Two essential tools for most bird watchers are their binoculars and a good field guide to identify the birds they see with them. After they become serious "Birders", they often leave the field guides at home, but not their binoculars. Instead, the second essential tool will be a spotting telescope for viewing more distant birds, mainly waterfowl and sandpipers, and the occasional rare sparrow perched across a field.  
  
Since they are essential tools, you need to know which kind of binoculars are best for you. And that really depends on who you are – whether you’re an experienced hard-core “Birder” who has used binoculars at least weekly (on average) for years,, with the experience and the skill to quickly find your bird in field of view before the bird flies away, or if instead you’re a casual user or a beginner, using your binoculars less frequently, or not practiced for many years. Coordination and your visual acuity will also have an impact on what you should be using.

7x35 means 7x magnification, and 35 millimeter diameter objective lenses, the larger ones in front where the light comes in. Porro prism refers to the shape, and to the type of prisms used in the binoculars. I’ll get to that.  
  
Beginners and casual users should stick with the basics – a 7x35 porro prism pair of binoculars.  
Many prominent, highly experienced ornithologists still use this kind, and won’t part with them.  
At 7x magnification, these will have a much wider field of view, making it much easier to find your bird in view before it moves.

Higher-magnifying binoculars will have a very narrow field of view, making it frustrating and much harder to find your bird. Also, the magnification isn’t only of the bird, but also of minor hand motions which make the image jump around, making hard to see details.

But many hard-core “Birders” will often want higher-magnifying binoculars, sacrificing field of view and image stability, in order to get a larger image and maybe see more small details on the birds, or to identify them from farther way. If you can get it in view. More expensive lenses are needed to resolve these extra details; economy-grade optics are adequate up to 7x magnification, but don’t reveal as much detail with 8x or 10x binoculars.

**Binoculars - shapes and lenses**

Most binoculars come in either of two shapes: porro and roof prism binoculars.



**Porro prism binoculars** are the ones with familiar shape with eyepieces offset rather than directly behind the larger objective lenses, where the light comes in. This form is heavier, bulkier, and not as durable as roof prism binoculars, nor as easily made waterproof. They often can be easily be knocked out of alignment, causing the user to see double. Handle with care.

But ..

P**orro prism binoculars offer the best optical quality for the money,** especially for economy models costing less than $100. They present a brighter, sharper, clearer image at this price range.

**Roof prism binoculars** are lighter in weight, more visually pleasing with the straight-through shape, and by their construction design, much more durable. B**ut it costs more to get good optical quality into roof prism binoculars**. Inherent optical flaws in the roof prisms do need correction, which costs money, and the cheapest models won’t have those “fixes”.

There is a **third form** of binoculars - **Galilean** type, a pair of simple "Galilean" telescopes. These telescopes have two lenses and no prism - one objective lens, and an ocular (eye piece) lens which is concave, thinner in the center, instead of convex. These are the oldest and simplest working telescope type, which work well at low magnification, but not as well at higher magnifications, such as needed for bird watching. This is what they look like:



Opera glasses are also Galilean telescopes, in miniature. Usually they magnify about 3 or 4x.

The next step up in telescopes after the Galilean type was the “Kepler” type, with convex lenses both for the objective and for the eyepiece. But this arrangement produces an upside-down, inverted image. Astronomers decided this wasn’t that important, compared to the improved image the Kepler telescopes produced, but people wanting to use telescopes to look at objects on land preferred to find a way to get the image right-side up. The purpose of the prisms in binoculars is to flip the image around, back to right-side up (or, more accurately, up-side up and right-side right). This could be done with sets of mirrors, but the air-to-glass surfaces with those multiple mirrors would reflect away and absorb some of the light. Prisms let more light come through.

**Roof prisms don’t make better images, but better lenses and better lens coatings do.**

In good light, a near-by bird with a dark background behind it will look about the same through any decent pair of binoculars.

**At 8x or higher magnifications**, especially in poor light (in shadow or backlit against a bright, glaring sky) or for tiny details on very distant objects, fancier (and more expensive) lenses produce a sharper, clearer image with tinier details resolved, and give the observer less eye strain in prolonged use. These lenses can be used in either porro prism or roof prism binoculars.

Other factors can also affect image quality, such as lens coatings (for better contrast), mirror coatings (in roof prism models, for brighter image), lens glass formula, and prism glass formula. The anti-reflective lens coatings can reduce internal reflections “washing out” dimmer portions of the image, allowing better viewing of backlit objects or seeing deeper into shadows in the bushes. All of these matter, but lens types make the most substantial difference, mainly in keeping colors focused together to reveal small details.  
  
Why do those lenses matter so much? It’s all to do with “chromatic dispersion”, the rainbow effect, causing different colors to fail to come in focus together, smearing the details in the image.  
With more lens elements, two or three colors can be brought into focus together and the other colors will remain closer to being in focus, so the image smear is smaller, and can be so small that the human eye can’t see it. But magnification makes not only the image larger, but also the smear, and also the moving image caused by minor hand tremors. And if you’re using a spotting telescope, with magnification higher than the binoculars, the smear is even larger and details can be lost altogether; the lens types become really critical at those higher magnifications.

What does "**7x35**" or "**8x42**" mean?

The number before the "X" is the magnification.

The number after the "X" is the size, in millimeters, of the objective lens which takes in the light.

The more the **magnification**, the larger the image of the bird will be, but the harder it will be to find the bird in the binoculars, and the harder it will be to hold that image steady so you can see the details. Higher magnification will also reveal the optical flaws in the cheaper classes of lenses.

The larger the **objective lens**, the more the binoculars will weigh, but the steadier they probably will be in your hands. The lightest ones, especially the miniatures with 21 to 28 mm objective lens size, are tiny and weigh next to nothing. (An inch is exactly 25.4 millimeters.) But they have a problem – they’re tiny and weigh next to nothing. With minor motions of your hands and fingers, the image will be jumping around, making hard to keep up with what you're looking at and see any details. Especially at higher magnifications. Larger objective lenses will also accommodate your expanded eye pupils for night-time star gazing. However, contrary to popular belief, larger objective lenses will not make the image brighter or sharper in day-time viewing.

**Field of View** - how much of the world in front of you is in your image. Typically measured as how many feet across you can see at a distance of 1,000 yards. This can be very important - you see a bird in a tree, bring up the binoculars and focus, and you see an image of leaves, twigs and branches…

But **which** leaves, twigs, and branches?

Which **tree**?

Where is the **bird**?

It took me years to gain enough skill to reliably find my bird, using 7x35 binoculars with a wide field-of-view. Binoculars with a narrower field, as is found at higher magnifications, make your bird much harder to find.

For beginners, casual users and visitors, using binoculars less than 2 hours per week on average, it's best to stay with 7x35 binoculars. They will be much easier to use than the higher-magnifying models with the narrow field of view.

Experienced birders will often want more magnification, and sharper, clearer details at those higher magnifications, which requires the higher-class optical lens grades for 8x and 10x binoculars.  
  
But they will need skill and coordination to use those higher-powered binoculars.

**To test** these parameters for yourself, and find the best combination of weight and magnification for your own use, you can start by attending some of the more popular bird club field trips, and try out other peoples' binoculars, comparing them with your own. Pay attention to the magnification and objective lens size (weight) while comparing. This test is mainly for finding what configuration works best for fighting the jumpy image, finding your bird, and to a lesser extent with how well you can see details on distant objects.

**The Book Test**

For a better measure of how well various models of binocular work for you in seeing small, distant details - If you can, get a good assortment of different types of binoculars to try out, set up a book, or other object with fine print, about 15-20 feet away. View the book with the binoculars and see just how far away you can put the book and still be able to read the text. No fair putting the binoculars on a non-moving surface to steady them; you won't be doing that in the field while you’re bird watching. This is to test what you can actually see in various kinds of lighting with various kinds of binoculars with different objective lens sizes, different magnifications, and different lens types, to see how well you can make out distant small details. To make the test even better, try it with difficult lighting - put the book in deep shadow or try to read it backlit against the glare of a bright sky. This should give you an idea of what configuration actually works best for you in making out fine details at a distance.

I tried this at home one day, comparing 8x42 and 10x42 roof prism binoculars, including one 8x42 model with a brighter image due to a brighter, silver mirror coating in the prisms. With that model, I could actually read fine print on a book about 15 feet away slightly better than I could with my standard 10x model (with HR aluminum mirror coatings). I believe some of that may have been due to the greater amount of jumping around of the image in the 10x model, and partly due to the brighter image. But I wasn’t expecting to actually see slightly more with the 8x binoculars.

Be that as it may, I do remain “addicted” to the slightly larger image of my 10x binoculars, even if I no longer feel certain I’m actually seeing any additional details in my viewing.

I have also similarly compared “standard” glass and “ED” glass binoculars, and found that the ED glass did allow me to more easily read text on a book, especially when comparing the two binoculars on the text in more difficult light. (Both binoculars are 10x42 models which I own.)

At a presentation with the Baltimore Bird Club in September 2013, several models of binoculars were on a table for attending people to try out on a book set up about 15-20 feet from the table. These included several economy-grade porro prism binoculars, an economy-grade pair of miniature roof prism binoculars, two mid-grade roof prism binoculars (including mine), and one premium-grade pair of Zeiss roof prism binoculars. Most of the observers felt that my mid-grade model and the Zeiss model stood out as clearly performing better than the others, although another club member said that to him they all looked about the same, and he preferred his own model primarily for how it felt in his hands. I personally also did compare my mid-grade roof prism binoculars with the premium Zeiss binoculars, and I noticed a clearer image of the letters in the book text, in the Zeiss binoculars. This test would have been better with a wider variety of different binocular types, including mid-grade porro binoculars, and with some more challenging lighting on and around the book.

* **So what’s out there?** (see more complete listing, with spec’s, later this article)

I divide the binoculars on the market into three major classes, with two sub-classes within each major class. The first major class is split by prism type, the next two are split by glass formula in the lenses.

Again, I define three major optical classes:

- **economy** ($11 - $250) : 2 + 1 , split by prism type,

2-element objective, 1-element eyepiece lenses

Good for up to 7x magnification

- **mid-grade** ($95 - $500) : 2 + 2 , split for ED glass in the lenses,

2-element objective and 2-element eyepiece lenses

Probably the best most users will ever need,

mainly used for 8x and 10x magnification

- **premium** ($900 - $2,900) : 3 + 2a , split at $1,700 for Fluoride glass in the lenses

3-element objective, 2-element aspheric/"field flattener" eyepiece lenses

Mainly for users with 20-20 or better visual acuity (as corrected)

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**Economy grade** : 2 + 1 = 2-element objective, 1-element eyepiece lenses ($11 - $250)

The group I call **economy-grade** binoculars have a 2-element "Achromatic" objective lens and simple single-element eyepiece lenses. These will produce a suitable image at magnifications of up to 7x, and passable at 8x, although the tiniest details in the image will, at 8x and up, be clearer  
in higher-grade binoculars, which come up later.

This group splits to:

- **Economy roof prism binoculars**

At the economy price range, the roof prism models won’t have the “fixes” needed to make them optically comparable to porro prisms. Even the very most expensive top-of-the-line roof prism binoculars can’t get prism performance quite up to that of porro prisms, but with money put into the “fixes”, they can get so close that the remaining difference, if any, is imperceptible to the human eye.

What about those cheap mini-sized roof prism binoculars?

Some ultra-cheap roof prism binoculars are available with objective lenses about an inch in diameter (21 to 28mm diameter - an inch is 25.4mm). They are very small and easy to stuff in a pocket and weigh and cost next to nothing. But they have a problem - they are tiny and weigh next to nothing. In your hands they don't hold steady. Larger, heavier binoculars tend to hold steadier in your hands, so the image doesn't jump around as much. This jumpy image is also a problem with higher magnification, even with the larger, heavier binoculars. Another thing to consider - cheap roof prism binoculars won't offer the optical quality of porro prism binoculars. At that price range, they won't have the "fixes" needed to deliver the bright, clear, detailed image of porro prism models.  
  
Two popular cheap roof prism models available for about $11 to $15 plus shipping from Amazon and/or Adorama are:

Tasco Essentials - the 8x21 roof prism model

Bushnell Powerview - also the 8x21 roof prism model.

At 8x and their low weight, they will have some of that jumpy image problem along with narrow field of view. But they're inexpensive, and much better than nothing. They should serve well for years as needed. They can easily be stuffed into a pocket.

Sealed, waterproof roof prism models include Tasco Sierra models, TS825D (8x25) $32 Amazon, and a full-sized 10x42 model for $44, again Amazon prices not including shipping. The sealed models should be more durable and withstand more abuse than other models which are either porro, or not waterproof, or both. The tiny 8x21 model (10x25 is also available) would serve as a pocket spare, and the full-size 10x42 would be a possible starter for a kid not yet ready to be trusted with a more expensive or fragile model. But all models at 8x or 10x magnification will have a limited field of view, not easy for a beginner to use, to find a bird before it flies away. And none of these will have the bright, clear image of the porro prism group (below).

* **Economy porro prism binoculars**

Porro prism models costing less than $100 have brighter, clearer, sharper images than do comparably-priced roof prism models. They will, however, be more bulky, fragile and easily knocked out of alignment. Handle these with care. Most models under $80 won’t be waterproof.

Two economy-grade porro 7x35 models are worthy of consideration for casual or beginning users, or for visitors to use. They have a wider field of view than most of the more expensive models with higher magnification in this article, making them much easier to use. They are the 7x35 porro prism Bushnell Falcon and the Tasco Essentials models, both about $30, March 2015 Amazon.com prices, plus shipping.

Another variation seen in porro prism miniatures places the two objectives closer together than the eyepieces. An example worthy of consideration for butterfly watching is the Pentax Papilio, which comes in 6.5x21 and 8.5x21 models. This model has an unusually close focus at less than 2 feet; the 7x35 models above get their closest focus about 15-20 feet out. The Papilios cost about $100 - $150, and will be more suitable for butterflies and other small, close objects than they would be for bird watching. These miniatures will have the jumpy image problem, more so with the 8.5x model.

Since these are porro prism models, and are not waterproof, handle with care.

To get a significant improvement over the $30 porro prism 7x35 binoculars models recommended above, requires getting models costing $80 or more, and IF you have the vision, coordination and skill to use one of these higher-powered binoculars, then I would recommend one of the sealed waterproof roof prism models, usually 8x32, 10x32, 8x42, or 10x42 models, from the higher lens classes below. If you don’t have the skill or coordination to use one of the higher-powered models, you should stick to 7x35, but you could upgrade to another model with the more expensive “BAK-4” glass formula in the prisms, which lets 15% more light through, for a brighter image.

**Mid-grade class**, 2 + 2 = 2-element objective and 2-element eyepiece lenses

The **mid-grade group** gets most of its improved performance from having 2-element "Achromatic" lenses for both objective and eyepiece lenses, for sharper details at 8x or higher magnifications, and BaK-4 formula glass in the prisms, which lets 15% more light come through. Most of these will be sealed, roof prism binoculars. Notable models here include the Wingspan roof prism 8x32 models, $91, Eagle Optics Shrike, $100 - $110, the Bushnell Natureview roof prism models, $115 - $126, and the Atlas Optics Radian, $130 - $140, all sold at Eagle Optics, prices as of Mar. 2015. For about $220, one can get a significantly better model, the new 2016 version of the Vortex Diamondback, with optical resolution perhaps as good as it gets in models costing under $600 or so. The very best "mid-grade" binoculars, at about $300 - $350, are the Monarch 5 ED models and the Zeiss Terra binoculars, with special mirrors and with ED glass in the lenses, giving them the brightest image with most intense colors among models costing under $500. Any mid-grade model (with the 2-element lenses) will, at magnifications of 8x or higher, produce a noticeably clearer, sharper image than any of the economy-grade binoculars, and even better than single-element eyepiece lens models costing up to $250. **See the optics synopsis for more up-to-date recommended models.**

The difference that improves the image is in the type of lenses, not the type of prisms. The sealed, roof prism models are preferred for their compact and durable construction, putting up with more abuse in the field than the heavier, more fragile porro prism models. At this grade and price range, they will have the “fixes” to make the roof prisms perform at a level fairly comparable to, if not fully up to, the porro prisms models.

**Image Stabilization**

Another interesting option for some people is Image-Stabilization. Some binoculars are made with an internal, battery-operated mechanism that moves the prisms to hold the image a bit more steady, compensating for minor hand movements. For viewers having trouble holding the binoculars steady enough to get a stable image, this option may really help. Most notable are models by Canon - an 8x25 model for $380, and a 10x30 model for $505. Canon also offers a more expensive 10x42 model for $1,300, which is in the premium optical class, featured later in this article.

* **Intermediate**: $500 - $900 – these models are mostly unknown to me. While they still have all 2-element lenses, the prices are higher. Probably most have more expensive lens coatings, for better viewing in difficult lighting, and the more expensive di-electric mirror coating for a brighter image. The Cornell study in fall, 2013 did rate the Monarch 7 model (about $600) better than the Monarch 5 ED (about $350); both have ED glass in the lenses and the di-electric mirror coating. The Nikon literature and the Cornell reviewers don’t say what makes the more expensive Monarch 7 model better; it’s probably better anti-reflective lens coatings, for improved contrast and visibility in difficult lighting. It might also have more field-of-view.

**The Premium Class**, 3 – 2a : 3-element objective, 2-element aspheric eyepiece lenses, priced $900 and up

This class features THREE-element objective lenses, for more uniform focus of the colors for even finer detail resolution, and two-element eyepiece lenses with special “aspheric” / “field flattener” shapes to get sharp focus across the full field of view. This produces a noticeably improved image, clearer and sharper, with even less eye strain in prolonged use, especially at the higher magnifications. According to the fall 2013 Cornell review, the Zeiss Conquest models, about $900 - $1,000, offer the best optics for models under $2,000 in price. If your vision, as corrected, is below 20-20, you might not see much, if any, improvement over the lower, less expensive lens grades. Most serious birders do settle for less pricey mid-grade models. But if your vision, as corrected, is 20-20 or better, and if you can afford one of these premium models and use it for a while, then you might not want to settle for anything less.

The next step up is a very small one in optical quality, but hikes the price to the $2,200 to $2,900 range, to get the **elite class** with the expensive **fluoride glass formula** in the lenses, for the very best optics money can buy. Elite-class models by **Leica**, **Zeiss**, and **Swarovski** are **rated about equal** for image quality by the Cornell reviewers, who also questioned whether the small improvement with the fluoride glass makes the extra price worth it. Additional details resolved by these fluoride lenses are beyond the limit of human vision. The almost imperceptible difference seen would be very slightly brighter colors, especially in difficult lighting. One new innovation, which Cornell reviewers didn’t consider important, is a higher-transparency “HT” fluoride glass formula by glass company Schott, affiliated with Zeiss. The formula, when used in the lenses, allows about 2% more light to get through the binoculars. Leica is now licensing from Schott to use the Schott glass (as they call it) in their new top-grade Ultravid-Plus and newer Noctivid series. Zeiss offers it in their Victory HT series and in their newest Victory SF series.

**Caveat**

I’m the only person I know of classifying binoculars and/or telescopes into these groups according to lens types, and naming those groupings as I do. The sales literature at manufacturers' and sellers' websites usually don't even mention lens types being used (Canon does), despite their importance. But optical test scores in the comparison studies by Bird Watchers' Digest, Birders' World, and Cornell do reveal the differences in optical performance between these groups. I do agree with the advertising literature that the lens coatings can make a big difference, primarily in seeing darker objects with bright light around them, backlit or in deep shadows. This gives the image more contrast.

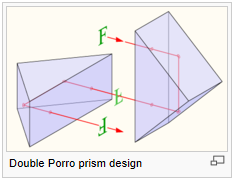
**More nuts and bolts – how things actually work**.

Three forms of prisms are used in binoculars, two of the “roof” type and one of the “porro” form.

**Porro prisms** were the first, and optically best, to be used for this purpose. They use internal, angled surfaces to act as mirrors (without the multiple air-to-glass interfaces) and reflect the light at angles four times to get the image righted. All internal reflections are 100%, and the only loss of light is in the surfaces of the prisms where light passes through air-to- glass interfaces, and inside the prisms, where, depending on the glass formula, some of the light may get absorbed by the glass itself.

Porro prism binoculars look like:

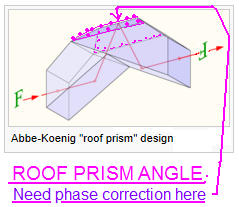


And here’s how the light goes through the porro prisms:  


Notice that the two Porro prisms shown are oriented 90 degrees apart, so they flip the light both vertically and horizontally.

**Roof prisms** come in two forms : **Abbe-Koenig** and **Schmidt-Pechan** sets. The Abbe-Koenig prisms tend to be larger and heavier, while the Schmidt-Pechan sets (of two different prisms, the Schmidt prism and the Pechan prism) come out lighter and more compact, and are more popular. The overwhelming majority of roof prism binoculars use the Schmidt-Pechan set. Both roof prism types include a “roof” –shaped surface which gives them their common name, and also a problem – at that unique split reflection surface, the two halves of the light reflecting through the “roof” get out of phase with each other, leading to a dimmer image with smudging and lack of fine detail definition. It takes a bit of money to apply a “phase correction coating” to fix this problem, and the cheapest roof-prism binoculars don’t have this “fix”.

Since it’s a bit simpler, we’ll start with the Abbe-Koenig prism, as used in one of the elite binocular models. Here’s how they’re shaped, and the path by which light goes through them:

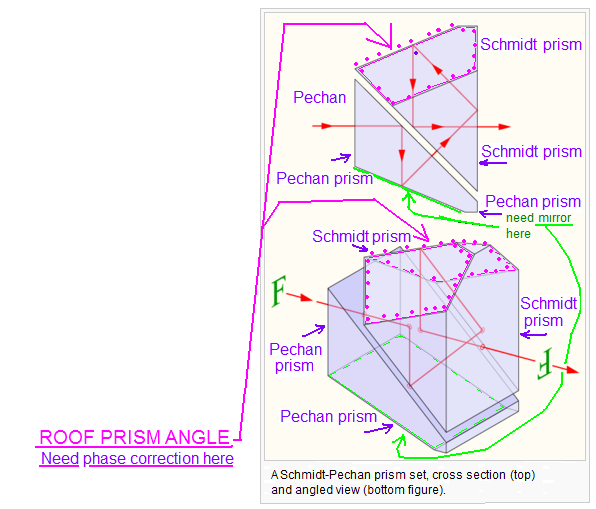


This illustration shows the “roof” surface on the top. That’s where the phase- correction coating needs to be added to fix the phase problem. As with the porro prisms, all internal reflections are 100%. Light loss is in light absorbed by the glass, and at the air-to-glass interfaces the light has to pass through. With proper phase correction, these will perform much like porro prisms.

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**Schmidt-Pechan** prism sets are a bit more complex. Two unequal prisms are used, with the Pechan prism used primarily to “feed” light into the complex Schmidt prism at a certain angle to make it work. But in doing this, the Pechan prism has to get light reflected at an angle where it would normally just pass through the glass-air interface and out of the prism instead of reflecting. A reflective mirror coating is needed at this surface to keep the light going along the proper path. A phase-correction coating is also needed at the “roof” surface on the Schmidt prism (on “top” in the illustration below), to get a clear image. The cheaper roof prism models won’t have the phase coating.

The Pechan prism, bottom in the illustrations that follow, receives the light, which goes through one normal, internal, 100% reflection, then another at an angle requiring the mirror coating, to send the light up into the Schmidt prism, above the Pechan prism in this illustration. After one internal reflection inside the Schmidt prism, it goes up to the top where the “roof” surface is, goes through that reflection needing the phase-correction coating, through another internal reflection, and out through the same surface that two steps back had reflected the light up to the “roof”. This is possible due to the angles at which the light is traveling in relation to the glass surface. As with all prisms, light loss happens with any absorbing the glass does as the light passes through it, at the air-to-glass interfaces the light travels through, a bit at the “roof” surface due to phase cancellation, and now also at the one mirror surface on the “bottom” of the Schmidt prism. See mirror coatings later in this article. The illustration below shows a cross-section of the two prisms, with the light path shown in red, and below that an illustration with an angled view, including the light path.



More on the durability of roof prism binoculars vs porro - some years ago, I purchased a sealed, waterproof porro model, Swift Ultra-Lite, but after a month or less of use, the eyepiece mounting broke, rendering the binoculars unusable. So I purchased, as a replacement, the Swift Ultra-Lite roof prism model, a “twin” to the porro model. The roof prism Ultra has proved its worth, surviving the “dog wars” – chewed up by the family dog, but still working just fine. For me, at least, it is now imperative that anything I purchase be rugged & durable, and sealed waterproof against the elements. Before the Swift Ultra’s, I owned a premium-class pair of Zeiss binoculars which, unfortunately, were NOT sealed waterproof, and over about 15 years of use, foreign material got in and ruined the view. They got to where I could hardly see through them at all, like looking through a heavy fog bank. Additionally, the focus mechanism got very stiff and hard to use, and also got out of adjustment, so the diopter adjustment to keep both eyes in focus couldn’t compensate for the large difference in focus between the two sides. I believe salt spray from some pelagic trips I took, and insect repellant spray droplets, may have done a large part of the internal damage. However, it must be noted that another bird club member with the exact same Zeiss model still has those same binoculars, and they still work fine, about 35 years after purchase. I’m just not as good at protecting my optics from damage. I also had an expensive, high-quality spotting scope by Questar, which also wasn’t sealed and which also became unusable, again fogged up by encroaching foreign material getting inside and obstructing the view, like looking through thick fog. My current binoculars and my current spotting scope are now both sealed against the elements, and I will no longer buy any that isn’t. Fortunately for klutzes like me, virtually all medium-grade and all premium-grade optical products today do come fully sealed, waterproof and fog-proof, and are designed to put up with more abuse than the older models were.

Now for some “technical” explanations, and terms and their meanings, mostly for binoculars –

**Objective lens size** – this determines how much light those objective lenses can “pull in” for the image. Popular belief has it that larger objective lenses make the image clearer and brighter, with more sharply defined details.

The actual truth is a bit more complicated –

**Exit Pupil** - The objective lens size, divided by the magnification, yields something called the “exit pupil”, which is the actual size of the shaft of light coming out of the eyepiece lenses for your eye to take in. For example, 7x35 binoculars will have 35 millimeters divided by the 7x magnification, producing an exit pupil shaft of light 5 millimeters wide. Now, in daylight conditions, your eye’s pupil will probably be dilated to about 2 – 3 millimeters. That’s how much your eyes will take in; the remainder of that 5mm shaft of light will bounce off the opaque surface of your irises and won’t get through your 3m pupils into your eyes. In fact, in broad daylight, binoculars with an exit pupil of 3mm or more will produce an image every bit as bright and detailed as binoculars with an exit pupil of 5 or 7 mm, popular belief to the contrary. This will hold up even in deep, shaded woods. But at twilight, or even more so at night-time, as your eyes adjust to the darkness, your pupils will dilate wider. A young person’s pupil may dilate as much as 7-8mm, while a middle-aged person’s pupils will probably only dilate to about 5mm. So binoculars (or telescopes) with an exit pupil of 5mm will give your eyes all they can take in, even in the darkness of night, unless your pupils can dilate wider than 5mm.

Some people use 50mm sized objective lens binoculars, but that’s probably heavier than you really need. 10x50 binoculars will produce a 5mm exit pupil, while 10x42 binoculars will have an exit pupil of 4.2mm. But that’s plenty for all but the darkest nights, and doesn’t really lose all THAT much even then. The popular 8x42mm size gets an exit pupil of 5.25mm, which is plenty. Even the 10x32 option puts out a 3.2mm exit pupil, which is plenty for day-time use. (The problem with 10x32 binoculars will be one of weight – they won’t resist hand tremors as much as larger models or models with less magnification, and the additional movement will make the image jump around, making it harder to see tiny details.)

At the darker light levels, even an unlimited exit pupil from extra-large objective lenses won’t produce a bright enough image to see colors well. If it’s too dark to see colors well without binoculars, you won’t see more colors looking through them, regardless. I know, I’ve tried.

Other arguments given for larger objective lenses is that they might have less diffraction of light around the edges, and that they can see “around” small atmospheric disturbances along the line of sight between the binoculars and the object being viewed.

The truth, as revealed in actual tests - with binoculars, with magnifications of 12x or less, there evidently is no enhancement in resolution visible to the human eye. In a Cornell study in 2013, a subjective test by observers, a statistically insignificant top optical score went to a Zeiss model with 32mm objective lenses, rather than one of the models with 42mm lenses. However, in another test by Bird Watchers Digest in (2015?), top-rated telescopes did reveal humanly visible improvements in resolution with models with larger objective lenses. This test was muddied by comparing smaller-lensed ‘scopes with lower magnification, with a larger-lensed ‘scope with higher magnification. However, the proportion of resolution improvement did exceed the proportion of difference between the magnifications, leaving a strong hint that the larger lens did actually contribute to the higher resolution score. This was comparing a ‘scope with 60x magnification and a 65mm objective lens, compared to a ‘scope with 70x magnification and a 95mm lens.

And the ‘scope manufacturers seem to believe this is real; they offer higher magnification with ‘scopes with larger lenses. Most spotting telescopes with 60 or 65mm objective lenses have their magnification topping out at 50x, while ‘scopes with objective lens size of 80mm or higher offer magnification up to 60x, and heavy 95mm models can even go up to 75x.

**Coatings**

All binoculars, even the cheapest, offer at least some **anti-reflective coatings** on at least some of the glass surfaces, to reduce light loss through reflecting when the light should be passing through the lenses and prisms. More expensive binoculars have fancier, more effective multiple-layer coatings that reflect less light. Most mid-price and high-price binoculars boast "FMC" meaning Fully Multi-Coated on all air-to-glass surfaces of lenses and prisms. Anti-reflective coatings reduce the amount of stray light bouncing around inside of the binoculars or telescope, bleeding stray light into the image. This improves contrast and color intensity, especially in difficult lighting – badly backlit objects or objects in deep, dark shadow. Low-dispersion glass in the lenses can also help with seeing slightly more color contrast.  
  
On a historical note, the Germans of World War II used roof prism binoculars, while Japan and the Allies all used porro prism binoculars. The German binoculars earned a reputation of extra high quality, making them prized souvenirs for Allied soldiers if they could get them on the battlefront in Europe. Phase-correction coatings to “fix” the roof prisms (see below) weren’t invented until 1988, so the Germans didn’t have them. What they DID have was the world's first anti-reflective binocular lens coatings, a single Magnesium Fluoride di-electric layer, discovered by accident in the 1930's to improve light transmission. This despite the published findings by England’s Lord Rayleigh in 1886 and a practical means developed in 1904 of making the coatings. The German re-invention in 1935, with refinements, was their military secret into the early part of World War II. The Allies and Japan all used porro prism binoculars without lens coatings.

Roof prism binoculars also need additional coatings on certain surfaces of their prisms to keep the light going through properly. The "roof" surfaces that give roof prisms their name need **phase correction coatings** to keep light reflecting through those two surfaces from getting out of phase with each other, interfering and getting darker and smudgy. The cheapest roof prism binoculars don't have this needed "Phase Correction" or "**P-coating**" on those surfaces. Their image will lack the detail and “definition” of better optics. Even with the P coating, they’re not perfect, but P-coatings, invented in 1988, have gradually improved to the point that top-grade P-coatings can reduce the phase problem to where human vision can no longer detect it.

Another surface on the Pechan prism, in the commonly used Schmidt-Pechan roof prism set, needs a reflective **mirror coating**, similar to the reflective coating on the mirrors in your house, to keep the light going along the path. While the mirrors in your house probably use aluminum, which reflects about 82% of the light, a more expensive silver coating can reflect 87% - 92% of the light. Stepping up in price, one can get a more expensive oxygen-free “HR” coating of either aluminum or silver – the extra steps to keep oxygen away make the metal surface brighter, reflecting about 88 – 90% for the HR process aluminum coating, or 97 – 98% with the HR process silver. A still more expensive di-electric chemical multi-coating, with alternating layers of di-electric material of high and low refractive index, up to 64 or 70 carefully placed layers, can reflect over 99% of light across the visible spectrum. For a price. Note that these mirror coatings are for Schmidt-Pechan roof prism binoculars only; porro prisms and Abbe-Koenig roof prisms already reflect 100% of the light at all reflecting surfaces and don’t need a mirror coating, and the porro prisms don’t need a phase correction coating either. All of them can still use the anti-reflective coatings where the light passes through air-glass interface surfaces.

All of these various coatings are used to increase the light transmission efficiency of the binoculars and reduce stray light reflections inside, to yield a brighter, clearer image with better contrast. More money will usually get better coatings and better contrast.

**Prism glass** - BK7 glass versus BaK-4 formula glass, and clear optical plastic

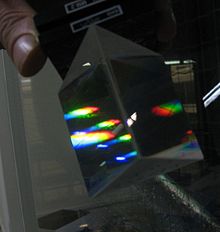
Another factor that affects how much light comes through the binoculars is the formula of glass used in the prisms. BaK-4 glass (Barium Crown formula no. 4) is more transparent (99+% in the prisms), but more expensive, than is BK-7 (Boron Crown formula no. 7) glass in the prisms (85 - 90%). So the more expensive BaK-4 glass in the prisms will yield a visibly brighter image, while the cheaper BK-7 glass will absorb about 15% of the light passing through. This is true for both porro prism and roof prism binoculars. Due to the shorter light path in the lenses, BaK-4 glass generally won't be used in lenses, just in the prisms, which have a longer distance of travel for the light going through them. Except for special low-dispersion formulas, most high grade lenses used in quality optical equipment are made with BK-7 glass. Eye glasses, due to the very short distance going through the single lens to the eye, can even use clear plastic, which absorbs more light than glass does, but weighs much less. For the longer light path through binocular prisms, the amount of light absorbed by clear plastic would be much more significant, making it impractical for plastic to be used in prisms or multiple sets of lenses in quality telescopes or binoculars.

**Eye Relief** – distance from the eyepiece lens surface to the optimal position for your eyes.

If you don’t wear glasses, a short Eye Relief is best, but most quality binoculars offer adjustable  
eye cups which can extend to hold the binoculars at the correct distance for eyes without glasses, while allowing the eyecups to retract if you are wearing glasses, so that your eyes will still be about the right distance from the eyepiece lenses. Generally, eye relief, as measured in millimeters distance between the eyepiece lens and the optimal spot for your eyes, is best at about 16 to 20mm, to allow your eyes to be properly positioned when wearing glasses; the eyecups can be extended to that same distance if you’re not wearing glasses, to keep your eyes at the right distance.  
If you don’t wear glasses, then eye relief isn’t very important; a shorter eye relief just means the eyecups will extend a shorter distance to keep your eyes in proper position, but that also means that, when wearing glasses, your eyes will be a bit too far out, and you’ll get a limited field of view, with the outer edges cut off by a ring of darkness around the outer part of the image. (If your eyes are too close, there’s a dark blur in the center of the image, right where you most want to see!)

**Chromatic Dispersion**

Most of you have, in school or elsewhere, seen the example of the visible light spectrum of colors as produced by rainbows and also with glass prisms which break up white light into the colors that it contains, spread out (“dispersed”) by the prism or rain droplets to show the colors therein. This is fine for prisms used for that purpose, but all transparent surfaces where light comes in at an angle do the same thing, to variable amounts, with their incoming light. This includes the glass lenses in the binoculars and telescopes. It causes light of different colors to fail to come to a focus at the same place, a problem when you want a full color, clear, sharp image.



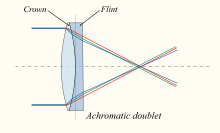
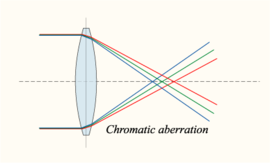
Images of prism and “rainbow” of colors – and on right, white lights seen through a prism with colors smeared by the dispersion.

**MULTIPLE-ELEMENT LENSES**

A partial fix for chromatic dispersion is the use of two-element "Achromatic" lenses, which have glass of two different formulas in them, compensating for this color "dispersion" and bringing two colors into the same focus. I believe all binoculars and telescopes offered for sale at all prices use 2-element achromatic (or better) objective lenses, and mid-priced and high-priced 'scopes and binoculars have achromatic or better (see below) eyepiece lenses also. Sometimes this 2-element lens is called the Kellner lens, named for its inventor.

With a simple single-element lens, colors don’t focus at the same point. Rainbow effect.

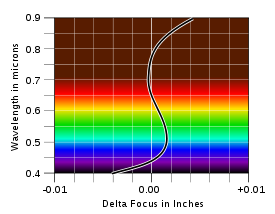
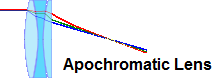
A two-element “Achromatic” lens partially fixes the problem.



The two-element “Achromatic” lens can focus two colors at the same point, typically red and blue, leaving the other colors like yellow, green and purple a bit off.

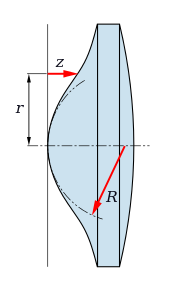
Yet another step in cost and refinement is the “Apochromatic” lens, with **three** elements,

each with differing dispersion properties, used to focus three colors of light onto the same focal point. Colors other than those three will also be closer to being in-focus along with the three which are fully in focus. Premium-class telescopes and binoculars (over $1,000) generally have apochromatic, 3-element objective lenses.



**"Aspheric" lens elements**

Another problem with refractive lenses is a geometric aberration in the way the light is bent, due to the varying thickness of the lens at different parts, thicker in the center and thinner out towards the edges. This leads to images being a bit out of focus on the outer edges of the field of view. Some optical manufacturers make special "**aspheric**" lenses, also called “**Field Flattener”** lenses, of complicated shapes to try to compensate for these effects and bring the outer part of the field of view into clearer, sharper focus, for a more uniform clarity across the full field of view. They try to make the image "flatter", more precisely focused across the full width of the image, not just in the center. This does introduce a “coke bottle” effect which bends the sides of the image a bit, more noticeable at lower magnifications than at higher magnifications. I’ve seen this with the premium Zeiss binoculars I used to have, and in a pair of Swarovski premium-class binoculars I tried out. I consider it a fully acceptable trade-off for the clarity of the image presented.



Premium-class binoculars and telescopes (“premium” and “elite” groups in this article) use a three-element “Apochromatic” objective lens to reduce color dispersion smears and reveal smaller details in the image, and 2-element eyepiece lenses with the “field flattener” / “Aspheric” shapes, for focus uniformity across the field of view. This produces a noticeably better image with more clarity, sharp edge-to-edge detail, and less eye strain for the observer when using the optics for extended periods of time. The higher the magnification, the more the image is improved with these optics.

**Special extra-low dispersion glass formulas**

Another, additional partial solution is to use a more expensive formula of glass called "low dispersion" glass, or XP, “HD”, ED, XD, or FL or HT glass. The various low-dispersion formulas differ in cost and effectiveness in reducing chromatic dispersion. These lenses use the low-dispersion formula glass in the main part of the lens. They still are multiple-element lenses (see above), to focus more than one color at a time. Note that the “HD” label in some sales literature is actually quite vague, since it can refer to ED glass with top-grade anti-reflective coatings, or to a fluoride glass formula. ED glass comes in the original Schotz ED formula, or a slightly lower-grade, cheaper Hoya formula used by Chinese manufacturers. And the “ED” glass in the mid-grade Vanguard Endeavor ED II and ED IV binoculars is actually a higher-grade XD-class formula glass. Fluoride (FL) glass, the highest-performing formula, has been with us in apochromatic lenses since 1963, and is still very expensive. The newer HT formula, a special variety of fluoride glass, appeared in 2013, and is even more expensive. Lenses with fluoride ion formula glass steps premium class binoculars up to the top elite class, and doubles their price. The new ‘HT’ Schott formula is a type of fluoride glass with a higher transparency than other fluoride glass formulas, letting about 2% more light through. This is featured in the new Zeiss “HT” and “SF” lines and the Leica Ultravid-Plus and Noctivid lines.   
  
The effects of these extra-low dispersion formulas show up as brighter colors, more sharply focused images (resolution), and enhanced contrast. Better lens coatings also enhance contrast (for seeing into shadows or backlit objects), but not the resolution of tiny details.  
  
**Other optical aberrations**While chromatic aberration, preventing different colors from coming into focus together, dominates resolution problems for tiny details under high magnifications, other forms of optical aberrations also occur. One is called “pin-cushioning”. Just have a look at a good night sky with binoculars – after going “ooh” and “ah” at how many more stars you can see than with your unaided eye, notice the shapes. You’ll see little wispy projections or “points” going out at various angles. Those aren’t really in the stars, they’re optical aberrations produced by the lenses, called “pin-cushioning”. The stars should actually look like you see them with your eyes – just tiny points of light without shape or projections of any kind. Higher-priced optics will reduce these various forms of optical aberration more effectively than cheaper optics.

Most of these aberration problems, and some of their partial solutions, have been with us for centuries, addressed by astronomers wanting to get wide-field photos of the night sky without distortion or loss of focus across their photographic films. Some of the low-dispersion glass formulas have been around at least since the 1930's, while others, especially the new top-of-the-line FL and HT formulas with fluorine ions in the glass, are newer. The introduction of ED and FL glass types into binoculars and spotting telescopes for bird watching is relatively new and still very expensive.

**SPOTTING TELESCOPES**

A recent innovation in **spotting telescopes** has been the introduction of the **angled eyepiece**. This is mostly useful for having a ‘scope set up on a tripod when observers of varying heights want to look through the ‘scope. Taller observers can simply bend a little lower to view through the angled eyepiece, while shorter observers stand up straight and look through. With a straight-through ‘scope, taller observers have to awkwardly hunch down to look through a ‘scope if it’s low enough for the shorter observers to see through.



Straight –through and angled spotting telescopes

'Scopes also offer zoom eyepieces, very useful for scanning through a group of birds at a lower magnification, then zooming in on one particular bird for a closer look.

With their higher magnification, spotting ‘scopes really need the better lenses to reveal small details on distant birds, which is what the ‘scopes are for.

Some cheap ‘scopes are available with economy-class optics, including single-element eyepiece lenses, but at the higher magnifications used with spotting ‘scopes, they are almost useless. One can see more details on distant birds with a decent pair of binoculars, and almost no detail at all with the cheap ‘scope.

The Alpen 788, $415 (Amazon, Mar. 2015), which I own, and the Nikon Prostaff, $600, with ED glass for brighter colors, are models with all 2-element lenses, and are good for viewing birds out to about 50 - 75 yards distance. At that range, they get an image which usually seems to be about as good as that of the top-grade 'scopes. These both use 2-element lenses. But for greater distances or for the tiniest details on distant, small birds, a more expensive 'scope is needed. For steps up, a Bird Watchers Digest article in 2009 recommends the Vortex Viper, about $900, and then the Vortex Razor, about $1,600 at Eagle Optics, for entry level into the premium class with 3-element objective lens and field-flattener eyepiece lenses. Bird Watchers Digest reviewers considered this Razor model almost as good as the top-of-the-line elite models. Then, for still more distant or smaller details, step up to those top-of-the-line elite fluoride glass models by Swarovski, Leica, Nikon (Fieldscope), Zeiss and Kowa, costing about $2,600 to $4,000 (Eagle Optics, Adorama, sportoptics.com). These top five are roughly tied in optical quality, and all but the Nikon model do so with the expensive fluoride formula glass in the lenses. (Leica and Kowa actually use fluorite mineral crystal.) Both 65mm and 80mm lens models are popular, but the larger 80mm models usually come with higher magnification available. Scores suggest there \*might\* be a tiny optical advantage with the Swarovski and Kowa models, but that's a matter of opinion among the reviewers. And the 95mm objective size Zeiss Diascope and a similar Swarovski model can zoom up to 75x, while the 80mm scopes stop at 60x. (60x and 75x - same ratio as 8x and 10x binoculars). The higher-priced ‘scopes can make out smaller details at greater distances, which is what a 'scope is for.

**So what's out there now?**

There are plenty more models than I show in my listings; those I do show have been chosen because I’ve seen reviews indicating that they probably are of good quality for the price; other brands and models not shown either got poor reviews for the price, or simply did not appear in any of the comparison review articles I’ve read, and therefore are of quality unknown to me. The majority of the mid-grade roof prism models use all 2-element lenses, having basically the same design, and are probably very similar in quality. They will vary mostly by mirror coatings or lens glass formula, or by the anti-reflective coatings on air-to-glass surfaces, or other factors.

**ECONOMY ROOF PRISM BINOCULARS**

These are economy-class, with single-element eyepiece lenses and no phase coatings. I list two ultra cheap roof prism mini’s which are NOT waterproof and one that is. (The funny-looking font appearing below is used to keep columns straight; the Garamond font used through most of this article won’t line up columns properly.) Prices as of March, 2015, mostly Amazon or Adorama internet websites.

“FoV” = Field of View; “relief” = eye relief, “focus” = close focus distance

\*Tasco Essentials 165RB

size price FoV relief focus weight

8x21 $11 383' 6.6 oz $10.50 Adorama

4 stars 121(!) reviews, a best seller at Adorama

\*Bushnell Powerview

size price FoV relief focus weight

8x21 $12 378' 10mm 21 ft 6.9 oz $12 Adorama

4 stars 291(!) reviews, best seller at Adorama

The following two are waterproof models available for a bit more, and being roof prism models they will tolerate more abuse than the more fragile porro prism models in the economy class.

Tasco Sierra TS825D

size price FoV relief focus weight

8x25 $17 350' 15mm 6.5 ft 11.7 oz $32 Adorama

Tasco Sierra TS 1042D

10x42 $44 293' 15mm 6.05 ft 25.0 oz $44 Adorama

I don’t recommend 10x miniature models, which are available for sale, because the image will jump around too much to make out much detail in the image. If you want a miniature, I’d limit the magnification to 8x or less. A miniature with 5x, 6x or 7x magnification, if available, would be much better.

One club member reports that his best-selling Bushnell Powerview 8x21 (not waterproof),

listed above, did not deliver the “definition”, i.e. fine focused details,

of his newer $250 Nikon Monarch full-size binoculars (a recommended mid-grade model).

Waterproof roof prism binoculars are more durable than porro prism models and will tolerate more abuse in the field. However, none of these economy roof models listed above can match the image quality of the recommended economy 7x35 porro prism models listed in the next group below. These cheap mini's might, however, be somewhat useful as pocket-size spares, and as starters for kids who can play with them and possibly learn to be more responsible, and "graduate", as they get older, to better binoculars, like the two $30 porro prisms models listed below.

Sort of example: as a kid, I owned a very poor quality "Space Telescope" gotten through a cereal box offer - a Galilean type telescope, 12x19mm, no sharp focus, couldn't resolve moon craters, but I thought it was the most wonderful possession I ever had as a kid. The color fringes (chromatic abberation) around the edges were a big bonus. For me, it was the most "Wonderful Toy" above all others, ever. I actually still have it as a sentimental relic from my childhood. It’s useless for serious viewing of much of anything, but it was such a wonder for me when I was a kid.  
  
**ECONOMY PORRO PRISM BINOCULARS**

The two following are **porro prism, not waterproof** but probably the best choice of the bunch, especially for beginners and casual users. None of the cheap roof prism binoculars can match these in optical quality, unless they cost $80 or more, which is entry price into the Mid-Priced group which does have significantly better optics and image at higher magnifications. These are still economy class models, with 2-element objective and single-element eyepiece lenses.

“FoV” = Field of View; “relief” = eye relief, “focus” = close focus distance

The first series of models below are economical, but not waterproof.

\*\*Bushnell Falcon

size price FoV relief focus weight

7x35 $23 420' 12mm 20 ft 21 oz $23 Amazon

4.5 out of 5 stars, 82 Amazon customer reviews

\*\*Tasco Essentials Zip

size price FoV relief focus weight

7x35 $30 500' 22.4 oz $24 Amazon

4.5 out of 5 stars, 21 Amazon customer reviews

- widest field of view of any binoculars in this listing

It may be possible to upgrade from these economy porro prism binoculars and go to waterproof models with BaK-4 glass in the prisms, producing a brighter image. There are some more expensive porro binoculars which are advertised as shock resistant and waterproof.

Nikon Aculon porro

rubber armored, BaK-4 prism glass, but NOT WATERPROOF, claims to have

“aspheric field flattener lens elements” .

“FoV” = Field of View; “relief” = eye relief, “focus” = close focus distance

size FoV relief focus weight price

7x35 488 11.8 mm 16.4 ft 24.2 oz $74.95 Amazon

8x42 420 12 mm 16.4 ft 26.6 oz $75.80 Amazon

10x42 315 11.6 mm 16.4 ft 26.8 oz $83.69 Amazon  
 The Cornell review clearly shows the optics of the above Aculons to be typical for the economy class, not up to mid-grade class optical level, despite the aspherics. They will sport the brighter image of models with BAK-4 glass in the prisms.

**THE FOLLOWING PORRO PRISM MODELS ARE WATERPROOF AND HAVE THE CLEARER BAK-4 GLASS IN THE PRISMS FOR A BRIGHTER IMAGE.**

Leupold BX-1 Yosemite waterproof Porro with BAK-4 prism glass

size FoV relief focus weight price supplier best price

6x30 420' 18.5 mm 15.7 ft 17.0 oz $83.00 Adorama

8x30 389' 15.5 mm 10.0 ft 17.0 oz $94.95 Adorama

10x30 11.0 ft 17.0 oz $110.00 Amazon

Leupold BX-1 Rogue waterproof Porro with BAK-4 prism glass

size FoV relief focus weight price supplier best price

8x42 341' 16.5 mm 24.0 ft 18.5 oz $139.95 Adorama

10x42 304’ 21.0 ft 24.2 oz $134.95 Adorama

Vortex Fury 6.5 x 32 - apparently discontinued; not on Eagle site.

Closest equivalent is:

Vortex Raptor - O-ring sealed, nitrogen filled, fog proof,

waterproof, BaK-4 glass porro prisms, rubber armored.

size FoV relief focus weight price supplier best price

6.5x32 410' 20 mm 15 ft 17.3 oz $95.00 Eagle Optics

8.5x32 $100.00 Eagle Optics

Note that the $83 6.5x32 model, waterproof with BAK-4 prism glass for brighter image, could be a possible upgrade from the economy 7x35 models listed earlier in this list.

These models carry a price which would better fit for models in the mid-grade group with all 2-element lenses (including eyepiece lenses), but these have only single-element eyepiece lenses, as revealed in optical scores in the comparison studies. The money is probably going mostly into waterproofing these porro prism models (more expensive than waterproofing roof prism models). The 6.5x model probably won’t suffer from the single-element eyepiece lenses, due to the lower magnification. The sales literature of most binoculars does not specify lens types, which make such an impact on optic performance at higher magnifications.

The older Vortex Fury model was recommended by Wayne Mones on the Audubon website, from personal use.

**BACK TO ONE MODEL WHICH IS NOT WATERPROOF, BUT ..**

Pentax Papilio and Papilio II **ultra-close focus for butterfly watchers**

6.5 x 21 or 8.5 x 21 porro prism binoculars with unique mechanism to compensate for parallax

at the **1.6 ft ultra-close focus** and aspheric lens elements. Pentax says the aspherics are critical for compact binoculars. These ARE mini's, and the 8.5x models will suffer from the jumpy image problem. They are very light weight, and easily fit into a pocket. The eyepieces move for focus; these are NOT waterproof. The Papilio models were designed, and named, for butterfly watching.

These do have BAK-4 glass in the prisms, for an even brighter image in full daylight conditions than most of the economy and mid-grade binoculars do. Most butterfly watching is done in full daylight in open areas with flowers attracting the butterflies, so dim light viewing conditions aren't very important in this use. For bird watchers, birds in the deep woods near dawn or twilight would still be harder to see, due to the small exit pupil. Being mini's, the 6.5x models have an exit pupil of 3.23, and the 8.5x model exit pupil is 2.47, both of which require full daylight for the image to be fully as bright as what you can see with larger binoculars. But larger binocular models don't offer the ultra-close focus of the Papilio. These are not waterproof; they use a special mechanism to move the eyepieces and keep them tracking with the objectives at this extreme close range. Note that these models are mini’s, and the 8.5x model may have the jumpy image problem.

bright = relative brightness ; might reflect transmission performance

“FoV” = Field of View; “relief” = eye relief, “focus” = close focus distance

FoV eye close bright weight price

Papilio II 6.5x21 393 15 1.6' 10.2 $100 - $130 Adorama 2/17/15

Papilio II 8.5x21 315 15 1.65' 6.3 10.2 $130 - $150 Adorama 2/17/15

* - - - - - - -

\*\* The following Nikon Action Extreme EX porro prism series is

nitrogen-purged & sealed waterproof, and claims to be shock resistant.

These Nikon models are waterproof and do have BaK-4 glass in their porro prisms. Optic scores from the comparison study in 2005 are well below scores for the mid-grade group (with 2-element eyepiece lenses), so they evidently are still using single-element eyepiece lenses, despite the price. And as Porro models, they are bulkier and heavier than roof prism binoculars of the same objective lens size.

Nikon Action EX price

size FoV relief focus weight price supplier best price

7x35 489' 17.3 mm 16.4 ft 28.2 oz $122 Adorama

8x40 429' 17.2 mm 16.4 ft 30.2 oz $129 Adorama

10x50 341' 17.2 mm 23 ft 35.8 oz $166 Adorama -

One of our bird club members uses the Action 10x50's. I haven't tried them myself.

At these prices, one can do much better by buying a model from the next group up, Mid-grade, with two-element “Achromatic” lenses throughout, not just in the objective lenses, for sharper, more detailed images at 8x and higher magnifications. But the 7x35 model has the BAK-4 glass in the prisms for the brighter image, and is also waterproof and somewhat shock resistant.

**THE MID-GRADE GROUP BINOCULARS, $90 - $500 (and up)**

Mostly sealed roof prism binoculars, a couple of sealed porro prism models also here

This class of binoculars features 2-element achromatic lenses throughout, BaK-4 glass in the prisms, and in roof prism models, phase corrective coating on the "roof" surface of the Schmidt prism and a mirror coating where it’s needed on one of the Pechan prism surfaces.

I personally recommend that anyone contemplating spending $90 or more should consider purchasing a model from this group (or higher), due to the higher optical performance and the more durable construction, protecting your investment in the optics. Among birders gathered in the field, either for rare birds or on field trips, the majority of binoculars in use belong to this group, which hits the “sweet spot” of near-perfection and reasonable price. Lesser numbers of birders are still using economy-grade models, mostly porro prism, while a still lower percentage are using the more costly premium or elite-grade models.

Most roof prism models in this mid-grade group use an aluminum mirror on the surface of the Schmidt prism, same as in the mirrors in your home. The Swift Ultras, Alpen, and some others enhance the aluminum coating with an "HR process" keeping oxygen out, for a brighter surface. Older Eagle Optics Rangers and the Atlas Intrepid ED models used a more expensive silver coating for a still brighter surface. The newest Eagle Optics Rangers and Monarch models step up to a di-electric mirror coating for 99% plus reflectivity, brightest available, previously only found in premium-grade or elite-grade binoculars. These two models previously used silver coatings; probably the increasing market price of the precious metal made the upgrade to the di-electric coatings feasible.

In the Baltimore Bird Club demo and talk at Cyburn, September 2013, the mid-grade roof prism binoculars on the table clearly did out-perform economy porro prism binoculars in image quality, according to the people who tried them out and compared them.

In that tryout, I also noticed a smaller step up in image quality and clarity from the mid-grade to the premium-class Zeiss binoculars on the table, despite the fact that they were older than most of the other binoculars on the table, and didn't have any of the fancy ultra-low dispersion glass formula in the lenses as used in today's premium and elite class binoculars.

Considering what I've seen in several models, I suspect that most of the mid-grade binoculars actually are fairly similar in optical quality, probably because they are all of the same basic design, with Schmidt-Pechan roof prisms using the BAK-4 glass formula and phase correction coatings, and 2-element achromatic lenses for both eyepiece and objective lenses, differing slightly in brightness of the image, due to the type of mirror coating, the anti-reflective coatings on air-to-glass surfaces, or in some cases an improved glass formula with lower color dispersion in the lenses. According to actual comparison reviews, the lens glass formula doesn't always guarantee better optical performance.

There are also some sealed, waterproof porro prism binoculars with BaK-4 glass in the prisms, including the Swift Audubon series (with one roof prism model added among them). Swift Ultra previously included some porro models. (I bought one and subsequently broke it.)

The waterproof porro's are bulkier and heavier than roof prism models of the same objective lens size, and are more fragile. None of the porro models need or use a mirror coating or a phase correction coating on their prisms.

The following are about the cheapest in mid-grade roof prism models, but have major endorsing recommendations and are known as true quality waterproof binoculars.

“New” to the market are the Wingspan series from Polaris Optics, which claims a new manufacturing process enables them to put out more quality at lower prices.  
Most of their models are actually marketed as a series of “different” models marketed slightly differently but identical in optics and price.

"FeatherView" and "WingSight" in black, and "GoHawk" in gray/teal color

Wingspan "FeatherView", “WingSight”, “GoHawk” 8x32  
 size price FoV relief focus weight source

8x32 $91.73 414 16.3 6 ft 20 oz Amazon

“WingCatcher” in black, “NaturePro” in gray/teal

size price FoV relief focus weight source

8x42 $130 430 17.2 6 ft 20 oz Amazon

The Eagle Optics Shrike ($100-$110) was rated least expensive waterproof, quality binoculars by a couple who write for Bird Watchers Digest, who also conducted one of the major comparison studies and ratings of binoculars in medium and high-price categories - but this model does have below average field of view. They did also score below average for the mid-grade group in optical quality (at a lower-than-average price) in the Cornell comparison study (fall 2013).

“FoV” = Field of View; “relief” = eye relief, “focus” = close focus distance

Eagle Optics Shrike

size price FoV relief focus weight

8x42 $100 341' 17.6mm 13.1 ft 23.2 oz $100 Eagle Optics

- 5 stars 18 reviews Eagle customers

10x42 $110 304' 13.6mm 13.1 ft 22.4 oz $110 Eagle Optics

- 5 stars 5 reviews Eagle customers

The Atlas Optics Radian ($130-$140) was rated least expensive binoculars recommended for bird watching by the staff at Eagle Optics internet store, overlooking their own store-brand Shrike recommended above by Bird Watchers Digest, and the Radian does have closer focus and a slightly wider field of view than the Shrike has, for an extra $30. Rated average for the mid-price group in optical quality in the newest Cornell review. And a bargain at the price.

Atlas Optics Radian

size price FoV relief focus weight

8x42 $130 375' 17.5mm 6.5 ft 23.0 oz $130 Eagle Optics

- 5 stars 36 reviews Eagle customers

10x42 $140 305' 15.5 mm 6.5 ft 23.0 oz $140 Eagle Optics

- 5 stars 23 reviews Eagle customers

Bushnell Nature View - most Nature View models are unsealed porro prism models, but the three models I list below are sealed roof prism models with rubber armor.

These should be competitive with the Shrike and Radian models above, both in price and quality.

Note the much better close focus with the 8x models and field of view better than either the Shrike or the Radian for all three models. The Radian, not the Nature View, has the closest focus among these three lines for the 10x binoculars.

Bushnell Nature View

size price FoV relief focus weight

8x32 $ 91 393' 16.6 mm 5 ft 16 oz $ 78 Adorama

- bargain for mid-grade binoc's

8x42 $102 393' 17.5 mm 5 ft 23.1 oz $ 94 Adorama

10x42 $118 325’ 15.2 mm 13 ft 22.4 oz $120 Adorama

Here are some more models of mid-grade roof prism binoculars, gradually working up in price:

Leupold BX-2 Acadia

size FoV relief focus weight best price and where

8x32 394' 5.0 ft 18 oz $145 Amazon

10x32 288' 5.0 ft $156 Amazon

8x42 394' 15.5mm 7.5 ft 23.1 oz $184 Amazon

10x42 368' 15.5mm 9.0 ft 23.5 oz $215 Amazon

Leupold - I have some confusion with their "Cascades" and "Acadia" model lines. Their website implies that the more expensive "Cascades" have rubber armor and the "Acadia" does not, but sites like Amazon and Adorama put some question to that. The website does not otherwise specify any obvious difference between "Acadia" and "Cascades" models, but the spec's and prices differ, and the Acadia models have closer focus than the more expensive Cascades.

My sister-in-law has the Leupold BX-2 Acadia 10x42 model, and they seemed OK to me when I looked through them. My Swift Ultra's were slightly brighter; I believe the Ultras have HR process aluminum mirror coating; the Leupold probably has the standard aluminum mirror without the extra HR process brightening. I did notice one awkward feature in the Leupold Acadia model - instead of a stiff rotating eyepiece for bringing both eyes to focus together, this model uses a lever next to the regular focus knob for bringing both eyes to focus, and it’s easily dislodged, requiring more frequent adjustment to get proper focus alignment. Both models have BaK-4 glass roof prisms. Either one would do fine for birding, no complaint. This is very probably true for almost any of the mid-grade roof prism models offered for sale by all makers; the basic design is the same, even though slight differences do show up in the field of view, eye relief, close focus and weight. Optics score differences in the studies may have been due to the brighter image with models with better mirrors, or better anti-reflective lens coatings, or perhaps the formula of glass in the lenses. Some models at the end of this list of mid-grade models feature ED glass lenses for brighter colors.

continuing with more models with higher prices -

Bushnell Legend Ultra HD series - rubber armored, "extra-low dispersion", "ED Prime Glass" objective lenses (similar to Alpen Apex XP?). Year 2009 upgrades to objective lens glass formula, more Field of View at cost of less eye relief. Magnesium body, and improved antireflective lens multi-coatings.

These were rated bottom of the group optically in the 2011 comparison review by Bird Watchers Digest, despite the improved glass formula and improved antireflective coatings. But they’re still recommended by Wayne Mones on the Audubon website. This reinforces my impression that virtually all mid-grade roof prism binoculars should be good for bird watching and meet with his (and my) approval.

“FoV” = Field of View; “relief” = eye relief, “focus” = close focus distance

Bushnell Legend Ultra HD series

size FoV relief focus weight price & where

8x36 426' 15.4 mm 6.2 ft 20.7 oz $192 Amazon

10x36 341' 15.4 mm 6.2 ft 20.7 oz $289 Adorama

8x42 420' 17 mm 6.5 ft 22.4 oz $200 Amazon

10x42 340' 15.2 mm 6.5 ft 24.7 oz $204 Amazon

Vortex Diamondback (before new 2016 model)

size FoV relief focus weight price & where

8x32 420' 10 mm 5.3 ft 18.4 oz $190 Eagle Optics

10x32 420' 10 mm 5.3 ft 18.4 oz $200 Eagle Optics

8x42 420' 18.0 mm 4.5 ft 25.2 oz $220 Eagle Optics

10x42 345' 16 mm 5 ft 24.4 oz $230 Eagle Optics

Vortex new 2016 Diamondback model

size FoV relief focus weight price & where

8x32 426' 15.6 mm **2.4 ft** 15.5 oz $185 Eagle Optics

10x32 340' 13.6 mm  **2.4 ft** 15.4 oz $

8x42 393' 17 mm 5.0 ft 21.8 oz $220 Eagle Optics

10x42 330' 15 mm 6.7 ft 21.4 oz $230 Eagle Optics

the new BWD study in 2016 rated optical resolution of the 8x42 model

as even better than the $300 Monarch 5 ED model recommended below

in a study comparison of 13 8x42 models by 10 manufacturers.

And the two 32mm models rival the Pentax Papilio for ultra-close focus

"Wild Bird Centers" (store brand, manufacturer unknown, possibly Alpen?)

size price FoV relief focus weight best price and where

8x42 no specs $240 (2013) at the Wild Bird Center store

10x42 no specs $250 (2013) bird club member Kevin Graff loved his 10x WBC's.

and, for a bit more, the best in my under $500 group:

- - - NIKON MONARCH BINOCULARS - - -

these are the standard to compare with other mid-grade binoculars.

Nikon Monarch 3

size FoV relief focus weight best price 11/27/13

8x42 330' 24.1 9.8 ft 24.7 oz $227

Nikon Monarch 5 - see the ED group, below

Nikon Monarch ATB

size FoV relief focus weight best price 11/27/13

8x42 330' 19.6 8.2 ft 21.5 oz $297

10x42 299' 17.4 9.8 ft 24.7 oz $247

Nikon Monarch ATB (WA)

size FoV relief focus weight best price 11/27/13

10x42 314' 15.5 8.2 ft 21.1 oz $327

Nikon Monarchs come in a confusing variety of models of various vintages and prices.  
 Models include :

Monarch 3, -DCF, (silver mirror), (discontinued models still in stock)

Monarch 5, -ATB, and -7 models (dielectric mirror)

Monarch ATB has wide angle and extra light weight, no ED glass mentioned in the advertising literature.

Monarch 7 has ED glass, rubber-armored, "super" lens and prism antireflective coatings.

$477 at Adorama. No mention in the 7's advertising blurb about "apochromat" or "field flattener" lenses. I believe those features are reserved for the premium class (and premium priced) Nikon EDG models.

One club member tried several models including the $300 Eagle Optics Ranger SRT (see below) and decided his favorite was a Monarch model. But now he currently uses a much more expensive premium-class model.

Alpen Apex XP (model numbers in the 600’s series)

size FoV relief focus weight best price 11/27/13

8x32 340' 16mm 4 ft 19 oz $269.10 Amazon

10x32 314' 16mm 4 ft 19 oz $279 Amazon , $310 Adorama

8x42 341’ 20mm 5.0 ft 22 oz $287.10 Amazon , $319 Adorama

10x42 315' 16mm 5.0 ft 22 oz $315 Amazon , $350 Adorama

The Alpen Apex earlier model 493 (8x42) was rated slightly below average optically in the Bird Watchers Digest comparison in 2007, but the newer Apex XP model 693 (8x42) scored near the top, well above most others, including Monarch, in the 2011 reviews.

The published field of view, eye relief, and close focus spec’s remain the same as for the older 400-series models (8x42 was 493). One source reported the upgrade was in improved anti-reflective lens coatings (for better viewing in difficult lighting) and in diopter adjustment range for distance between the eyes of the observer (which wouldn’t affect optical quality).

Eagle Optics Ranger - now uses di-electric coating (99% reflectivity), not aluminum or silver (92 - 98% reflectivity), for the mirror. The older Ranger SRT used a silver mirror. Ranger also comes with a model featuring ED glass, but costs more than the four ED model lines featured later in this listing.

Eagle Optics Ranger

size FoV relief focus weight best price

8x42 341' 19.5mm 5.2 ft 22 oz $300 at Eagle Optics

- 5 stars 202 reviews by Eagle customers

10x42 314' 16 mm 5.2 ft 21.6 oz $309.99 Eagle Optics

- 5 stars 102 reviews by Eagle customers

- The older Ranger SRT (silver mirror) is the high quality 8x binocular that (barely) beat my Swift Ultra 10x in fine details seen reading fine print at 15 ft distance, mainly due to slightly brighter image with higher contrast. They now use an even brighter di-electric mirror coating, brighter than the standard aluminum mirror which most models use.

Swift Ultra

size FoV relief focus weight best price

Swift Ultra 8x42 $301 341' 19.5mm 6 ft 24 oz $301.30 Adorama

Swift Ultra 10x42 $302 314' 16 mm 6 ft 25 oz $302.34 Adorama

- These 10x are my old standard binoculars.

Note the smaller field of view with the higher magnification of 10x, compared to 8x binoculars.  
The Swift Ultra roof prism model has a slightly, but visibly, brighter image than most roof prism models due to a low-oxygen “HR” process used in depositing the aluminum coating on the Schmidt prism. Alpen Apex XP models use this same coating. See mirror coatings earlier in this article.

Swift also has an Ultra in porro prism, weighing 28 oz, “Ultra Lite”, with waterproofing. I actually bought those first, but they broke at the eyepiece, so I went for the more durable roof prism binoculars which are now my (old) standard. The roof prism binoculars proved themselves by surviving the "dog wars" - chewed up by the family dog but still working just fine. I believe the porro models might be slightly better optically than my roof prism standard, and better than the current Swift Audubon series binoculars offered for sale at a higher price. But they failed my durability test. Note their longer close-focus spec compared to my Ultra roof prism binoculars. (Spec’s for the Ultra roof prism models above, for the Ultra porro models below.) Note that the 10x42 model is now offered by Swift only without the rubber armor as a “Horizon” model, but with the same lens coatings used by the Ultra models. (The Horizon roof models have cheaper anti-reflective lens coatings, lack the rubber armoring of the Ultra models, and probably aren’t up to the optical quality of the Ultra models.)

\*\*Swift Ultra porro 8x42 approx. $300\* 341' 18 mm 13 ft 28 oz

\*\*Swift Ultra porro 10x42 approx. $300\* 288' 18 mm 13 ft 28 oz

The Swift Audubon binoculars (below) show what one can do with putting money into porro prism binoculars, making them more durable and waterproof and putting in the optical coatings. One roof prism “twin” is sibling to the “regular” porro model, and one ED porro model is offered. The ED model costs more and has better optical quality due to the glass formula. All three are 8.5 x 44.

Swift Audubon porro

size price FoV relief focus weight

8.5x44 $329 430' 16 mm 14 ft 24 oz 4 stars 7 reviews

SWift Audubon roof

size price FoV relief focus weight

8.5x44 $388 336' 19 mm 9 ft 23 oz 5 stars 5 reviews

twin to the porro prism model, but with different spec's, lighter weight

Swift Audubon porro ED

size price FoV relief focus weight

8.5x44 $430 430' 16 mm 10 ft 29 oz 4 stars 7 reviews

I looked through the Audubon roof prism model, and found my Swift Ultra's were brighter. (Probably HR vs non-HR aluminum mirrors.)

What about those Vortex models offered through Eagle Optics- ?

- Crossfire (about $160), Diamondback (about $220), Viper (about $590), Razor ($1,180)? What makes those models different? I’m guessing the Crossfire uses simple aluminum mirrors, while the sales literature implies that the New Diamondback uses the brighter di-electric mirrors, like the premium models do. I guess the Viper has better lens coatings for tough lighting, while the Razor is a premium-optics model.

Also note the significantly lower optic score for the Bushnell Legend Ultra HD with the special grade glass, contrasting with the significant upgrade in optic score for the Alpen Apex XP vs the older non XP Apex in the 2009 comparison tests. The two Apex models used the same configuration, lens focal lengths, etc for the same field of view, close focus, eye relief etc , yet differ significantly in their optic scores. One source indicates improved lens coatings may have made the difference. “Improved” lens glass formula didn't lift the Bushnell Legends up to the top at all, according to the reviewers.

= = special sub-group: mid-grade binoculars with ED glass = =

Here are a few new mid-grade ED binocular models, $110 - $400.

With the ED glass, these should have images with brighter colors. I found that, as with the premium and elite classes, most of these appear at the same price at Amazon, Adorama, and Eagle Optics. In this case, I suspect 2 of the 4 are distributed THROUGH Eagle Optics. Like most of the other mid-grade binoculars, these will have BaK-4 glass in the Schmidt-Pechan roof prisms, with phase corrective coatings. These will have both objective and eyepiece 2-element achromatic lenses. They are O-ring sealed, waterproof, nitrogen-purged roof prism binoculars. They differ in their mirror and lens coatings and reviewer ratings.

The Vanguard entry is the only one appearing in the BWD article of 2012. In their mid-grade group it bested all of the other mid-grade models. But they scored slightly BELOW average for mid-grade binoculars in the newer 2013 Cornell review. Probably the truth is somewhere in the middle. (I have noticed narrow depth of focus when using them.) I have compared these to my old standard Swift Ultra roof prism model, both 10x42, and usually the two seemed about the same, but in one subdued lighting situation, looking at bare wood on a tree snag, first with the Swift Ultra and then with the Vanguard ED, it seemed as if a light had just been turned on; the colors did seem to jump out at that time. The ED glass (and coatings?) does also help in backlit objects somewhat, as revealed in a book viewing test in my yard.

The Cornell review in 2013 placed the Monarch 5 (an ED model) at the top of the group. ((But note that this model has lower Field of View than most models in this group.))

The cheapest of the four, Atlas Intrepid ED, not only has the ED glass but also a silver mirror coating, brighter than the standard aluminum. **It also offers a 7x36 model, an upgrade alternative to the $30 7x35 porro prism binoculars** and the **best close-focus** in this group of four models.

FoV = Field of View, in feet wide at 1,000 yards distance

eye = eye relief, in millimeters (mm)

close = close focus, in feet from the objective lens

weight = in ounces

Wingspan ED models  
 Wingspan “ProBirder” (black)

size FoV relief focus weight price

8x32 393' 17.8mm 6.6 ft 19 oz $110 Amazon 1/9/18

Wingspan “SkyView” (black, closed-bridge design)

8x42 393' 17.8mm 6.6 ft 22 oz $160 Amazon 1/9/18

Wingspan “CrystalView” in black, “NatureHawk” in gray-teal, open bridge

8x42 425’ 17.8mm 6.6 ft 27 oz $197 Amazon 1/9/18

The following two Wingspan models are carried

By Amazon but do not appear on the Wingspan website.

I have no spec’s for them, just color and price.

Wingspan “Valkyrie” (black, closed bridge) 10x42 ED $170 Amazon 1/9/18

I suspect all of these Wingspan products use standard aluminum mirrors

and cheaper lens coatings than the following, pricier models

Wingspan “Thurnderbird” (sic) (black, closed bridge)

with flat-field/aspheric lenses, ED glass

8x42, $280 Amazon 1/9/18  
 (At this price, this model might have better mirrors and lens coatings -?)

Atlas Intrepid ED - silver mirror coating (brighter than aluminum)

size FoV relief focus weight price

7x36 477' 16.8mm 5.1 ft 22.8 oz $300

8x42 420' 17 mm 6.5 ft 26.6 oz $290

10x42 342' 15.0mm 6.5 ft 26.6 oz $300

Vanguard Endeavor ED – apparently with HR-process aluminum mirrors

size FoV relief focus weight price

8x32 377' 17.5mm 6.6 ft 17 oz $250 Amazon 1/9/18

8x42 400' 19.0mm 8.2 ft 26 oz $230 Amazon 1/9/18

10x42 340' 16.5mm 8.2 ft 26 oz $242 Amazon 1/9/18

Vanguard Endeavor ED II

(newer, closer focus, XD-class “ED” glass formula; an ED IV is coming soon)

size FoV relief focus weight price

8x32 377' 17.5mm 6.6 ft 17 oz $350 Adorama (Feb ‘17)

8x42 377' 19.5mm 6.5 ft 27 oz $400 Adorama (Feb ‘17)

10x42 340' 16.5mm 6.5 ft 27 oz $400 Adorama (Feb ‘17)  
 note ED II prices same at Amazon and Adorama, different for original ED

Vanguard also has an Endeavor ED IV ($500) using more expensive SK-15 glass in the prisms, higher refractive index for smaller, lighter-weight prisms and presumably the same XD-ED glass formula in the lenses. The original Endeavor ED probably has the Chinese Hoya ED formula in its lenses.

I bought the 10x42 Vanguard Endeavor ED (not the newer ED II) on sale in Sep. ’13. Note a very narrow depth of focus, making it a bit more demanding getting these in focus, with more eye strain when they’re just a bit out of focus. I did also confirm brighter colors in subdued lighting, compared to non-ED binoculars. They became my new standard in-use binoculars in 2016.

Nikon Monarch 5 (ED, with dielectric mirrors, brightest in group)

size FoV relief focus weight price

8x42 300' 19.6mm 8.2 ft 21.5 oz $297 Adorama 2013, 2015

10x42 288' 18.4mm 7.8 ft 21.6 oz $330 Adorama 2013, 2015

Note one distinct disadvantage to these otherwise top-of-the-line Mid-grade models Monarch 5’s here - lowest Field-of-View of all models listed in this group.

Zeiss Terra ED - mid-grade ED, not premium optics,

best close focus for 8x42 or 10x42 in this group

size FoV relief focus weight price (July, 2016)

8x42 375' 18mm 5.25 ft 25.4 oz $400

10x42 330' 14mm 5.25 ft 25.4 oz $450

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**IMAGE-STABLIZED MODELS** made by Canon

Canon makes five Image-Stabilized models which use a little motor and motion sensor to move one of the two porro prisms inside to compensate somewhat for minor hand motions and suppress the jumpiness of the image a little bit, for a slightly clearer view. Two of the five models have excessive magnification and even with the image stabilizer won’t be able to hold the image still enough for a sharp view unless the binoculars are placed on a steady surface – which doesn’t help with looking at warblers flitting through the leaves in trees. But three are suitable and could help some people a lot. All of these (and the Papillio butterfly viewers) do have aspheric/”field flattener” eyepiece lenses, normally found only in the premium optics group. The aspherics produce sharp, crisp, detailed focus across the full field of view, edge to edge.

The first two below are mid-grade with 2-element lenses, objective and ocular, and they are NOT weatherproof. They do have the aspheric lenses.

model/size FoV relief close focus weight price (Jan, 2017)

Canon 8x25 IS 347' 13.5 mm 11.5 ft 17.3 oz $294 (Amazon)

Canon 10x30 IS 314' 14.5 mm 13.8 ft 21.2 oz $461 (Amazon)

The next model has full premium-class optics including a 3-element objective lens, for resolving tiny details on far-away birds. Users with less than 20-20 vision (as corrected with glasses) might not see the extra, tiny details resolved. This model is sealed waterproof/fogproof.  
Users WITH 20-20 vision will probably see an image comparable to that from  
the best binoculars on the market.

model/size FoV relief close focus weight price (Jan, 2017)

Canon 10x42 L IS WP 342' 16 mm 8.2 ft 39.2 oz $1,079 (Amazon and Adorama)

**PREMIUM BINOCULARS GROUP, $900 - $2,000**

Binoculars in this class gain most of their superiority from a three-element Apochromatic objective lens, which can focus three colors to the same exact point, and eye piece (ocular) lenses with "aspheric" geometric correction for varying thickness in parts of the lens (see "Aspheric" earlier in this article, also refered to as "field flattener lenses"). This combination of Apochromatic and "Aspheric" corrections yields a significantly clearer image with less eye strain. Most of these will also have the di-electric iridescent mirror coatings and first-rate anti-reflective lens coatings. If your corrected vision is 20-20 or better, then once you've used any one of these models for a while, you may not want to settle for anything less. If you can afford it.

Prices are generally about the same for Amazon, Adorama and Eagle Optics with these premium products. This $900 - $2,000 priced grouping uses ED formula glass in the lenses.

**Zeiss Conquest HD** - transmission 90% + , T\* coatings , **best value in class**

"mid-sized" , 32 mm (less glass, lower weight and prices)

size FoV relief focus weight price

8x32 420' 16 mm 4.9 ft 22.2 oz $900 Amazon Feb ‘17

10x32 354' 16 mm 4.9 ft 22.2 oz $900 Amazon Feb ‘17

"full sized", 42 mm

8x42 384' 18 mm 6.5 ft 28 oz $970 Amazon Feb ‘17

10x42 345' 17 mm 6.5 ft 28 oz $936 Amazon Feb ‘17

The Zeiss Conquest rated best-in-class for binoculars priced below $2,000 in the Cornell study (which called them “Mid-Priced”). They were not only best in class in performance, but also more affordable than any of their competitors as well. I suspect their higher Cornell rating comes from their Zeiss T\* lens coatings. I would caution that the 10x32’s might have jumpy image problem due to magnification and size/weight.

Leica Trinovid - These Trinovids uniquely sport THREE ocular lenses, plus focus lens and objective lens. (Most of the other mid-grade, premium and elite models have two ocular lenses, a focus lens and an objective lens.)

size FoV relief focus weight price

8x42 378' 15.5mm 11.5 ft 28.6 oz $1,449.00 Amazon

10x42 324' 16 mm 11.5 ft 28.0 oz $1,499.00 Amazon

Nikon Premier - high-reflection **silver** coating, **not** the superior di-electric iridescent mirror

size FoV relief focus weight price

8x32 $1,196.95 Amazon

8x42 367' 20mm 9.8 ft 28 oz $1,449.00 Amazon

10x42 314' 18.5mm 9.8 ft 27.9 oz $1,599.95 Amazon

Nikon EDG

These DO have the di-electric mirror coating on the Schmidt prism. These, despite their price, aren’t rated as high in comparison articles as the elite-class models with fluoride glass. These do NOT have fluoride glass, despite the price.

There is a 7x model here, for a premium-class option in that magnification.

size FoV relief focus weight price

7x42 420 22.1 9.8 ft 27.7 oz $2,296.95

8x42 405 19.3 9.8 ft 27.7 oz $2,296.65 - 2,399.95

10x42 342 18.0 9.8 ft 27.9 oz $2,496.95 – 2,499.95

Swarovski Companion CL - mid-size 30 mm offerings in green, tan or black

size FoV relief focus weight price

8x30 372 15 mm 9.8 ft 17.6 oz $ 949.00 Adorama 11/27/13

10x30 300 14 mm 9.8 ft 18.2 oz $1019.00 Adorama 11/27/13

Swarovski SLC - their non-fluoride full-size 42mm offerings

size FoV relief focus weight price

8x42 408 18.5 mm 10.5 ft 28.5 oz $1729.00 Adorama 11/27/13

10x42 330 16 mm 10.5 ft 28 oz $1800.00 Adorama 11/27/13

**ELITE-CLASS BINOCULARS, $1,700 - $2,800**

The expensive FL or HT fluoride ion formula glass pushes Premiums up to the Elite state-of-the-art class, best that money can buy. Same optical configuration, almost imperceptibly brighter colors.

**Swarovski EL** - FL lenses, 90% transmittance These seemed to be the best-sellers and highest-priced among the elite binoculars as of spring 2013, but comparatively lower-priced 2018, and have very good field of view, close focus, eye relief, and weight specs. They were previously called Swarovision EL, now just EL. The Swarovsky EL 10x, Zeiss SF 10x and the mid-grade Atlas Intrepid 10x are the only 10x models in my listings to exceed 350 ft field of view. And get a look at that best-in-class close focus these Swarovision EL 42mm models can bring in. Mid-size and full size available.

Swarovski EL (formerly SwaroVision) – these have very good spec’s

size FoV relief focus weight price range

8x32 423' 20mm 6.2 ft 20.5 oz $2,200 3/16/15

10x32 360' 20mm 6.2 ft 20.5 oz $2,300 3/16/15

8.5x42 399' 20mm 4.9 ft 29.4 oz $2,530 3/16/15

10x42 336' 20mm 4.9 ft 29.6 oz $2,500 3/16/15

**Leica** offers 7x binoculars which could serve as an elite-class alternative to the $30 porro prism 7x35's in economy group 2, or the $300 Atlas Intrepid 7x36 in the top of the mid-grade group 3. With the better grade glass and the apochromatic objective and aspherics in the eyepiece lenses, they would offer the world's best view in a 7x binocular. At a price.

Leica Ultravid HD

Mid-size 32mm

size FoV relief focus weight price

8x32 404 **13.3** 7.2 ft 18.9 oz $1,950

10x32 352 **13.2** 6.9 ft 19.9 oz $2,050

Full-size 42mm

size FoV relief focus weight price

**>>** **7x42 420 10.8 ft 27.2 oz $2,150**

8x42 390 9.8 ft 27.8 oz $2,000

10x42 336 9.5 ft 26.4 oz $2,300

Leica Ultravid HD-**plus** with the Schott HT glass for 92% light transmission

Full-size 42mm

size FoV relief focus weight price

**7x42 420 10.8 ft 27.2 oz $2,400**

8x42 390 9.8 ft 27.8 oz $2,450

10x42 336 9.5 ft 26.4 oz $2,500

Note – the 7x42 HD-plus is the highest-grade 7x model on the market.

Leica now has an updated line, redesigned to compete with the Zeiss Victory SF line.  
I saw, on the cutaway view, that it has six separate lenses (or “lens elements”) on each side,  
with the first three comprising the composite of a three-element “apochromatic” objective lens,  
and the next three the eyepiece (ocular) set. It looks like the prisms and the final objective lens  
element might move together for focus. Comparison reviewers found, that, like the Zeiss, the focus is now fully sharp out to the very edges of the field of view with no visible “coke bottle” effect. The literature spoke of “varying radius” lens elements, implying that more than one is aspheric / field-flattening, to accomplish this. Maybe all of them. This is their new “Noctivid” series. Like the preceding Ultravid-Plus, they use the Schott HT glass and get 92% light transmission, tied with the more expensive Zeiss Victory SF series below.

Leica Noctivid  
 size FoV relief focus weight price 01/08/18

8x42 408 6.2 ft 30.3 oz $2,600

10x42 336 6.2 ft 30.3 oz $2,700

**Zeiss** Victory FL - Zeiss has moved the 42mm models from the Victory FL line to the HT and SF lines. With Victory FL, choose 32mm or 56 mm objective size. The Zeiss website says these have the normal Schmidt-Pechan roof prisms, not the Abbe-Koenig roof prisms used in the HT binoculars.

I list only the "mid-sized" 32mm binoculars below.

These 32mm binoculars will weigh less, for people who don't want the regular full weight binoculars. This 32mm size is currently considered "mid-sized" and is growing in popularity.

These smaller Zeiss FL 32mm models weigh less and cost less than 42mm "full size".

But the lower weight in the hands might cause more image jitter for some users, especially at 10x magnification. The 2013 Cornell study gave these the highest (by a tiny fraction) optic score of all.

Zeiss Victory FL with 32mm objective lens:

size FoV relief focus weight price

8x32 420' 15.5 6.56 ft 19.75 oz $1,750 3/16/15

10x32 360' 15.2 6.56 ft 19.75 oz $2,000 3/16/15

The HT and SF models by Zeiss feature a new, proprietary Schotz HT high-transparency FL glass formula, and produce the brightest image of any binoculars on the market, with a published transmittance performance of 95% (HT models with Abbe-Koenig prisms), or 92% (SF models with Schmidt-Pechan prisms, same as the new Leica Noctivids above). (Swarovski has 90% transmittance.) Most of the comparison reviewers hadn't seen the HT's yet when they did their reviews. Comments on the internet suggest these may possibly be overtaking the Swarovski models as the most popular elite class binoculars. The Cornell reviewers in 2013, who DID see these, rated them about the same as all the others in this group, a virtual three-way tie among Zeiss (both flavors), Leica, and Swarovski.

Zeiss Victory HT with Abbe-Koenig prisms and HT glass for 95% transmittance

Size FoV relief focus weight Amazon, Adorama 3/16/15

8x42 408' 16mm 6.2 ft 27.7 oz $2,250

10x42 330' 16mm 6.2 ft 28.4 oz $2,300

Zeiss Victory SF (new in 2014) 92% transmittance, HT glass, Schmidt-Pechan prisms

Featuring wider FoV angle, more eye relief, closer focus, ergonomic upgrades with fast-focus, shift weight towards the eyepiece end, slightly lighter weight, open bridge design, etc.

Size FoV relief focus weight Amazon, Adorama 01/11/18

8x42 444' 18mm 5.0 ft 27.5 oz $2,850

10x42 360' 18mm 5.0 ft 27.5 oz $2,900

Reviews seemed to indicate the Leica, Zeiss and Swarovski were tied at the very top for optical quality. The Swarovski’s seemed to be the best sellers of the bunch, with first the Zeiss HT’s and now their SF’s possibly catching up to take the lead in sales. I’m not sure which is currently best-selling. Reviews generally show a three-way tie among Leica, Zeiss and Swarovski for top performance honors.  
  
The Cornell reviewers came to the opinion that the Zeiss Conquest models in the Premium ($1,000 - $2,000) class group, costing a thousand dollars less, are close enough in quality that the extra money might not be justified for the very small improvement gained by going up to the FL glass Elite group.

Another, newer review in July, 2015 by Bird Watcher’s Digest of just the top three – Leica Ultravid HD-plus (with the Schott glass also used by Zeiss), Swarovski EL Swarovision, and Zeiss Victory SF, found that resolution for all three is better than the eye can see, resulting in equal resolution as far as anyone’s eyes can tell. The reviewers also concluded that all three have better than 90% transmission, for about equally bright images in reduced light. They gave their favorite rating to the Zeiss SF models for ergonomics, including best close-focus, field-of-view, and eye relief.  
  
Prices quoted above will be approximate; they vary somewhat from day to day and month to month. It’s best to compare prices with the internet vendors listed next page to see which has the current best price. I made my two most recent purchases with the Bird Watchers Digest on-line store, including one bought as a single-use demo. But usually Amazon will have the best price or be tied for it.

Here is a list of the internet vendors I checked -

their names and their internet addresses (URL's) :

Amazon - - - http://www.amazon.com/

Optics4Birding - - - http://www.optics4birding.com/

Adorama - - - - http://www.adorama.com/

B&H Photo - - - - https://www.bhphotovideo.com/

Bird Watchers Digest on-line store - http://store.birdwatching.net/

Optics Planet - - - - http://www.opticsplanet.com/

Four local wild bird stores carry seed and feeders; one or more at least used to also carry some binoculars. Perhaps only the Audubon Naturalist Society’s D.C. area store still does. Department stores like Wal-mart, Target, etc. often carry economy-optics miniature binoculars. Some of the major hunting/sporting stores like Cabella’s carry some mid-grade roof prism binoculars.

Columbia area

Wildlife Unlimited, 10281 Route 40 west of Route 29, look them up in internet for directions

At one time carried both binoculars and telescopes, but doesn’t seem to now

Timonium area (off Padonia Road, either side of I-83)

Wild Birds Unlimited – a chain, one at 2438 Broad Avenue, Timonium, off Padonia Rd off I-83

Wild Bird Center – a chain, one at 12234 Tullamore Road, Timonium, off Padonia Road off I-83 north of the Beltway, at one time carried Alpen Apex line of binoculars, might not do so now

Olney, MD (southwest of Columbia)

The Backyard Naturalist – a store at 17910 Georgia Avenue (MD route 97, south of I-70) in Olney

Magazine articles with binocular comparison reviews which I used for this article:

the first group of articles following are my main reference sources:

Living Bird Magazine: Cornell review article, fall/winter 2013

http://www.allaboutbirds.org/page.aspx?pid=2674

Bird Watchers Digest High-End review published May/June 2012

http://www.birdwatching.com/optics/2012highendbins/review.html

Bird Watchers Digest Mid-Price reviews published Jan/Feb 2012

http://www.birdwatching.com/optics/2011midpricebins/review.html all 8x

http://birdwatching.com/optics/2010midsizebins/index.html 8x32 (approx)

still earlier reference sources:

Bird Watchers Digest Mid-Price review published 2007

Cornell "High-Price" 2005

Cornell "Economy and Mid-Price" 2005

**SPOTTING TELESCOPES**

Spotting ‘scopes aren’t as easily identified into their classes. I do recommend finding one with waterproofing, same with binoculars. None of my earlier, non-waterproof telescopes or premium binoculars work any more. Both of my current binoculars are waterproof, as is my telescope, and I will no longer buy one that isn’t. Fortunately, most of the mid-grade and premium-grade binoculars and spotting telescopes sold today are sealed and waterproof, protecting the investment in the expensive optics.

Spotting 'scopes have higher magnification in order to make out smaller details on more distant objects. This makes a higher demand on the lenses, and **lens types here really are critical**.

The basic design features, including coatings and fancier lenses, influence spotting telescope price and optical performance the same way they do with binoculars. The prices are a higher than with the binoculars, but not by a huge amount. A **cheap** telescope will be similar to a cheap pair of binoculars, only **much worse** – with the higher magnification, the **optical flaws** stand out more clearly and it’s harder to make out the finer details on more distant birds; you won’t be able to see much through a cheap ‘scope, and may even see more details with your binoculars. It gets more important to invest in a costlier ‘scope which will reveal more details on distant birds, since that’s what the ‘scope is for. My Alpen 788, $415 (Amazon), and the Nikon Prostaff, $600, both have mid-grade 2-element Achromatic lenses (2 + 2) and are good for viewing birds out to about 50 - 75 yards distance. At that range, they get an image which usually seems as good as the top-grade 'scopes. Beyond that, one needs to spend more. The Bird Watchers Digest article in 2009 recommends the Vortex Viper, about $900, then entering into the premium class with the Vortex Razor, about $1,600 to $1900 at Eagle Optics, and the Zeiss Conquest line includes a Conquest Gavia 30-60x85mm angled ‘scope for 1,900 – 2,00 Eagle Optics, then for even more distant or smaller details, step up to the top-of-the-line elite models by Swarovski, Leica, Nikon (Fieldscope), Zeiss, and Kowa, costing about $2,200 to $4,000 (Eagle Optics, Adorama, sportoptics.com prices). Both 65mm and 80mm lens models are popular, but the 82 - 85mm sized models usually have higher 60x magnification available, while the 60 – 65mm models remain limited to 50x. Scores suggest there \*MIGHT\* be a tiny optical advantage with the Swarovski and Kowa models. That's a matter of opinion among the reviewers.

price checks 08/31/17 :

"almost FL premium-plus" :

Vortex Razor 27-60x85 angled ‘scope (complete) $1600 - $1925 Eagle Optics 08/31/17

Zeiss Conquest Gavia 30-60x85 angled scope (complete) $1900 - 2000 Eagle Optics

full FL elite :

Kowa TSN 773 25-60x77mm angled scope body 1600-2300 + eyepiece 630-650  
 -> $2230-2950 complete (Eagle Optics) – a best buy. (See last sentence of preceding paragraph.)  
 But note that this one doesn’t use the Fluorite.

Kowa TSN 883 25-60x88mm angled scope

body 2450, eyepiece 700 -> 3150 Amazon,

body 2300 - 3150, eyepiece 630 - 650 -> 2930 - 3800 complete  
 This one DOES have crystal fluorite for the main objective lens element.

(I bought this one fall of ’18 for $2804 at Bird Watchers on-line store.)

Note that the Kowa ‘scopes might \*possibly\* be a bit less durable than the following models.

Leica Televid APO 25-50x82 mm body 2700 eyepiece 850 -> 3,550 complete, limited to 50x

Zeiss Diascope 20-60x85 T\* FL spotting scope – only Adorama has it, a straight model, not angled, for $3,300. A massive 95mm model exists, with 25-75x magnification, and a higher price,  
if you can find it.

- Eagle and Amazon don't carry the Diascope 85; Adorama carries straight only (see above).

Swarovski ATX 25-60x85 mm modular,

objective module 1600 - 4408 (?),

ocular module w angle 2370 - 5307 (?)

-> 3970 - 9715?? Eagle Optics

Purchasing these high-end ‘scopes is a bit more complicated – you usually buy a ‘scope body (with objective lens) and separately buy the eyepiece to go with it. (The Swarovski is different – it sells separately sealed modules, a module with the eyepiece and back of the ‘scope body, and an objective lens module, for the front half of the ‘scope. Both modules are fully sealed, even when separated.)

The majority of users find the zoom eyepiece, with variable magnification, to be very useful and prefer to buy their ‘scopes with one. However, some purists prefer instead to purchase fixed-power eyepieces, which do offer slightly higher resolution. I do use a zoom eyepiece myself, finding it easier to search through a flock at lower magnification, then zoom in on a particular bird of interest for a closer look.

For spotting ‘scopes, I’ve found three studies dated 2007, 2009 and 2010, with almost no overlap for models of mid-priced ‘scopes covered. I found the Bird Watchers Digest article from 2009 to be most helpful, and used it to choose the Alpen ‘scope I’m used ‘til I bought the Kowa.

\*\* REPRISE AND OVERVIEW \*\*

I've owned and used binoculars at all three major grades, and telescopes of the two higher grades, and been satisfied with them all. However, having experienced them all, I do prefer the clearer, brighter, sharper (more finely detailed) images of the higher-grade models when I can afford them.

Another perspective: expensive optics are a long-term investment. For the price of a very cheap used car, one could splurge and get top-of-the-line binoculars and telescope, and have money left over for a trip or two to exotic location(s) for exotic birds. The optical equipment will, with reasonable care, last much longer than a new car will. If you expect to be using your optics a lot over the next 15 years or more, the pleasure they give you over that time should justify the expense of getting the best you can afford.

Stay tuned; I’ll periodically update this article on the club web page. I can also be reached at [pete6314webb@gmail.com](mailto:pete6314webb@gmail.com) with any questions, comments, or corrections you might like to make.

Here is a list of the internet vendors I checked -

their names and their internet addresses (URL's) :

Amazon - - - - http://www.amazon.com/

Optics4Birding - - - http://www.optics4birding.com/

Adorama - - - - http://www.adorama.com/

B&H Photo - - - - https://www.bhphotovideo.com/

Bird Watchers Digest on-line store - http://store.birdwatching.net/

Optics Planet - - - - http://www.opticsplanet.com/

Best-Price (a price comparison website) <http://www.best-price.com/>

Three local stores (or chains) used to carry good optical quality binoculars and/or telescopes:

The Wildlife Authority, off Route 40 west of Route 29, look them up in internet for directions

Wild Birds Unlimited – a chain, two or three stores in the Baltimore metro area

Wild Bird Center – a chain, at least one store in our area, off Padonia Road off I-83 north of the Beltway. There is an Audubon Naturalist Society store in the D.C. area which I believe still carries optics; one might look them up and see. I also noticed that Leica has an authorized seller somewhere in the D.C. area. The ANS store probably would have more variety to check out.  
Another, more distant store with a variety of optics would be the Cape May observatory visitor center and store in New Jersey. Local department stores like Walmart, Target, etc. will have a few choices in-store, mostly lower quality economy-grade miniatures, both porro and roof prism.

MORE REPRISE, NOTES AND WRAP-UP

My experience - I've used economy, mid-grade and premium binoculars at times in my life, and was content with each grade, but always liked the higher grades, when experienced, more than the lower ones. One sees a fairly noticable improvement in image sharpness and clarity going up from economy to mid-grade, more subtle but still perceptible going up to ED, and again up to premium (tough light or tiny details, reading very distant signs or book text). I have not compared premium with elite-grade (fluoride-lens) binoculars; I'm taking the advice of the Cornell reviewers here. The additional improvement is so tiny that the human eye can barely perceive a slight enhancement in color intensity. With 'Scopes, the higher magnification makes the differences more visible, especially with small, distant details. Here I would not hesitate to recommend the top-performing 'scopes; they will bring out visible details that lesser 'scopes just can't deliver. And that seems to be the decision most serious “birders” make – good mid-grade binoculars and top-gun ‘scopes are what most of them appear to use in the field.

- notes on astronomy / star gazing

In astronomy - looking through 8x or 10x binoculars, especially with the moving image in hand-held binoculars, no matter how good the binoculars actually are, my eyes can't resolve details as small as Saturn's rings or the two gray bands across the face of Jupiter, however sharply they might actually be resolved by the binoculars themselves. Saturn's rings and Jupiter's gray bands are easily visible but slightly blurry in my Alpen 'scope (on a tripod), at magnifications of 20x or higher. The elite top-of-the-line 'scopes will make Saturn's rings or Jupiter's bands look much sharper and clearer.

When viewing stars or a fuzzy object like a comet, optics with larger objective lenses bring a distinct advantage - with the wider exit pupil, your eyes' pupils, expanded in the darkness of night, can take in more light, so faint but diffuse objects will be brighter than with optics of lesser exit pupil. Of course, there's a limit - my eyes' pupils probably won't dilate more than about 5mm, so optics with more exit pupil than my eyes' actual pupil size won't get all of that light into my eyes. So for me, 8x40 (or 8x42) or 10x50 binoculars will bring in all the light my eyes can take in. When I was younger, and my eyes' pupils could expand to 7mm or more, a pair of 7x50 binoculars would have made a comet or even the stars a bit brighter. Oddly enough, for me with my middle-aged eyes, I’ll see more, brighter stars with 10x50 binoculars than with 7x50, where the extra brightness won’t be perceived because my eyes’ pupils won’t take in all of that 7mm exit pupil shaft. Instead, they will take in about as much as with 7x35 binoculars, an effectively 35mm “objective lens” for star gazing at that magnification and my 5mm pupils. A bright object like the moon (even during lunar eclipse), Jupiter or Saturn will be bright enough that the reduced exit pupil of a spotting 'scope wouldn't matter much at all, while for comet viewing, binoculars, with a wider exit pupil, are a much better choice. And something like the aurora or a meteor shower, if the opportunity should come along, would be best seen without optical magnification, for the wider field of view of unaided eyes. But to get the colors in auroras, nebulas or the Andromeda galaxy, as seen in photographs, one needs long-exposure cameras, not real-time viewing by eye, with or without optics. Andromeda will just be a faint blur by eye, which is actually just the brightest portion near the center of that galaxy. For a solar eclipse, I used a ‘scope or my binoculars to project an image onto a flat surface (cardboard, car floor, etc.) until the eclipse was total, then viewed through my binoculars until the total part ended and brightness began to reappear on the moon’s edge, then back to projections by ‘scope or binoculars onto a flat surface again.

And to see any detail on Mars, or more than just the two gray bands on the face of Jupiter, one needs a true astronomical telescope, with much higher magnification and a motor-mount to keep the 'scope tracking as the earth rotates the sky above us. Of course, those come with a price tag.

And that specialized equipment is not for bird watching.

- PW