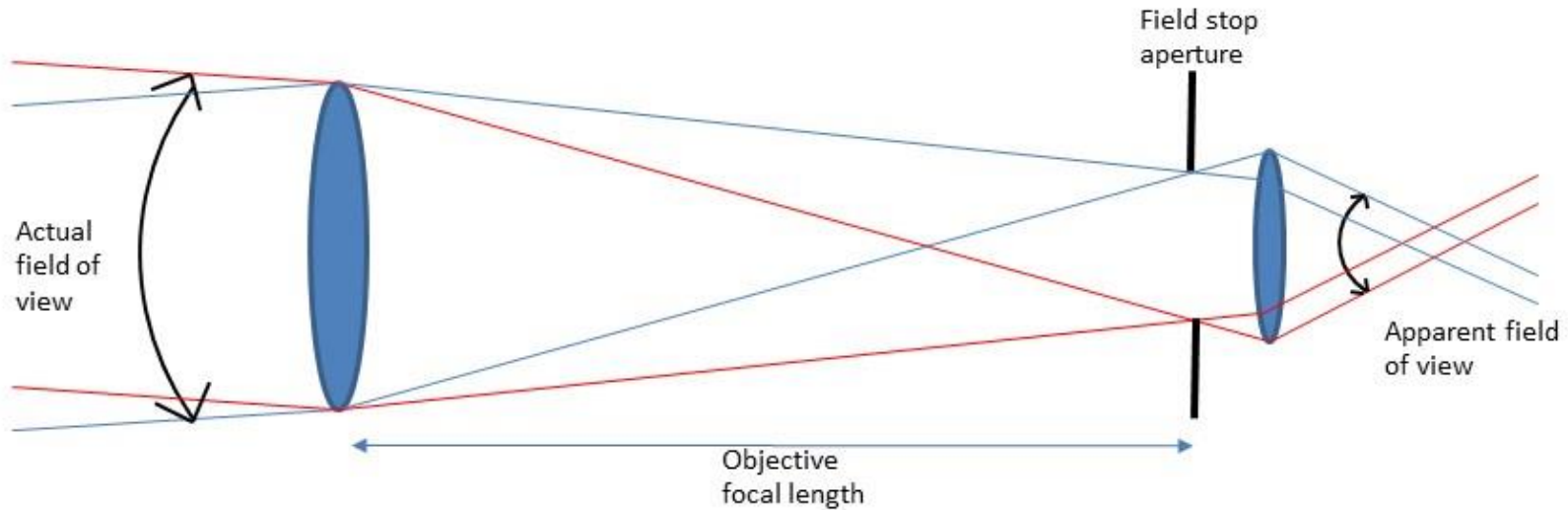
The eye relief is the distance between the eyepiece and the eye's entrance pupil. The eye relief only depends on the eyepiece itself – not the telescope.

The exit pupil is the diameter of the virtual aperture, that is the diameter of the light ray going into the eye. The exit pupil depends on the objective diameter and the magnification.

$$\text{Exit pupil} = \frac{\text{Objective diameter}}{\text{Magnification}} \quad \text{or} \quad \frac{\text{Focal length of eyepiece}}{\text{Telescope f-ratio}}$$



Apparent & Actual Field of View



Apparent field of view is the angle under which the entire field of view is seen. The apparent field of view only depends on the eyepiece itself – not the telescope.

Actual field of view is the angular size of the amount of sky that can be seen through the eyepiece. The actual field of view depends on the focal length of the objective and the diameter of the field stop aperture in the eyepiece.

Precise calculation: Actual field of view = $\text{ATAN}\left(\frac{\text{Field stop diameter}}{\text{Objective focal length}}\right)$

Rule of thumb: Actual field of view = $\frac{\text{Apparent field of view}}{\text{Magnification}}$



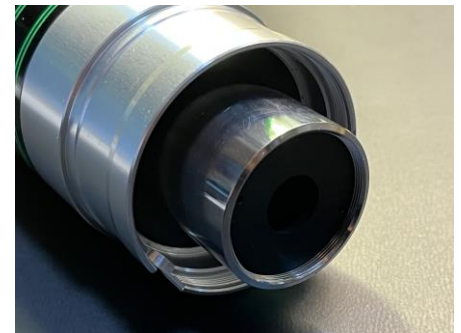
Parfocality

- Parfocality is a handy feature for sets of eyepieces:
 - It means that once you have one eyepiece at focus and you replace it with a parfocal eyepiece that eyepiece will also be at focus.
 - In reality, it means you will only need to make small adjustments when you change eyepieces.



Barrel Size

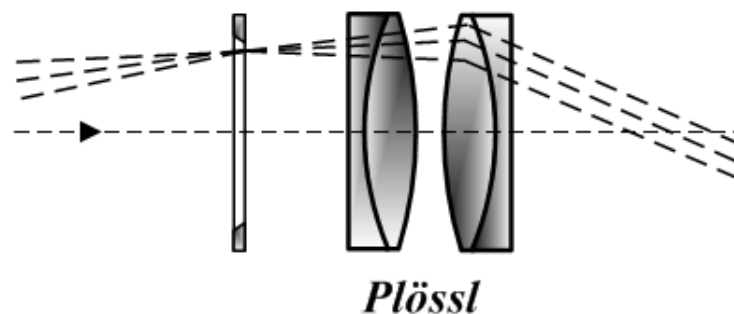
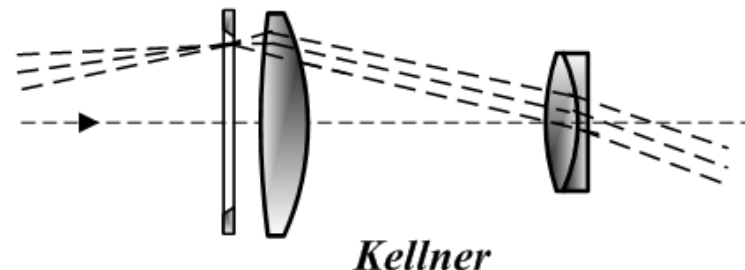
- 2", 1.25", and 0.965"
 - 0.965" only used in older telescopes.
 - Rarely used today.
- Most telescopes will accept 2" and 1.25" eyepieces.
- A 2" barrel is needed when the desired AFOV and focal length require a field stop that will not fit into a 1.25" barrel. The longest focal lengths for a given AFOV are:
 - 13mm for 100°
 - 16mm for 82°
 - 20mm for 72°
 - 32mm for 50°
- Some eyepieces have 1.25" barrel and a 2" skirt.





Types of Eyepieces

- Kellner
 - First modern achromatic
 - 3-lens design
 - 40-50° APOV
 - Short eye relief
- Plossl
 - Two doublet sets of lens
 - Usually, 52° APOV
 - Short eye relief
 - Quality varies widely

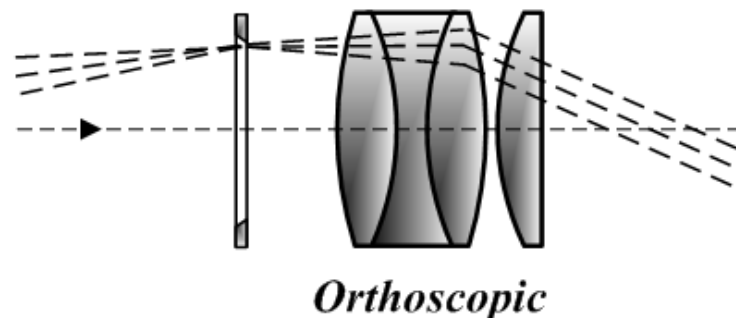




Types of Eyepieces

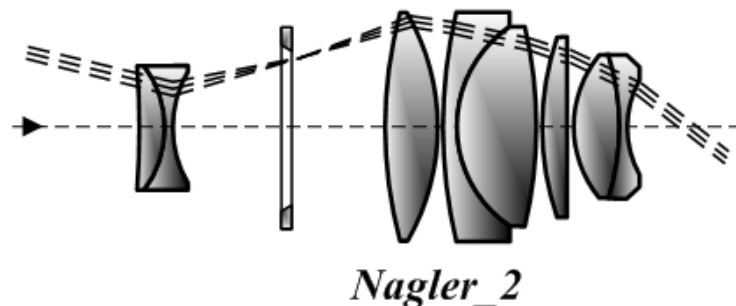
- Orthoscopic

- 4 elements
 - Singlet lens
 - Convex-convex triplet lens
- Good eye relief



- Nagler/Ethos/Delos

- Up to 8 elements in 4 or 5 groups
- Large APOV (82°)
- Ethos achieves $100-110^\circ$ AFOV
- Widely copied
- Tend to be heavy
- High cost





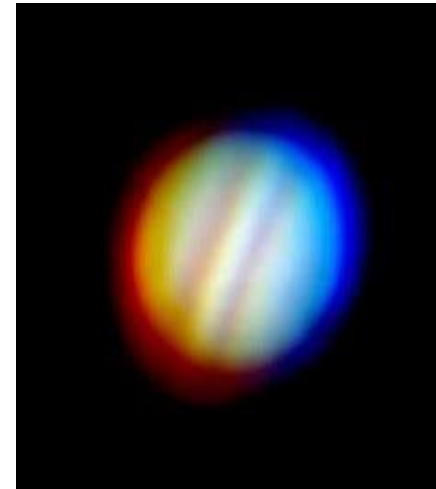
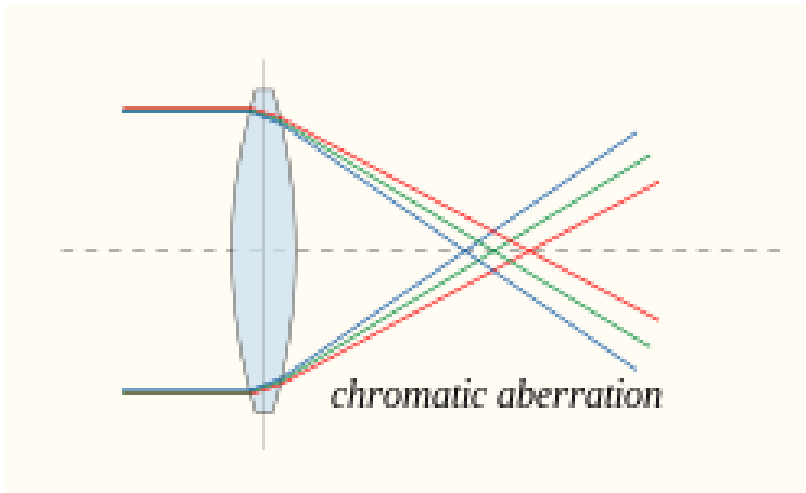
Barlow Lenses

- Magnifies the view through an eyepiece by diverging the light.
 - For the eyepiece it is a focal reducer.
 - For the objective lens it is a focal extender.
- Available reduction/extensions are: 2x, 2.5x, 3x, & 5x.
- Available with 2" or 1.25" barrel sizes.
- TeleVue Powermates are an advanced Barlow that use additional elements to reduce vignetting and maintain the intended eye relief.
 - Vignetting: A reduction in image brightness at the edges of the field of view.



Chromatic Aberration

- Chromatic aberration is the name for the simple fact that different colors of light have different refractive indices. In an eyepiece this means that one will see color fringe around an object. Modern color corrected eyepieces will have very little chromatic aberration.





What Focal Lengths Do I Need?

- Most used magnifications for observing:
 - 50
 - Wide FOV
 - Good for star hopping
 - 100
 - Good for observing most deep sky objects
 - 150
 - More detail for objects that will take the extra magnification
 - Split close doubles
 - Planets
- Example:
 - For a 1500mm 12" Dobsonian a good selection is:
 - 24mm (63 magnification)
 - 15mm (100 magnification)
 - 10mm (150 magnification)



Computations

- “Which Eyepiece Focal Length?” by Jim Kaminski
 - On TAAS Website.
 - Education, Outreach, & Events > Papers & Handouts
- More details than I have presented here.
- Provides general guidelines for choosing eyepiece focal lengths.
- Discusses focal length spacing.
- Explains a spreadsheet that you can use to make the calculations you need.
 - The spreadsheet and examples are available on the Papers & Handouts webpage.



Eyepieces Crib Sheet

I make a table like this for my telescopes and have it handy or attach it to the telescope.

Eyepiece	FL	Mag	FOV
Tele Vue Panoptic	41	37	1.8°
Tele Vue Panoptic	24	63	1°
Tele Vue Delos	17.3	87	0.8°
Tele Vue Delos	10	150	0.5°
Tele Vue Delos	6	250	0.3°
Tele Vue Delos	4.5	333	0.2°
Telrad Rings: 0.5, 2, and 4 degrees			



What Should You Purchase?

- There is a very wide range of prices for eyepieces:
 - \$30 for a 10mm or 25mm Plossl.
 - \$1300 for a 9 mm Explore Scientific 120°.
- Recommendation:
 - Spend about the same amount for your three eyepieces as you will for your telescope.
 - If you have \$2000 for your purchase, consider about \$1000 for the telescope and about \$1000 for the eyepieces.
 - Keep in mind that you can use the same eyepieces with a future telescope, so it makes sense to invest in good quality eyepieces that provide you a good APOV and eye relief.



Some Recommendations

- Agena Starguider or Astro-Tech Paradigm Dual ED
 - 60° AFOV in 3.2 to 25 mm focal length
 - 16-20 mm eye relief
 - \$65 to \$95
- Antares W70 UltraWide
 - 66-72° AFOV in 4.3 to 31 mm focal length
 - 12-16 mm eye relief
 - \$60 to \$100
- Celestron X-Cel LX Eyepieces
 - 60° AFOV in 2.3 mm to 25 mm focal length
 - 16 mm eye relief
 - ~\$100



Some Recommendations

- Celestron Luminos
 - 82° APOV in 7 to 31 mm focal length
 - 12-27 mm eye relief
 - \$150 to \$300
- Explore Scientific
 - 50° to 120° series in a large range of focal lengths
 - 13+ mm eye relief
 - \$150 to \$1300
- Tele Vue Nagler, Panoptic, Delos, DeLite, & Ethos
 - 62° to 100° APOV in a large range of focal lengths
 - 13 to 27 mm eye relief
 - \$270 to \$900



Additional Information

- Jim Kaminski provides additional thoughts in his paper titled “Average Eyepiece Choices”.
 - Available on the TAAS website.



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Questions?