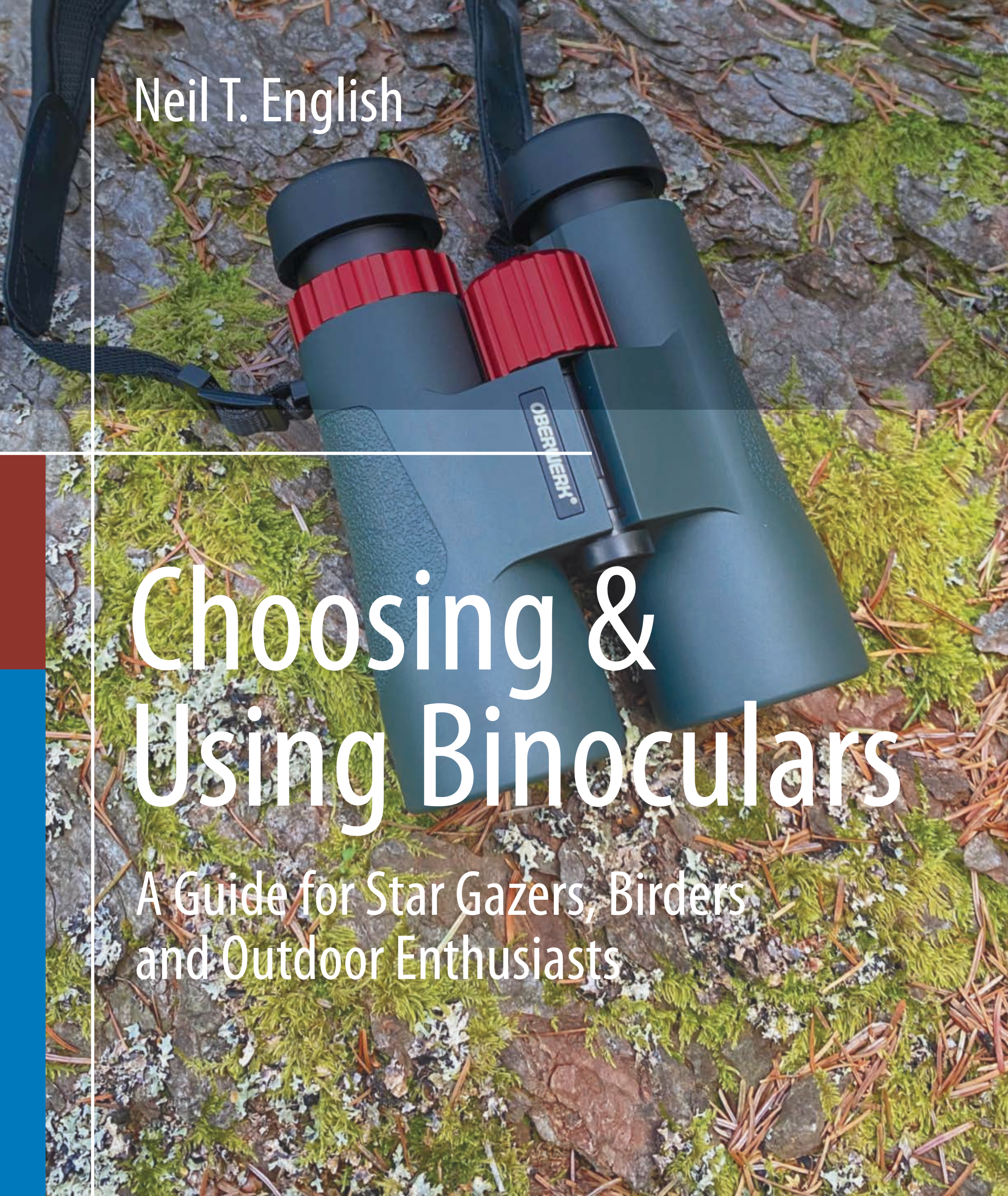
Neil T. English



Choosing & Using Binoculars

A Guide for Star Gazers, Birders and Outdoor Enthusiasts

Springer

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Foreword

Which binocular enthusiast has never been in this situation: Restlessly searching for a new binocular while being hopelessly confused by the enormous variety of models he has just dug up on the Internet, and by their contradictory reviews, created by observers of most diverse backgrounds, demands and habits.

With this book, *Choosing & Using Binoculars: A Guide for Star Gazers, Birders and Outdoor Enthusiasts*, Dr Neil English has succeeded in a most sovereign manner in bringing order into the chaos. Binoculars from all price ranges and produced for every conceivable field of application are systematically presented and analyzed, often accompanied by field reports compiled during daytime observations or under the starry sky. Moreover, these reports are composed by an author who has decades of experience with optical instruments and written numerous articles for the magazines *Astronomy Now* and *Birdwatching*, not to mention the books he has authored in the field of amateur astronomy.

This book begins with a short but systematic introduction to binoculars, to provide the novice with a basis from which he can gain knowledge in the chapters to come. After an interesting outline of the history of binoculars, several rather extensive chapters follow, in which binoculars in numerous fields of applications are discussed. At this point even the most experienced binocular connoisseur gets his money's worth, and I readily admit that as a veteran binocular geek, I have encountered plenty of models here for the first time. In the next part, the book alters its perspective and now the manufacturers or distributors of binoculars with their most important product lines are presented. This section offers the reader an opportunity to gain insight into the different product philosophies of these manufacturers. After useful accessories for binocular observation have been introduced, a highly instructive practical chapter follows, which is dedicated to the testing of binoculars in the field, and which reflects the author's vast experience with visual optical instruments. Here also the optical aberrations and the systematic tests which lead to their discovery are included. The work is rounded out with a very insightful selection of top bargains, followed by a selection of further binocular literature and a delightful exhibition of selected classic binoculars.

I consider the existence of this book a fortunate circumstance. Never before has such an extensive overview of the binoculars on offer been compiled in such a professional manner. With its many supplementary chapters, it is a fascinating read for the beginner as well as for the experienced scholar. Those who are lucky owners of this book may feel urged to do what Dr English recommends in Chap. 31, which I regard a concluding highlight of this work: Go outside, equipped with a binocular, with this book and perhaps a deck chair, and enjoy the beauty and tranquility of nature!

Dresden, Germany Holger Merlitz

The original version of the Acknowledgement has been revised. It was inadvertently published with the erroneous statement that the magnification of Celestron Granite binoculars is 9×33. The correct magnification is 7×33. The revised version is now available with the corrected information.

Acknowledgements

A book of this magnitude of undertaking could not have been achieved in a vacuum. Very special thanks are given to Paul Wehr, who kindly shared his knowledge of many contemporary and classic binoculars with me and who contributed a great piece on the perennially loved Swift Audubon binoculars of yesteryear. A big thank you also to Gary Murphy, who kindly lent me his Celestron Regal ED 8×42 for evaluation and also for contributing his knowledge and experiences with many Canon IS binoculars. My gratitude is also extended to Dr Holger Merlitz, a wonderful scholar and friend to the binocular community with his erudite technical knowledge of binocular optics and his boyish enthusiasm for sharing his experiences with others. He kindly read some of the chapters of an early draft of the manuscript and provided some very constructive feedback on its content. He also wrote a wonderful short review of the Leica Retrovid 7×35 for me, which I'm very grateful for.

I've also enjoyed many helpful discussions on all things binoculars with my former student and friend, Joe Stearn, whose observations have been very enlightening. My thanks are also extended to Richard Duff, for sharing his thoughts on his world-class Fujinon binoculars, Philip Grimsey, a keen British birder who provided his thoughts on the Celestron Granite 7×33, as well as for his interesting conversations about classic binoculars, and Rob Nurse who kindly provided his opinions on the Olympus DPSI binocular. Thanks are also extended to David Laughlin who kindly provided his opinions on the Athlon Cronus 8.5×42. A special mention of thanks is also extended to Steve Graham, Director of First Light Optics, who kindly supplied a number of binoculars to me for testing and evaluation. Gratitude also to Henrik Rundgren, Chuck Hill, Sam Shepherd and John Magera for providing binocular images used in the book. I would also like to thank Rich V, based in Nevada, for interesting discussions on the Nikon E II 10×35.

A big shout out to Michael Maimone, my editor at Springer Nature, for engaging so enthusiastically with the book content and offering many helpful suggestions about its layout. And finally, I would like to graciously thank my wife Lorna and my sons for their support as I pursued this project to its conclusion. Your patience and love are inspirational!

Introduction: The Joy of the Binocular

The author's Nikon E II 8×30. All images credited to the author unless otherwise stated

Oh, my dear little 8×30,
Thou art a wonder to behold,
A tool of great utility,
A treasure worth more than gold.
Thou bringest to me a world of sights,
That my eyes would never see,
A world that's full of beauty,
And of endless mystery.

Thou revealest the majesty
Of the soaring bird in flight,
The grace of the running deer,
And the power of nature's might.
Through thy lenses I see,
A world that's full of life,
A world that's full of wonder,
And of endless beauty rife.

Oh, my dear little 8×30,
Thou art a precious gem to me,
A companion on my journey,
And a portal to my dreams to be.
May thy lenses always be bright,
And thy magic never fade,
May thou continue to bring,
A world of wonders unafraid.

So here's to thee,
my dear companion in sight,
May thou always be by my side,
And may thy little frame forever lend,
A view of the world so wide.

Binoculars are life-enhancing instruments. They bring joy to so many people. By magnifying distant objects, binoculars help us observe wildlife in their natural habitats and appreciate the beauty of landscapes that would otherwise be out of reach. Birdwatching is a popular activity that requires the use of binoculars, and it allows people to observe and appreciate the incredible diversity of bird species around the world. At night, binoculars allow us to peer more deeply into the universe in all its glory, bringing myriad faint stars, galaxies, and nebulae into view.

Whether it's attending a sports event, a concert, or a theatrical performance, binoculars can significantly enhance the experience. By magnifying the action on stage or the field, binoculars allow us to see the details that we would otherwise miss, and thus enhance our enjoyment of the event. Binoculars also allow people to explore new and exciting places, such as mountains, deserts, and oceans. By magnifying distant landscapes and wildlife, binoculars make it possible to appreciate the beauty and wonder of these places and inspire us to explore even further. Binoculars can also create a sense of discovery and excitement. The ability to see things that are usually hidden from view can provide a sense of wonder and awe, which can be incredibly satisfying and uplifting. They provide a sense of connection to the world around us. By allowing us to observe wildlife, landscapes, and events, binoculars help us to appreciate the interconnectedness of all things and our place in the world.

Binoculars are complex optical instruments that use lenses and prisms to magnify distant objects and make them appear closer. The newcomer to the world of binoculars will quickly become inundated by the number of models in today's market, making it almost impossible to see the woods for the trees. But just like shoes, one size doesn't fit all. Some are ideal for travel, others are better suited to detailed nature observation, and still others are designed to study the night sky. But how do you choose? And what attributes make for a good binocular? How good a binocular will you need if you're just looking out from a window at a birdfeeder in your back garden?

In this book, you'll find the answers. We shall explore together the fascinating world of binoculars; their optical properties, their various formats and the strengths and weaknesses inherent in choosing a model that best meets your needs and expectations.

Although I've been a keen amateur astronomer since childhood, you may be surprised to learn that I'm a latecomer to the world of binoculars. You see, I never embraced the philosophy that many astronomy authors were promulgating in the books I read in my youth; that the best instruments to learn the sky with were binoculars and not telescopes. I went straight to the latter, and so it remained for many decades. During the COVID lockdowns, however, with more time on my hands, I kindled a very strong interest in binoculars which led me to explore, test, and evaluate many different models from different brands. This collective knowledge has found its way into this book, where I give my honest opinions on binoculars in different price classes.

They say you get what you pay for. That's largely true, but like everything else in life, there are always exceptions. Today, you can buy excellent quality gear at prices that won't break the bank, and in this book I'll be highlighting several models from each genre that represent exceptional value for money in today's market. What's more, you can achieve a great deal using very modest instruments – it's all about your attitude!

While the modern binocular market is flooded with the newer roof prism models, the reader will learn that the old-school Porro prism binoculars enjoy many advantages over the former. Indeed, the author has given roughly equal weight to both these types of binoculars to help redress the unmerited bias in the contemporary market to promote the sales of roof prism models. Furthermore, the reader will soon learn the many reasons why this author prefers Porro prism binoculars over their roof prism counterparts. You will also learn about some terrific models from the past – models that serve up fields of view so wide that they'd make even the most impressive contemporary wide-angle models feel rather ordinary!

A brief note on terminology. I refer to binoculars in the singular, that is, "a binocular." It's grammatically incorrect to use the phrase "a pair of binoculars," as the word "binocular" is a collective noun implying two telescopes mounted side by side. If you're offended by this choice of wording, then I apologize in advance.

The first part of the book begins by exploring many of the technicalities of modern binoculars, as well as a brief overview of their history. Following this, we explore the major formats on the binocular market today including small pocket-sized instruments, compact formats, full-size instruments, and more specialized low-light binoculars, discussing their relative strengths and weaknesses. We also take a whistle-stop tour of the various kinds of binoculars best suited for stargazing, observing in the marine environment, range-finding, and image-stabilized models.

The reader will forgive the author if his/her favorite binocular brand is not mentioned in the text. Because the market has so many models, it's well-nigh impossible to have evaluated them all. Moreover, because many binoculars available today, especially in the low- and mid-priced market, are clones of each other, the chances are good that an evaluation of one brand is probably representative of many others on the market.

The second part of the book is dedicated to exploring the main binocular manufacturers and their product lines, as well as discussing the many accessories used by binocular enthusiasts. It also includes a chapter on how to test binoculars and what those tests reveal about your instrument. We explore a series of classic models that have totally surprised this author in regard to optical and ergonomic performance and which offer a glimpse of what the future of binoculars may look like! Finally, the book winds up with a passionate call for binocular enthusiasts to get out and about and use their binoculars to explore nature in all its glory, whether on earth or in the skies above. After all, that's what your binoculars were designed for!

Fintry, Scotland, UK Neil T. English

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The original version of the book has been revised. A correction to this book can be found at https://doi.org/10.1007/978-3-031-44710-5_33

Part I
A Survey of the Binocular Market

Chapter 1
Binoculars 101

A prospective buyer unacquainted with binoculars will likely quickly become inundated with the number of makes and models on the market. Some have funny Z shaped anatomies, others look like opera glasses, where the objectives are in-line with the eyepiece lenses. Some are tiny, fitting in the palm of one's hand, while others are enormous and heavy, requiring a substantial mount to do them justice. You've probably been daunted too by the huge range in their price ranges, with the cheapest coming in at $10 or $15, while other brands, sporting binoculars that outwardly look the same as those cheap instruments command price tags in excess of $2000. How can we even begin to make sense of the enormous numbers of models available today? A good place to start is to briefly explain the basic features of all binoculars before delving into a more detailed discussion about the major differences between modern binocular designs.

The vast majority of binoculars used for recreational purposes and surveillance come in two flavors; either Porro prism or roof prism binoculars. Porro prism binoculars are probably the kind most familiar to the public. Indeed, if one were to stop someone at random on a busy high street and ask them to identify a binocular, chances are they would point to a Porro-prism model, characterized by its zig-zag shape. Roof prisms are often smaller, more streamlined, and more compact, with both its barrels being straight.

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Two binocular designs: a Porro prism instrument (left) and roof prism model (right)

All binoculars, whether Porro or roof prism types, are adorned with two numbers. For example, 8×30, 10×42 or 12×50. The first number indicates magnification while the second number indicates the aperture of the front-end (objective) lenses. Thus, an 8×30 instrument magnifies 8 times and has objective lenses with diameters of 30 mm. A 12×50 has a magnification of 12 and objectives that are 50 mm across, etc. Most binoculars also state the field of view that can be seen by the observer. This is usually expressed in feet at 1000 yards (or meters at 1000 m in Europe). For example, a binocular that sports a field of view of 350 feet at 1000 yards means that you will be able to see 350 feet from one edge of the image to the other when viewed from a distance of 1000 yards. Alternatively, in Europe, field of view is more commonly expressed in the number of meters visible at a distance of 1000 m. More on this topic later in the chapter. In general, the lower the magnification of the binocular, the wider the apparent field of view.

Antireflection Coatings

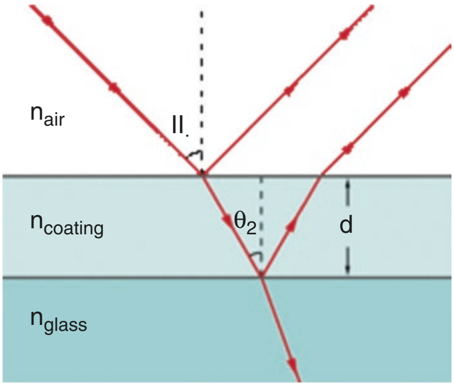
Lens blooms from the application of antireflection coatings

Perhaps you've noticed a strange blue, green or purple bloom on the surface of your binocular lenses. These are called anti-reflection coatings, which greatly boost the amount of light passing through the binocular and help eliminate annoying internal reflections. Uncoated optical glass reflects 4% of the light that hits its surface, meaning that 96% passes through (actually a bit less than this as some light is absorbed by the glass as well). A typical binocular has between 6 and 10 lenses and prisms, each having two surfaces. Now, 4% light loss doesn't sound especially large until you do the math which considers the total light transmitted. If only 96% passes through each of say 20 glass surfaces, then the total light transmitted will be 0.96 raised to the power of 20 which results in 0.442, that is, only 44.2% of the light gathered by the objectives reaches your eyes. Put another way, more than half of all the light gathered by the binocular will be either scattered or reflected away, drastically reducing both image brightness and contrast.

Thankfully, modern anti-reflection coatings greatly increase light transmission and reduce light loss from internal reflections and light scatter. They work by causing selected wavelengths of light to destructively interfere with each other. Fully coated optics usually have a single layer of magnesium fluoride applied to each glass surface but all decent modern binoculars are either multicoated (possessing 2 layers of antireflection coatings) or fully broadband multi-coated, having up to 8 layers of coatings vacuum deposited on the surfaces of all the lenses and prisms ensuring progressively higher light transmissions of the order of 80–95+%.

Antireflection coatings work via a process called *thin layer interference* of light waves being reflected off materials of different refractive indices. The refractive index, often symbolized by the letter ‘n’. tells you how much a light ray changes direction as it leaves one medium and enters another. The greater the refractive index, the greater the degree of light bending that takes place. The refractive index varies from 1.0 for air or a vacuum to greater than 2 for some transparent materials. For example, water has a refractive index of 1.3 and ordinary window glass has a larger refractive index of 1.5. Other transparent materials like diamond, Perspex, and transparent polycarbonate materials have their own unique refractive index.

Now when light waves reflect off a surface with a higher refractive index than the medium they have been travelling through (air to glass for example), they undergo a phase change of 180 degrees (pi radians). Conversely, when light waves reflect off a surface with a lower refractive index (glass to air for example), they do not undergo a change of phase.



How antireflection coatings work. Light waves reflected off the top and bottom of the coating destructively interfere with each other and so cancel each other out so long as the path difference between the waves is 180 degrees. The thickness of the coating determines the wavelength of light eliminated. (Image Credit: Wiki Commons)

By applying a coating with a certain thickness, optical engineers can cause the ray reflected off the top and the bottom of the coating to merge and undergo so-called destructive interference, thereby cancelling themselves out. Since green light (wavelength of ~550 nm) is the color the human eye is most sensitive to, optical designers preferentially aim to cancel these rays when light reflects off optical surfaces, resulting in the reflection of much dimmer red and blue wavelengths, which we perceive as a purple lens bloom. The thickness, d, of the coating determines the color of light that is cancelled by interference according to the equation:

$$d\left(minimum\right) = \frac{\lambda}{4n}$$

where λ is the wavelength of light undergoing destructive interference and n is the refractive index of the coating. It turns out that if we use a common material such as magnesium fluoride to cancel out light in the middle of the visible spectrum, the coating will have to have a minimum thickness of about 100 nm.

By applying multiple layers to the lens surfaces, reflections are brought to a minimum and light transmission is optimized.

Exit Pupil Considerations

If you hold your binoculars up to the light and look at the eyepieces, you'll see two small circular shafts of light. This is known as the exit pupil. The size of the exit pupil will vary from model to model, and usually falls within the range of 2 mm all the way up to 7 mm. To calculate the size of the exit pupil on your binocular, simply divide the aperture of your objective lens by the magnification of the binocular. So, for example, an 8×20 pocket binocular will have an exit pupil size of 20 divided by 8 or 2.5 mm. A larger 10×50 binocular will have an exit pupil twice the size at 5 mm. Why is the maximum set at 7 mm? Well, the pupil of the human eye maxes out at 7 mm for most people, when the eyes are fully adapted to darkness. Thus, having a binocular with an exit pupil larger than 7 mm will result in wasted light, as not all the light collected by the objectives gets directed into the eye.

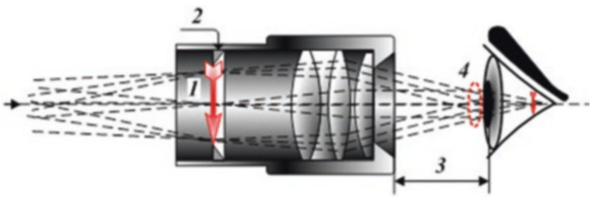
The exit pupil is the circular shaft of light seen when a binocular is held up to the light

The upper maximum of 7 mm is true for most young people. It is widely believed that as one ages the maximum size of the exit pupil decreases. While this is generally true, there are many examples of older people having very large exit pupils and some now consider this decrease in exit pupil size with age to be a bit of an urban myth. I think it's safe to say that while there is a decrease in exit pupil size with age, the shrinking is far less drastic than previously believed. And while many sources claim that by age 60 or 70, the dilated pupil shrinks to 5 mm, it may not be true for the majority of people.

Large exit pupil binoculars have clear advantages in low light conditions or while observing faint objects in the night sky. But during daylight applications, smaller exit pupils can be used profitably. Indeed, during bright sunny days, the human exit pupil shrinks to just 2 or 3 mm. Are there other advantages to using larger exit pupils? Yes! For one thing, many observers find it easier to center their eyes in the eyepieces, reducing the incidence of blackouts and improving the comfort and immersivity of the views. Conversely, small exit pupils make it more difficult to comfortably center one's eyes to such a degree that some observers cannot get on with binoculars with exit pupils less than 4 mm. That said, smaller exit pupils may help bespectacled folk who normally wear glasses to use their binoculars without them. The reason for this is that smaller exit pupils expose far less of the aberrations found in the outer part of the eye lens and so, effectively, they will be using the best part of their eye lens to view the scene. In addition, this author enjoys exit pupils less than 5 mm when viewing astronomical targets as it darkens the sky better than using instruments with larger exit pupils. Star images appear slightly more pinpointed and crisper at those smaller exit pupils too.

Eye Relief

The eye relief of a binocular, usually quoted in millimeters, is the distance from the eyepiece that your eye needs to be placed in order for all the light from the eyepiece to fall onto your retina when the exit pupil is the same size as the size of the pupil of your eye. It's measured from the back surface of the eye lens.



Schematic of the eye looking through a binocular eyepiece. The number 3 indicates the relief of the eyepiece. (Image Credit: Wiki Commons)

In the past, binocular eyepieces had very poor eye relief making it difficult for the bespectacled among us to access the entire field. But over the last few decades, optical designers have put much more effort into creating eyepieces with more generous eye relief so that even if you happen to observe with proverbial 'milk bottle' glasses, you can now enjoy the full field of view. In the past, older eye piece designs were fitted with soft rubber eyecups that could be folded down to allow the user to use his/her spectacles to image the field. Modern binoculars usually have more advanced twist-up eyecups offering a number of positions that can enable the user to get the best views from their binoculars. In general, about 15 mm is usually quoted as the minimum eye glass wearers require to successfully access the entire field, though in practice many manufacturers advertise overly optimistic figures with the result that the quoted eye relief for a given model is often not what they experience in practice. But is more and more eye relief a good thing? No, not at all. You see, as eye relief increases it becomes increasingly more challenging to position one's eyes precisely behind the eyepiece which can exacerbate blackouts while viewing though the instrument. In practice, rarely will anyone require more than 20 mm of eye relief.

Interpupillary Distance (IPD)

Humans have widely variable distances between their eyes. Some are very wide-spaced, while others have very closely-spaced eyes. The distance between your eye pupils is called the Inter-Pupillary Distance (IPD) usually measured in millimeters. Smaller individuals, like children and women usually have smaller IPDs anywhere between 50 and 60 mm. Men usually have larger IPDs anywhere from 60 to 75 mm. Binoculars vary quite a bit in their IPD range, and this is an important consideration when finding binoculars that best fit your face. Many children, for example, cannot use large and medium sized binoculars because the eyepieces cannot be spaced close enough for them to merge the images properly. Thus, it's always good to check the IPD range of your binocular prior to purchasing. Better still, and if possible, try the binocular before you buy!

Collimation Considerations

In order to derive the best possible images out of your binocular, the optical elements must be aligned in each barrel but also must be aligned in such a way that the images can be merged into a single stable viewing field, when the eye-brain system can perceive depth. Not only must the barrels be aligned to each other but also to the hinge or other axis about which your IPD is adjusted. Furthermore, the optical axes must be aligned both in the vertical and the horizontal directions. Moreover, accuracy of collimation scales directly with magnification. A binocular magnifying 16×

has a collimation tolerance only half that of an 8× instrument. This becomes particularly important in high power binoculars used for terrestrial distance viewing and astronomy, where achieving collimation can be far more challenging and indeed limits the highest powers that can be profitably employed.

Magnification Considerations

You've probably noticed that most compact binoculars come in magnifications anywhere from 6× to 12×, while the most common powers are 8× or 10×. Most novices make the mistake of thinking higher power binoculars will be better. They reason that higher magnifications will give a more enlarged image, with more details popping into view. While this is broadly true, they fail to consider the difficulties of hand-holding a binocular delivering powers of 10× or 12×. While the weight of the binoculars may not be substantially different, holding a 12× glass steady is much more challenging than using a 10× glass, and an 8× instrument will be easier again to hold steady. Image steadiness is very important in order to glean as much detail as possible from the binocular image, and how steady you can hold the binocular in your hands will dictate your preferred magnification choices.

Magnification will also dictate to some degree the brightness of the images your binocular will deliver, especially when the light fades in the evening or while glassing at dawn. For example, a 7×42, which delivers a 6 mm exit pupil will serve up a noticeably brighter image than a 10×42 – all other things being equal – under low light conditions. For astronomical applications, larger aperture binoculars offering much high powers are quite common. The author owns and uses a 20×60 mm Pentax Porro prism binocular that he uses for observing the Moon and the brighter deep sky objects. But if you think such an instrument can be hand-held, think again! Without a tripod, this high-power binocular will magnify the shakes in your hands and make observing fine details hopelessly impossible.

Aperture Considerations

Binoculars come in a huge range of objective diameters, anything from 20 mm right up to 150 mm or more. For daylight applications, when the light is good and strong, smaller apertures between 20 mm and 42 mm will serve you well for most purposes. Take for example, a small pocket binocular with specification 8×20. Because the human eye pupil shrinks in size in broad daylight down to 2 or 3 millimeters, the small exit pupil of 2.5 mm on the 8×20 lets through plenty of light to give very satisfying views of the landscape. Indeed, many observers report no gain in image brightness comparing binoculars with various size exit pupils when the ambient light is good.

The advantages of larger apertures come into their own during dull overcast days or when glassing under a heavily shaded forest, as well as at dusk and dawn when the intensity of sunlight is minimized. During these times, it's best to switch to a larger aperture binocular possessing a larger exit pupil, so you can take maximum advantage of those low-light conditions. Another advantage of larger apertures is that they can resolve finer details, though it may not be obvious in hand-held field use.

For most birding or general nature observations, smaller binoculars with apertures less than 42 mm will probably meet all of your requirements. Having used many different binocular apertures over the years, this author has come round to thinking that apertures of 30–35 mm are probably ideal. Using magnifications of 7× or 8× these apertures will transmit enough light to your eyes to sate all your demands during the day but will show their limitations as the light levels drop off at dusk or dawn. Other birders prefer to use 42 mm instruments perhaps because their exit pupils are larger making it easier to get the eye box squared up with your eyes. But that comes with an increase in carrying weight. In general, the larger the binocular you use, the heavier it becomes. That may not present as a problem if the instrument is used only casually or for short excursions, but in my experience, carrying around a 42 mm aperture binocular over many miles for a few hours every day quickly induces neck strain. That's where the considerably lighter weight of the 30–35 mm binocular class really comes into its own as these tend to be about 50% lighter than the equivalent 42 mm instrument, all other things being equal. Hunters often prefer larger, low-light binoculars in apertures of 50 mm or 56 mm and employing magnifications anywhere between 7× and 10×. These will greatly extend the time one can engage with their targets as the light fades in the evening or at dawn. And as one might expect, these large aperture binoculars are an excellent choice for stargazing, as they collect more light than smaller aperture instruments.

Glass Types

For the vast majority of the history of the binocular, the lenses making them up were composed of two types of glass, called crown and flint. By combining these two types of glass, much better color correction could be achieved. Indeed, until the end of the nineteenth century, such telescopes were the best in the world. When the magnification is increased however, high contrast objects will show a blue or purplish fringe around the edges of objects which opticians refer to as chromatic aberration. This is caused by the slightly different angles by which the different colors of white light emerge from the objective after being focused by the objective. Fortunately, because most common binoculars used by birders and naturalists employ low powers (mostly less than 10×), chromatic aberration is not much of an issue, but folk vary in their ability to detect it. Some people are just more sensitive to chromatic aberration than others. In general, the higher the magnification, the greater the chromatic aberration seen.

In recent years, traditional crown & flint binocular objectives have been replaced with so-called extra low dispersion (ED) glass. In ED objectives, the crown element is mated with a type of flint made from exotic materials such as calcium fluorite or some synthetic version of calcium fluorite. The resulting doublet focuses the individual colors of light more tightly than traditional crown and flint objectives, resulting in a slightly sharper image with greater contrast. When used alone, low dispersion glass can cause its own type of color fringing, which is why it is often paired with ordinary optical glass to achieve the best possible optical performance.

The Abbe number is a measure of the amount of dispersion or chromatic aberration that occurs when light passes through a material. Dispersion refers to the phenomenon where different wavelengths of light bend or refract by different amounts when they pass through a material, resulting in color fringing or blurring of images. The Abbe number is defined as the ratio of the difference in refractive index between two specific wavelengths (usually the spectral blue F line at 486.1 nm and the red C line at 656.3 nm) to the refractive index at the yellow sodium D line at 589.3 nm. A material with a higher Abbe number has a smaller difference in refractive index between the blue and red wavelengths, indicating lower dispersion.

In optical systems, chromatic aberration caused by dispersion can be corrected by combining lenses made from different materials with different dispersion properties. A lens made from a material with a high Abbe number (lower dispersion) can be paired with a lens made from a material with a low Abbe number (higher dispersion) to reduce chromatic aberration. Therefore, the Abbe number is an important factor to consider when selecting optical materials for lenses, prisms, and other optical components. A material with a high Abbe number is desirable for applications that require minimal chromatic aberration, such as high-quality camera lenses, telescopes and binoculars. Conversely, a material with a low Abbe number may be more suitable for applications where dispersion is intentionally used, such as in diffraction gratings and dispersion prisms.

By combining low dispersion glass with ordinary optical glass, lens manufacturers can create a lens that has a more balanced refractive index across the visible spectrum of light, leading to better color correction and reduced color fringing. This is known as an apochromatic lens, or APO lens. In short, the combination of low dispersion glass with ordinary optical glass is done to create a lens that can achieve the best possible optical performance with minimal color fringing.

While ED glass has been used very successfully in refracting telescopes- see my book, *Choosing & Using a Refracting Telescope* – which use high magnifications more or less routinely, their benefits in low power binoculars is not nearly so dramatic. Yes, when properly executed, ED binoculars will present a slightly crisper, more contrasted image, but the effects are often quite subtle. In this author's experience, ED glass is not something he would insist on when making a prospective purchase of a new binocular for birdwatching, as he has seen many models with traditional crown & flint objectives give better results than those sporting poorly executed ED glass objectives. What's more, not all ED glass is of equal quality. Some ED glass shows barely perceptible results, while higher quality ED glass binoculars show noticeably improved images.

There are many types of ED glass available today. For example, FPL51, FPL53, and fluorite are all types of optical glass that are commonly used in high-quality lenses and optical systems. Here are the key differences between these three materials:

FPL51: This is a type of ED (Extra-low Dispersion) glass produced by Ohara Corporation. It has a relatively high Abbe number of around 81, which means that it has lower dispersion than standard optical glass. FPL51 is used in many high-quality lenses and optical systems and is known for its ability to reduce chromatic aberration.

FPL53: This is another type of ED glass produced by Ohara Corporation. It has a higher Abbe number than FPL51, at around 95, which means that it has even lower dispersion. FPL53 is often used in lenses and optical systems where the highest level of color correction is required.

Fluorite: Fluorite is a naturally occurring mineral that has very low dispersion and is highly transparent to visible light. It is sometimes used in lenses and optical systems where the highest level of color correction and image quality is required. However, fluorite is relatively rare and expensive, and can be difficult to manufacture into optical components.

In general, FPL51 and FPL53 are synthetic glasses that are more readily available and less expensive than fluorite. FPL53 has a higher Abbe number than FPL51, which means that it has even lower dispersion and is better at correcting chromatic aberration. However, both FPL51 and FPL53 can have higher levels of dispersion than fluorite, which can limit their performance in certain applications. Fluorite, on the other hand, has the lowest dispersion of the three materials and is therefore often used in applications where the highest level of color correction is required.

In more recent years, other designations have appeared including HD or UHD or some such. HD presumably stands for 'high definition,' (or ultra-high definition in the case of UHD) but it's often unclear to the consumer what this entails. Better coatings and better figured glass elements might bring about a boost in contrast making the images appear more sharp or more highly contrasted, but these instruments may not, in fact, possess ED glass elements. Often these monikers are merely marketing hype more than anything else, so buyer beware!

One myth promulgated by some binocular reviewers is that the presence of ED glass boosts image brightness. That is not the case, or rather, not strongly attributed to the finer focusing of the various wavelengths of visible light. ED glass can improve image quality by reducing chromatic aberration, it does not necessarily make the images appear brighter. Brightness in binoculars is primarily determined by the size of the objective lens and the quality of the coatings on the lens surfaces. A larger objective lens allows more light to enter the binoculars, which can result in a brighter image. Coatings on the lens surfaces can help to reduce glare and improve light transmission, further enhancing perceived image brightness.

By itself, the slightly tighter focusing of the individual wavelengths will increase image brightness by a tiny fraction of 1%. So where does the claim that ED glass deliver brighter images come from? Most sources of misinformation usually have a grain of truth to them. I believe this might have arisen by considering how much light is reflected off materials of different refractive indices. It was after studying some of the work of Augustin-Jean Fresnel (1788–1827) that I got a lead. His equations provided important advances in computing how much light is transmitted and reflected with materials possessing different refractive indices.

Many of the Fresnel equations are quite complex, as they involve light incident upon a surface at different angles. Let's look at one particular equation:

$$R = \left[\frac{\cos x - \left(n^2 - \sin^2 x\right)^{1/2}}{\cos x + \left(n^2 - \sin^2 x\right)^{1/2}} \right]^2$$

Where R = the amount of reflected light from an optical surface

x = the angle of incidence and n = the refractive index of the material.

We can simplify this greatly by considering light arriving directly along the normal (i.e. looking at the center of the lens head-on, so x = 0), from which we obtain the much simpler equation:

$$R = \left[\frac{1-n}{1+n} \right]^2$$

So the amount of reflected light only depends on the refractive index of the optical glass used. Now consider regular crown and flint glass having a refractive index of about 1.5. The amount of light reflected off such glass for normal incidence is:

$$R = \left[\frac{1-1.5}{1+1.5} \right]^2 = 0.04$$

Note: This is the origin of the 4% figure often quoted in telescope optics texts for uncoated glass.

Next consider extra low dispersion (ED) glass like fluorite or FPL 53 or some such, with a refractive index of 1.44. Plugging this number for n into the Fresnel equation delivers a value of 0.03 or 3%.

This means that regular crown or flint glass transmits 96% of the light incident upon it compared with 97% for ED glass.

This is a very small difference but considering that only one or two elements in the optical train employ ED glass, and the applications of multiple layers of antireflection coatings further reduce the light losses for both types of glass, the visual difference in brightness will be all but indistinguishable.

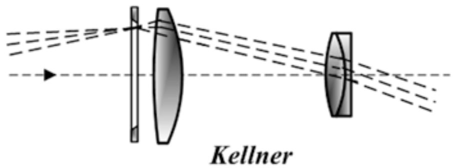
So there you have it! Although the Fresnel equation allows for a 1% difference in transmission, it amounts to effectively negligible differences in overall transmission, all other things being equal.

Don't believe the hype!

While ED glass does not directly affect image brightness, it can help to improve contrast and color accuracy, which can make images appear more vivid and detailed. So, while ED glass is not a direct factor in image brightness, it can contribute to overall image quality and clarity. In sum, never purchase binoculars solely based on whether they have ED glass or not. There are many more important features that need to be executed well before you'll even begin to see the benefits of having it. Indeed, some of the best binocular optics don't contain any ED glass elements, so something to think about. What *will* boost image brightness in dim light however, is greater transmission of blue light, as the eye becomes more sensitive to shorter wavelengths as the light fades.

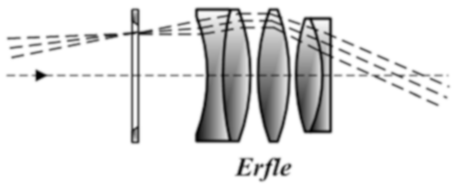
Binocular Eyepiece Designs

Most binoculars sold on the market today consist of three or more lenses arranged in two or more groups. By far the most common is the venerable Kellner eyepiece dating all the way back to 1849, which consists of a single field lens and doublet eye lens. Another common design is the reverse Kellner, a design that was introduced in 1975 by David Rank of the Edmund Company, where the doublet becomes the field lens and the eye lens is a singlet, which presents a slightly wider field of view than the original Kellner design (50 degrees vs 45 degrees) and much better eye relief.



Schematic of the Kellner eyepiece design. (Image Credit: Wikipedia)

Wide angle binoculars usually employ a more advanced Erfle or modified Erfle, having five or six elements in three groups to better correct off axis aberrations. These Erfle designs had their first prototypes in 1917, after which they first hit the market in the early 1920s were first used in the Zeiss Deltrentis 8×30, as well as the Delactis and Delturis 8×40 models.



The 5 Element Erfle design. (Image Credit: Wikipedia)

Diopter Adjustment

Very few people have identical eyes. The quality of the image in one eye may be noticeably superior to the other, or there may only be small subtle differences between them. Because binoculars employ both of your eyes, some provision is usually necessary to adjust the focus on one eye independently of the other. This is where the diopter compensation adjustment comes into play. Most lower cost binoculars have a ring located under the right eyepiece, usually set to zero when it comes out of the box, but with+or – scales. Most binoculars offer a range of+/− 4 or 5. Diopter adjustment is one of the first things you will need to do in order to get your binocular working correctly. First cover the right objective and look through the binocular. Only the left-hand barrel will be showing its image. Focus the image on a target in the middle distance, at least 40 meters away. A signpost with some lettering or numbering on it is ideal. Using the central focusing wheel, bring the image to sharp focus, so that you can clearly make out the letters or numbers. Next, cover the left objective and once again look through the binocular at the same target. This time don't touch the central focusing wheel but instead move the diopter ring either clockwise or anti-clockwise until you get the image as sharp as you possibly can in your right eye. Once you've done this, your binoculars are good to go. Just use the central focusing wheel from now on to get the crispest views your binoculars are capable of.

Many top-rated binoculars have more sophisticated diopter compensation mechanisms usually involving a lockable diopter adjustment. Probably the most frequently encountered designs involve pulling the central focusing wheel out, which exposes a diopter scale. This is adjusted by rotating the focuser while undergoing the same procedure outlined above. Once your desired setting is achieved, the focus wheel is pushed down again, locking your desired setting into place. Locking diopters have the obvious advantage of maintaining your preferred diopter setting. In contrast, the non-locking types tend to move in field use necessitating re-adjustment every now and then. Of course, if you share your binoculars with others, a non-locking diopter may turn out to be a better choice, as each observer will likely require a different diopter setting.

Depth of Field

If you use a variety of binoculars, chances are you'll notice that some instruments keep targets sharply in focus over a large range of distances. The wider this range within which sharp focus can be maintained is known as depth of field. It can be shown with a bit of optical theory that magnification is the key factor determining how much depth of field your binocular will deliver. In general, the lower the magnification, the greater the field depth. More technically, the depth of field scales inversely with the square of magnification. So, if one were to compare two binoculars of the same type, say 6× and 12×, the 12× glass will have a depth of field four times smaller than the 6× glass.

Depth of field is a very important consideration, especially during daylight applications. Birders, for example, find it highly desirable to use binoculars with large depths of field in order to follow their avian targets which may suddenly flit from one tree to another. Having a binocular with a large field depth means that less vigorous focusing (or none at all) is required and that means you can spend more time enjoying and studying your subject. Field depth is far less important when using binoculars to view astronomical targets since all these objects are located at infinity, or nearly so. That's especially fortunate, as most specialist binoculars used for astronomical viewing employ high magnifications. Before leaving the subject of field depth, the above discussion did not consider near depth perception, that is, how sharp the image appears in the foreground within the closest focus distance at infinity. Field curvature can have a major impact on this and can enhance the sense of field depth of objects in the near ground. It is this near-depth perception that will probably vary most among individuals, with younger eyes experiencing the most dramatic effects owing to their enjoying greater focus accommodation.

People who have strong myopia (shortsightedness) may need greater 'beyond infinity' focus to reach a satisfactory focus with a given binocular. That's because a normal individual's position of infinity focus will not be quite enough to allow a strongly near-sighted person to achieve an adequate focus of a distant object. It's advised that such individuals always check that an object located at distance- say half a mile or more away – can be sharply focused. Furthermore, when the pupil of such an individual dilates at night, the depth of focus of his/her eyes will decrease further – requiring even more 'beyond infinity' focus to observe comfortably. For more on depth of field and depth perception, I would refer you to Holger Merlitz's *Binocular Handbook*.

Field of View

Another important binocular consideration is the field of view available for observing objects. There are various ways in which the size of the field of view can be expressed. Perhaps the most common is to use feet at 1000 yards. For example, if your binocular provides a field of view of 350 feet at 1000 yards, this means that you can view objects 350 feet across when viewed at a distance of 1000 yards. In Europe, meters at 1000 m is more commonly employed.

Astronomers prefer an alternative expression for the field of view. They use angular degrees. To convert feet at 1000 yards to angular degrees divide by 52.4. So, a binocular offering a field of view of 342 feet at 1000 yards will have an angular field of view of 342/52.4 = 6.53 degrees. Put another way for my European readers, each degree of view is equal to 17.5 m at 1000 m. When surveying the specifications of a binocular, you'll often come across the terms, Apparent Field of View (AFOV) or Apparent Angle of View (AAOV). These both refer to the same thing: the angle of the magnified field when you look through the optics. This figure is approximated by multiplying the actual field of view by the binocular's magnification. Binoculars with AFOV greater than 65° are considered "wide angle."

In general, the lower the magnification a binocular provides, the wider the field of view available. The size of the field has absolutely nothing to do with the size of the objectives used but has much more to do with the types of eyepieces employed in the design of the instrument. Over the last few decades designers have steadily increased the fields of view available, so today it's not uncommon for a typical 8×42 binocular to provide a field of view of 8 degrees or more. Throughout the golden age of the Porro prism binocular between the 1960s and 1980s Porro prism binoculars usually had much wider fields at the same magnification than the equivalent roof prism model, but in recent years the latter design has caught up, where it now offers fields of the same size or larger than current Porro prism designs.

Wide fields of view have many obvious advantages, the most important of which is the swathe of terrain that can be examined at a glance. Birders typically go for binoculars with wide fields of view because their subjects – fast moving birds – can suddenly take to flight, flitting from tree to tree. Having a wider field will allow the birder to keep the subject inside the field of view as it moves around. Wide fields are also good for scanning large areas quickly. On the other hand, higher magnification fields of view are more restricted but are often better for spotting objects at a distance. Some folk get too distracted using overly large fields and prefer to 'frame' their subjects better in a smaller field with less distractions. In the end, there is a strong personal dimension to the size of the field of view one can enjoy. And while some claim that once you go to super wide fields of view, there is no turning back, this author enjoys binoculars with fields that vary in width from 2.2 degrees right up to 9.5 degrees!

Porro Prism Binoculars

Let's now take a closer look at arguably the most familiar type of binocular recognized by the general public; the time-honored Porro prism binocular. Prior to 1960, these were practically the only type of binocular used by outdoor enthusiasts and stargazers alike. And while the roof prism models have made great strides over the decades, Porro prims binoculars are still excellent choices for modern observers.

Porro prism binoculars are much cheaper to make well compared with a roof prism model of equivalent quality. Porro prisms are of a much simpler geometrical shape than roof prisms and transmit between 12% and 15% more light through the binocular compared with entry-level roof prisms. That's because the path the light takes through the Z-shaped Porro prism system is far less complex than in a roof prism instrument. For one thing, the light moving through Porro prisms undergoes 4 reflections, whilst the roof binocular requires five such reflections. This also contributes to the Porro prism binocular delivering brighter images. By design, a roof prism requires one surface to be coated with a reflective material like aluminum, silver or modern dielectric coatings in order to reflect light through the binocular. As