

## Chapter 3

# Binoculars Are Binoscopes

Binoculars are considered binoscopes. We usually just think that binoculars are just binoculars. In reality, they are really in most cases a smaller version of a binoscope. Basically they are two small refractor telescopes that are optically aligned on the same object for viewing. Of course there are larger versions of the binocular. Some have objective lenses that are 150 mm in diameter and often 25 power or more. Being so large of a binocular, they have to be supported on a large tripod or pier. The view through a pair of 150-mm Fujinon binoculars is stunning to say the least. However, the expense that one has to pay for a pair of these fantastic large Japanese binoculars is often out of reach for the average individual.

There are so many different types, sizes, and brands of binoculars that range in just about every imaginable size and price range. An individual who is shopping around for a good deal would not have a problem finding a pair of good binoculars at a very reasonable price. And that's the key to finding a good deal on a quality pair of binoculars is to "shop" around and look for a good pair of brand name binoculars that are on sale or discount. Of course, the internet offers hundreds of binocular websites that sell just about every size and kind of binoculars. The best part about looking for a real deal on the internet is when you actually find a pair of binoculars and it only takes a credit card number to have them sent to your house within 5–10 days. However, returning them to the dealer for a refund or exchange may be difficult or impossible if they break. If you are buying binoculars on the internet, find out who the original manufacturer is and where they were made. You'll know more about what to expect once you have this information. Keep in mind that everything looks good on the surface until you do a little more research.

## A Condensed History About Binoculars

In order to better understand the evolution of binoculars, let's trace the origin of the first binoculars. The history goes far back in time and most of it is still a mystery, as it may remain for years to come. The historical evidence we do have starts with the discovery of glass around 3510 BCE. It then took about another 4950 years or so for it to be formed into something that was useful, such as a lens, which was ultimately used for the construction of the first telescope. But even the telescope's true origin is somewhat mysterious. It is generally accepted that binoculars came about as part of the natural evolution of the telescope. One of the big advantages that binoculars have compared to a single telescope, is that they provide a three dimensional view for the observer by producing a combined perspective. The result is a more realistic perceived field of view with greater depth.

History claims that the invention of modern binoculars is attributed to the Dutch spectacle maker named Hans Lippershey. In the winter of 1608, he discovered that a lens of a convex shape and a concave lens can be combined together to magnify an object of some distance. In simple terms, this discovery is the simplified "version" and origin for the telescope! After his initial discovery, Lippershey on October 2nd, 1608 decided to present his new telescope invention to the Netherland's States General. As a result of his newly invented telescope, it was requested that he build a telescope version for military purposes that could be used by an observer using both eyes. He complied with the request and as a result, created three sets of "two eye telescopes", which at the time, was not very impressive because of their poor optical performance. At the time, telescopes had low magnification and produced poor-quality images. Lippershey submitted a request for a patent on his new so-called telescopic invention but it was initially rejected. As a result, there is serious doubt as to whether or not Lippershey was in fact the first one to combine a convex lens with a concave lens. Nonetheless, by the early part of 1609, the early version of the "binoculars" or "spyglasses", which were referred to as telescopes, became extremely popular in Paris.

The first "actual" binoculars were the so-called "Galilean binoculars". Historical records tell the story of how the famous Italian physicist Galileo Galilei had heard about Lippershey's new optical invention and decided to build a telescope to experiment with. Over time, Galileo made around one hundred telescopes, with magnifications ranging from about three powers up to about thirty powers. Observing through his telescopes, Galileo was able to observe the craters on the Moon and Jupiter's four largest satellites, and that was the beginning of real astronomical research. Galileo's original telescopes consisted of only two lenses: a simple convex lens at the front end, called the objective lens, and a concave lens at the rear or eye end, which was called the eyepiece. With a Galilean telescope, the observer could see magnified, upright images. He could also use his telescopes to observe the night sky. Galileo during the early part of the 1600s was one of the few who could build telescopes that were good enough for observational astronomy. In Aug. of 1609, he demonstrated one of his early telescopes which magnified images

up to about 8 or 9 times, to Italian lawmakers. Galileo's telescopes were also a profitable sideline business for him—he sold to merchants who found them useful both at sea and as items of commerce and trade. Galileo published his initial telescopic astronomical observations in his brief treatise entitled *Sidereus Nuncius* (*Starry Messenger*) which he published in March of 1610.

Galilean binoculars up until the 1850s were very popular accessories, used in theaters, operas and social events. They were often covered with ornaments such as pearls, silver, gold, ivory or bone and even colored leather (Fig. 3.46). Even their Galilean binocular shape was modified to resemble glasses of elegant beauty that held dignity and importance. The very simple Galilean design, which uses two simple lenses to produce an upright low magnification image, is still being used today in the most common “opera glasses”.

A new and somewhat innovative type of binoculars was introduced in 1854 by the famous Italian optician Ignazio Porro. These popular Italian binoculars were named the Porro Prism binoculars. The Porro Prism binoculars were improved in the 1980s by manufacturers, such as the famous German optical company (now called Carl Zeiss AG) who specialized in quality of design in all of their products. The Porro Prism binoculars were designed to be wider and performed better than the Galilean binoculars, which as a result, made the once popular Galilean binoculars less sought after. However, starting with the late 1880s, the Roof Prism binoculars became the age's popular accessory item. The well-known French manufacturer Achille Victor Emile Daubresse is the creative designer of these binoculars and his incorporation of roof prisms may have appeared as early as the 1870s. Most roof prism binoculars use either the Abbe-Koenig prism design (named after Ernst Karl Abbe and Albert Koenig and patented by Carl Zeiss in 1905) or the Schmidt-Pechan prism design (invented in 1899) to erect the image and fold the optical path. They have objective lenses that are appropriately aligned with the eyepieces.

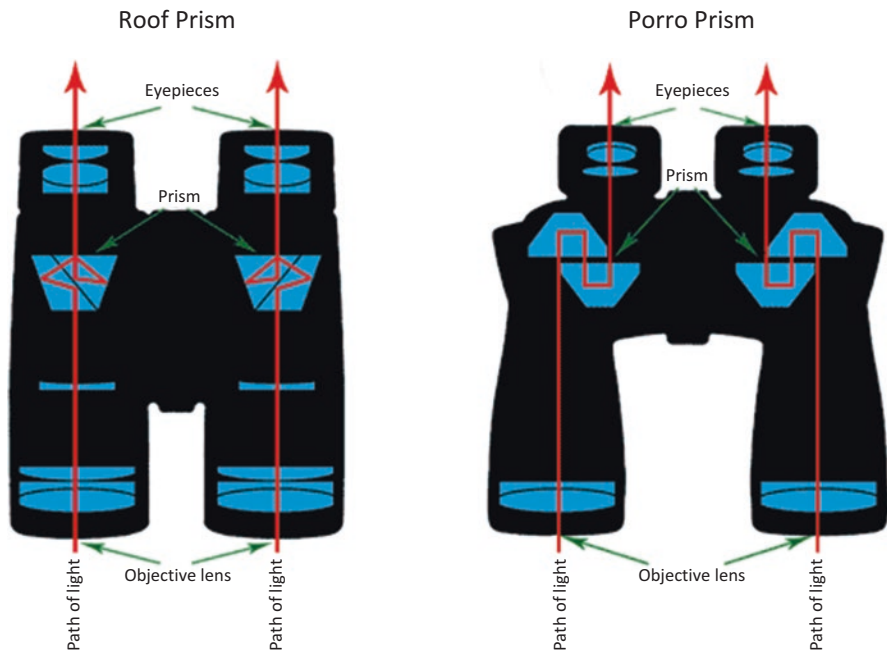
Roof Prism designs create a binocular that is narrower and a bit more compact than Porro prisms. There is also quite a difference in image brightness. Porro prism binoculars will inherently produce brighter images compared to Roof Prism binoculars of the same magnification, objective size, and optical quality. This is because the Roof Prism design employs silvered surfaces that reduce light transmission by approximate range from 12 to 15%. Roof Prisms designs also require tighter tolerances for proper alignment of their optical elements (collimation). This obviously adds to their overall cost since the design requires them to use fixed elements that need to be set at a high degree of collimation at the factory. Binoculars with a Porro prism design occasionally need their prism sets to be re-aligned to bring them into collimation. The Roof Prism fixed alignment design means the binoculars will normally not need to be recollimated.

There have been many other types of binoculars that have been created since the seventeenth century. If our old friend Galileo was still around, he would be amazed to see how far the evolution and technology of his original Galilean telescope has gone. Nevertheless, none of them have influenced or had such a profound impact on the market as did Lippershey's or Galileo's first optical glass creations.

## Binocular Prisms

Today's new binocular profiles, styles, and configuration usually come in two general shapes, and these shapes or profiles are a function of the type of prism system that is used in the binocular's optical system. Porro prisms used in binoculars have that familiar "dog leg" shape with the eyepiece offset to the one side with respect to the objective lens. Because of their familiar wide bulky shape, they provide the observer with a solid binocular package for hand-held visual observing, especially if you enjoy doing some binocular astronomy and tracking down those wonderful celestial objects with your trusty pair of Porro prism binoculars. The other type we often see in binoculars is the roof prism binoculars with their familiar straight narrow shape with the eyepiece situated directly behind the objective lens. One of the advantages in using a pair of roof prism binoculars is the focusing wheel is usually placed directly under the observer's hands and fingers, which ultimately increases the binocular's focusing speed and overall user's comfort. A desirable attribute indeed (Fig. 3.1).

The primary function of prism in a binocular system is to provide the observer with a proper oriented image. Prisms are expensive, but they are needed to produce a correct image for the observer. Without prisms, everything would be upside-down with reversed images. Physically speaking, Porro prisms are in fact, wider than they



**Fig. 3.1** In a typical binocular optical system, two types of prisms are commonly found (roof prisms and Porro prisms), joined together as in a set, which erect the image and shorten the overall length of the binoculars (Image credit: the Author)

are in terms of their length. Their physical profile shows them to have a shape for example, that is similar to a square-S design. If the prisms are made out of a quality optical glass and are properly aligned, then there is as a result, very little light loss or degrading of the overall image quality. An important disadvantage is using prisms is that they are rather large and somewhat bulky that require binocular housings that are somewhat relatively large for mounting purposes.

Binoculars with roof prisms are a relatively newer binocular design. Roof prism binoculars have a somewhat smaller house-shaped profile and are just a bit more compact compared to a pair of Porro prism binoculars. This allows them to be fitted into smaller and more compact binocular housings or spotting spots. However, standard roof prisms have a few inherent design elements that make them a little less desirable when it comes to choosing binoculars compared to a pair of Porro prism binoculars, especially when it concerns light loss. Generally speaking, a Roof prism produces images that are not as bright as a Porro prism because they have a % light loss at their mirror surfaces. Another reason why a roof prism is not as light efficient as a Porro prism is because the precise alignment and adjustment of a Roof prism is often more critical. Even a very small alignment error, less than the width of a human hair (0.002') will often degrade the image in a Roof prism just enough so as to make them visually uncomfortable for the observer to view with. As a result, it makes it more of a challenge to skillfully mount and secure them properly in a binocular housing. Another important reason is their images are split and then are rejoined again slightly out of phase when the light cone passes through a Roof prism. This results in an image that lacks less in visual resolution compared to a Porro prism of equal quality. Basically, the standard binocular Porro prism produces an image that is slightly sharper and brighter than a roof prism of the same standard optical quality. But thanks to today's coating technology, some Roof prisms can enjoy the benefit of enhanced coatings on their surfaces, which can reduce light loss to almost indiscernible levels. And even better yet, some of the newer roof prisms have special coatings that have a tendency to considerably reduce and even eliminate the phase problem. As a result of phase correction (or more commonly called PC), Roof prisms can produce images that are every bit the equal to some of the best Porro prisms used in the higher-quality binoculars. One of the draw-backs on this is that PC Roof prisms from some of the well-known higher quality binocular manufacturers such as Bausch and Lomb, Zeiss, Swarovski, and Leica are often very expensive and typically exceed a price tag of more than \$2000. However, their instruments are considered some of the finest made and represent the highest standard in quality and excellence, especially when it comes to commercial binoculars.

When it comes to wanting the best in resolution and sharp images in a pair of binoculars, keep in mind that Roof prisms without phase correction and special coatings can only do so much when it comes to producing high quality images. If you want the best in resolution and sharpness, you'll have to pay the price for a pair of phase-corrected Roof prism binoculars or choose a good pair of binoculars with Porro prisms instead. If you compare Roof prism and Porro prism binoculars that are on sale at the same price, it shouldn't be too difficult to decide which one you want to spend your money on. But if you have a tight budget for your next pair of

binoculars and want to spend less, then Porro prisms are the way to go. When you are out shopping around for a quality pair of binoculars for sale at a reasonable price, keep in mind that inexpensive Porro prism binoculars manufactured today are generally speaking, every bit the equal optically compared to the expensive phase-corrected Roof prism binoculars. They should make your new binocular investment a much more satisfying experience when it comes to visual observing. Plus as an added benefit, Porro prism binoculars because of their slightly larger objective lens separation produce a more noticeable stereo effect than a pair of roof prism binoculars. And before you make a decision to buy a pair of binoculars, it's always good to know the type and kind of prism glass that may be inside of those coveted binoculars when you are out there shopping around

Adapted from "Binocular Prisms: Roof or Porro?" (<http://www.shawcreekbirdsupply.com>)

### What Kind of Glass Are Binocular Prisms Made Of?

BaK-4 binocular prisms are also not-so-commonly referred to as Barileichkron and are typically made out of Barium Crown glass. BaK-4 prisms are generally considered to be optically superior to BK-7 prisms as they come with a higher refractive index (1.569) and that have an inherently lower critical angle compared to other types of commonly-used prism glass. The result is that that less light is "lost" along the prism's periphery through what is commonly called "non-total internal reflection." Also, when light is lost through non-total internal reflection, it causes blue-gray segments or "cutoffs" in the exit pupil. It's interesting to note that many Chinese optical devices have been found labeled as having BAK4 prism glass, which in reality is not the same as the Schott BaK-4 prism glass. The Chinese BAK4, contrary to popular belief, is in fact, not Barium Crown glass, but instead, is made out of a cheaper phosphate crown glass that has a medium range refractive index of approximately 1.5525 and a dispersion factor of  $-0.0452$  (Schott:  $-0.0523$ ). It also has a higher permissible bubble count rate than Schott BaK-4 glass. Remember, bubbles are notorious for scattering light.

*BK-7 prisms* are usually found in the cheaper commercial binoculars. Even though they are said to be good enough for use as binocular prisms, they are for example, still considered to be below the level of optical quality that are typically found in BaK-4 prisms. Prism optical glass quality will often vary widely between the various commercial binocular models. This is one of the many reasons why there is such a wide range in price that you will find in the stores that sell binoculars. The less expensive commercial binoculars usually come with the cheaper BK-7 prisms. When shopping around for a new pair of binoculars, if you look down the front objective lens of the binoculars, you can see the difference between BK-7 and BaK-4 (much better prism quality). If the binoculars are made with BK-7 prisms, if you look closely, you can actually see the BK-7 prisms with their squared-off sides. BaK-4 prisms present a more typical round somewhat circular shape, that

ultimately results in more light that is transmitted with an image quality that is much sharper to the eye.

*SK15 prisms* are very high-quality prisms made from SK15 glass that minimize undesirable internal reflections and thus provide a very crystal clear high contrast image.

A Schott 2007 refractive index comparison of the different prism glasses that are described above:

	Refractive index	Abbe number
BK7	1.51680	64.17
BaK-4	1.56883	55.98
SK-15	1.62296	58.02

As the index table of refraction above illustrates, BaK-4 glass has a higher refractive index than BK7 as well as a steeper light cone, which in turn enables the manufacturer to make a shorter, and more smaller compact binocular design than those that use the BK7 prism glass.

*Note:*

BK7 however has a higher Abbe number and therefore has a lower light dispersion.

SK15 glass is a good compromise between the two with a higher refractive index than BK7 and BaK-4, permitting a more compact binocular, but still has a lower light dispersion than the BaK-4 prism glass.

Amici prisms are in the group commonly called “roof prisms” or otherwise known as “right-angle roof prism” designs that are often used in today’s modern optics. An Amici roof prism was invented in 1860 by Italian astronomer Giovanni Amici and is similar to the Schmidt prism design. They revert and invert the image as well as bend the line of sight through a 90° angle. They bend a beam of light by 90° while at the same time invert the image. Roof prisms are excellent when used as prism diagonals in binocular and telescope optical systems, because they will erect an inverted image. They are also ideal for use in spotting scopes, and any optical instruments where it is desirable to take an inverted image from an objective lens, turn it right side up, and bend it through a 90° angle, to maintain the correct visual orientation. The various binocular body shapes that are typically offered commercially come in various somewhat different shapes that are often recognized and typically labeled by common three-letter codes: ZCF, BCF, BWCF, DCF, MCF, or UCF. Each of these three-letter codes typically represent an individual and even separate variation in the primary Roof prism or Porro prism designs.

Chromatic aberration which is also commonly called color fringing, achromatism, or chromatic distortion is a type of distortion or aberration in which an optical lens fails to focus all spectral colors where they converge. Chromatic aberration in binoculars and telescopes produces overall soft images, and color fringing adds edges with high contrast, similar to an edge between black and white. Described in another way, chromatic aberration is caused by the inability of a lens to focus different wave-lengths of light onto the exact same focal plane and/or by the lens magnifying various lights wavelengths differently. These

particular types of chromatic aberration are most commonly referred to as “longitudinal chromatic aberration” and “lateral chromatic aberration” and can often occur at one and the same time or more commonly referred to as “concurrently”. The amount of chromatic aberration in an optical system really depends on the inherent dispersion qualities of the glass. If you look at an image through a lens with chromatic aberration, color fringing may occur. To correct this, some higher-quality commercial binoculars use the more expensive, extra-low dispersion (ED) glass.

## The Importance of the Exit Pupil in Binoculars

Exit pupils are basically a virtual aperture or opening in a binocular’s optical system. In a typical pair of binoculars, the exit pupils can be seen in the center of the binocular eyepieces as two uniformly bright circles or discs of light while holding the binoculars at a short distance or at a normal arm’s length and pointing the binocular objectives toward a reasonably bright area. Another easy way to see the exit pupil is to first totally pull back or fully retract the rubber eye cups and then focus the binoculars onto an area that’s relatively bright. Then hold a white place card or piece of folded piece of paper up to the eyepiece, allowing the binocular eyepieces to project a small disk or relatively small circle of light onto the place card or white paper. Then move and position the place card closer to or further away from the front of the binocular eyepiece until you see a very small (the smallest) possible circle or disc of light. The overall diameter of the bright circle of light displaced by the center of the eyepieces is the actual diameter of the exit pupil. Note that the exit pupil should always appear to be round and circular and be of uniform brightness. If shadows are noticeably visible or present, this could be a possible indication of a binocular’s overall quality level, which is considered poor or even worst. The size of exit pupil and its importance in viewing with a pair of binoculars cannot be understated. Note that the exit pupil is an important item, because the larger the exit pupil diameter, the greater amount of light that will be transmitted to each of your eyes. It is therefore an important aspect when comparing the theoretical brightness of two optical instruments and that’s something important to consider when choosing your next pair of binoculars, especially for use in poor light conditions such as in the early dawn hours just before sunrise or dusk (sunset) and/or for astronomical observation. Another important thing to remember is that the larger the exit pupil diameter is, the brighter the field of view will be. This is an important consideration when using binoculars in dark and low light conditions and for astronomical viewing. The human pupil typically opens to about an average 2 mm or slightly larger during the daylight hours and about an average 7 mm in somewhat darken conditions or the night time. If you use a pair of binoculars with a 2-mm exit pupil in daylight, you will not be able to readily perceive the darker images. Also note there also will not be much noticeable overall variation or change in brightness whether you use binoculars with a 7-mm or 2-mm exit pupil.



### *Exit Pupil Math for Binoculars*

$$\text{Exit pupil} = \text{aperture} / \text{mag.} = \text{exit pupil dia. (mm)}$$

$8 \times 50$  binoculars — The equation is :  $50 \div 8 = 6.25$  > The diameter of the exit pupil is 6.25 mm

$10 \times 50$  binoculars — The equation is :  $50 \div 10 = 5.0$  > The diameter of the exit pupil is 5.0 mm.

$7 \times 56$  binoculars — The equation is :  $56 \div 7 = 8.0$  > The diameter of the exit pupil is 8.0 mm

The magnification and the diameter of the objective lens determine the size of the exit pupil. The diameter of the exit pupil determines how much light is transmitted to your eye. The actual diameter of the exit pupil is easily computed. Divide the diameter of the front objective lens (in millimeters) by the magnification of the binocular. For instance, take a pair of standard size  $7 \times 50$  binoculars. Divide 50 (diameter of the objective) by 7 (the magnification) and you get approximately 7 mm (7.143 mm), which is the diameter of the exit pupil for  $7 \times 50$  binoculars. When it comes to using a pair of smaller compact binoculars, the exit pupil of a pair of  $8 \times 21$  binoculars is only 2.63 mm (21 divided by 8 = 2.63 mm). A lot less light reaches your eye from compact binoculars than it does from standard size binoculars. Light is what you will be sacrificing if you want to get a pair of compact size binoculars. An important question often arises: Does the size of the exit pupil matter? Generally speaking, as long as there is enough ambient light so that the pupils of your eyes are smaller than the exit pupils of your binoculars, but when the ambient light becomes dimmer, and the pupils of your eyes start to accommodate for the change of light by enlarging, the exit pupils of your binoculars may become the limiting factor. Referring to the  $8 \times 21$  compacts in the example above, when it gets dim enough for the pupils of your eyes to exceed 2.63 mm in diameter, the binoculars are restricting the light available to your eyes. Ideally, human eyes in healthy condition can achieve about a 7-mm pupil opening. So a 2.63-mm exit pupil from your compact binoculars can be quite limiting in dim light. You can probably see more without your binoculars. But the  $7 \times 50$  binoculars in the first example above have 7-mm exit pupils, as large as young, fully dark-adapted human eyes, so they never limit what you can see, even at night.

As one ages, the human eye loses its ability to adapt to dimmer light, as a result, for a person who is middle aged, their maximum pupil size is typically around 5 mm. As we get older, the exit pupil size we normally need becomes increasing smaller with age. The relative brightness or more commonly called the relative brightness index (RBI) in a pair of binoculars attempts to measure image brightness. It is calculated by squaring the exit pupil. For example,  $7 \times 32$  binoculars have a 4.57-mm exit pupil (32 divided by 7 = 4.57). Their relative brightness index (RBI) is 22.88 (4.57 times 4.57 = 20.88). A relative brightness index (RBI) of 25 or greater is considered good for use in dim light. Since we already have discussed (above)

how to calculate the actual exit pupil size, and what it means, the relative brightness index (RBI) becomes largely redundant.

The twilight factor is a somewhat subjective measurement that purportedly reveals how much detail one observer can supposedly see in twilight conditions. It tends to favor magnification somewhat, which is good for binocular sales. For instance, Celestron computes the twilight factor of  $7\times 50$  mm binoculars as 18.7 and the twilight factor of  $10\times 50$  mm binoculars as 22.4, even though the former has a 7.1-mm exit pupil and the latter only a 5.0-mm exit pupil. The increased magnification supposedly makes up for the decrease in brightness in “twilight conditions” (when the individual’s eye is not yet fully dark-adapted). This rather somewhat artificial measurement can be useful for the average hunter and typical birdwatcher, since animals are often spotted just before sunrise and just after sunset.

Astronomical binoculars often use higher magnification as well as larger aperture. For example, Celestron  $25\times 100$  mm binoculars have a 4-mm exit pupil. Vixen makes binoculars with replaceable eyepieces, meaning the exit pupil can be any thing. A good pair of quality prism binoculars is very handy for locating objects in the night sky. Once an object has been located with binoculars, it is easy to train a telescope on it for a more detailed view. The binocular astronomer needs very high quality, very bright binoculars. For general hand-held use,  $7\times 50$  mm,  $8\times 56$  mm, and  $9\times 63$  mm binoculars will work very well. Choose the highest power that you can hold reasonably steady without a shaky image. Giant binoculars are in a class by themselves for binocular astronomy. These require a solid tripod mount, but reveal spectacular views of large objects like open star clusters. The  $20\times 80$  size is the most popular, and perhaps represents the best compromise between magnification, brightness, and field of view for general astronomical observing.

The larger the exit pupil, the less critical it becomes to align the binoculars to your eyes. When the light is dim, another effect of the size of the exit pupil becomes more important. Assuming two binoculars are the same power, the one with the bigger aperture will have the larger exit pupil. As the size of the exit pupil increases, the image appears brighter, up to the point at which the exit pupil is the same diameter as the pupil of the eye and the entire area of the pupil is illuminated. After that, further increases produce no real gain in brightness if any at all. As people age, the maximum opening of the pupil diminishes. The pupil of a healthy young person’s eye has a diameter of about 2 mm in bright light, 5 mm in dim, and 7 mm in the dark. People in their 30s typically have a maximum pupil diameter of about 6 mm, which shrinks to 4.5–5 mm in their 40s. Before evening, at dusk, people in their twenties would see a brighter image through  $7\times 50$  (exit pupil dia. 7 mm) binoculars than through  $7\times 35$  (exit pupil dia. 5 mm) binoculars, but persons in their 60s would perceive no difference. Some manufacturers give a “relative brightness index” that is found by squaring the size of the exit pupil in millimeters. The highest number allowed in this index is 49, since human pupils open no more than about 7 mm. Binoculars eye relief is the distance between the eyepiece and the point of focus of the exit pupil (see Fig. 7.6). Currently binoculars that are commercially available have eye reliefs ranging from 1 to 23 mm. The former (1 mm) is overly small. Eyelashes coated with cosmetics, such as eyeliner, may dirty and contaminate an eyepiece lens. Binoculars with large eye reliefs around 15 mm are needed by



**Fig. 3.2** Mr. Antony Kay and the 180 mm IJN binoculars, which have two-power eyepieces mounted on turrets that can be rotated to present the eyepieces for use. This binocular is 1.04 m (41 in.) long and weighs a hefty 64 kg (141 lb). Once serviced, this giant binocular was filled with nitrogen. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.3** Here is an example of a Carl Zeiss 3×20 mm Teleplast (Circa: 1907–1911) It has Sprenger prisms and triple element field lens. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.4** A French inter-war binocular of unusual porro prism construction mounted on a flat plane. It has no IPD adjustment. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.5** A rare binocular telescope after restoration in the OptRep workshop. It was made by G&S Mertz (Munich) circa 1850 and its specification is 10x (approx.) with 35 mm air spaced objective lens, a rack, pinion eyepieces and telescopic eyepiece tubes. Fully extended, 11 in. in length. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))

persons who wear eyeglasses while viewing. Even though the focusing adjustments of most binoculars can accommodate near and farsightedness, they cannot compensate for astigmatism. Some people prefer to wear their glasses while using binoculars, simply because they don't like taking them on and off while viewing (Figs. 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, and 3.10).



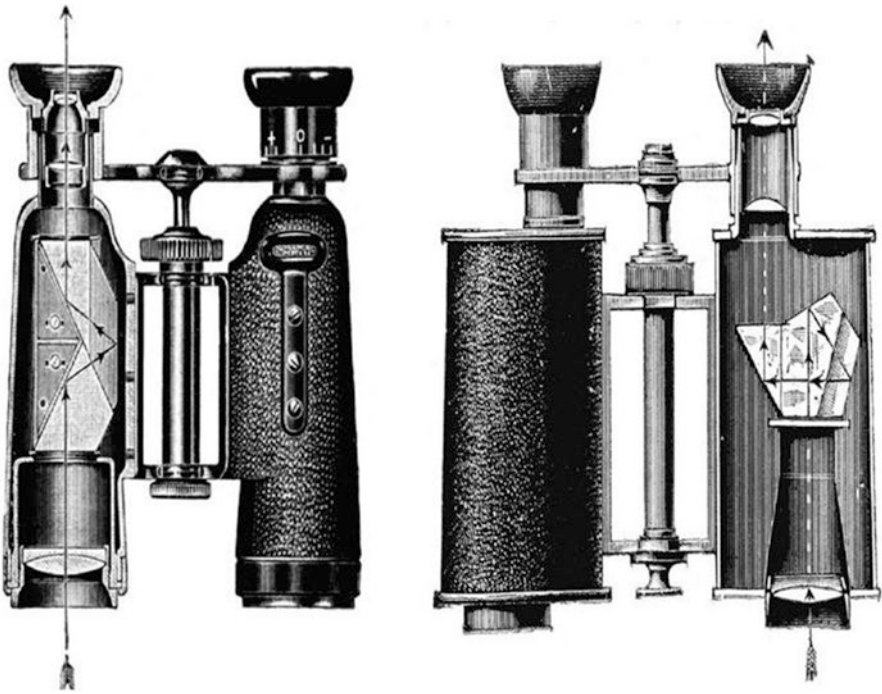
**Fig. 3.6** A Carl Zeiss 10×50 mm (left) “Dekar” (circa 1950) and a Hensoldt (right) 10×50 mm “Dialyt” of post war vintage. Both are collectables (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



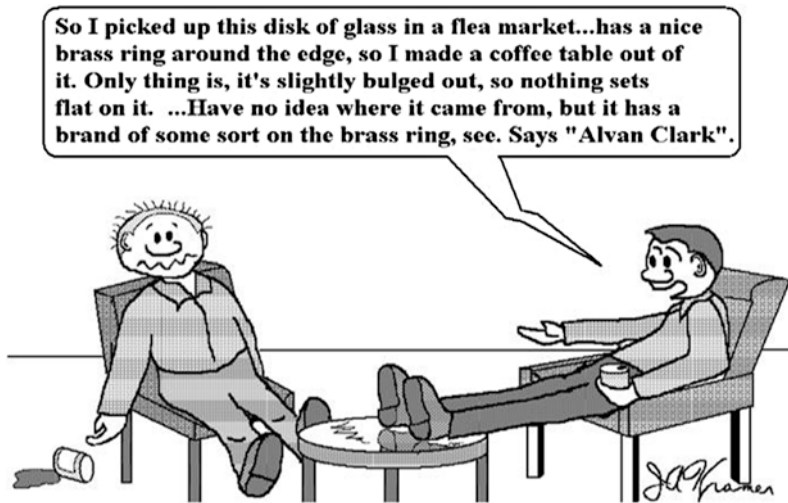
**Fig. 3.7** These are Russian “Intes Bi 152mm Maksutov-Cassegrain f/12” binoculars with 1-1/4 in. astronomical eyepieces and an adjustable IPD. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.8** A modern Fuji 40×150 mm “Meibo” binocular (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.9** Two pairs of the late-eighteenth century double prism binoculars designed by Montz Hensoldt (Image credit: Wikimedia Commons)



**Fig. 3.10** (Cartoon credit: Jack Kramer)

The evolution in binocular design has come a long way since the early part of the nineteenth century. However, the use of double-prism binoculars to invert and revert the images in a pair of binoculars of that era was not totally indifferent compared to today's common binocular prism designs. It's interesting to see what a pair of the late-eighteenth-century double-prism binoculars that were first designed by Montz Hensoldt in 1784–1797 looked like as they were the common binocular design that was introduced during that era (Fig. 3.9).

Author's note: Having seen firsthand the excellent optical quality images from the Intes Bi 152mm f/12 Maksutov-Cassegrain, one wonders why this rare dual Maksutov-Cassegrain binoscope setup wasn't produced commercially. That's how good this Russian Maksutov-Cassegrain really is. I can only envy the owner of the one pictured in Fig. 3.7.

## Binocular Mirror Mount

By Carl Vehmeyer

When I bought my 28×110 binocular in 2008, it was obvious that this instrument needed a big stable mount. The binocular weighs approximately 7 kg. Although I initially wanted to build a mirror mount for this binocular, I wasn't able to find a good enough mirror. In the end I build a parallelogram which worked fine but restricted observing to a maximum altitude of 60°. Also I found using a mount like this a bit uncomfortable, so a mirror mount remained on my wish list. When a friend started his own mirror-making company (Huygens Optics) last year, I asked him to make me a couple 160×120 mm flat mirrors. I had a lot of discussions with



**Fig. 3.11** Carl Vehmeyer made this splendid example of a binocular mirror mount. Notice the “trap door” for his binocular access to the sky (Image credit: Carl Vehmeyer)

friends about the required quality of the mirrors. In the end, it seemed that a PV of  $\frac{1}{2}$  lambda is more than sufficient for a  $28 \times 110$  binocular (Fig. 3.5).

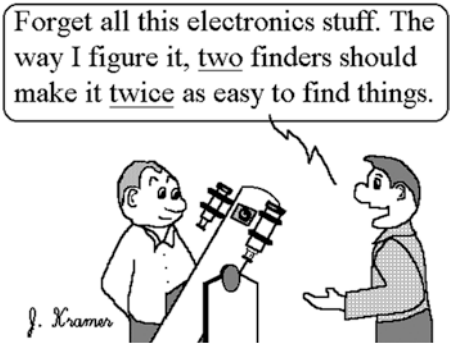
The mirrors were installed at a  $40^\circ$  angle. This way one can easily see the zenith and can observe as low as  $5^\circ$ . Lower didn't seem useful and by setting the angle at  $40^\circ$ , one could get away with smaller mirrors. The mirrors are glued to four-point mirror cells. Small ball magnets are used to attach the mirrors to the cells; this way the mirrors can be easily removed for transport. Both mirrors are tilted on different axes to collimate the binocular. The mirror box was constructed with 9-mm plywood. A 4-mm thick aluminum plate was used to reinforce the box where the binocular is attached to it. The plywood used for the mount was 12-mm thick. Since I didn't see the need for high-quality wood, the mount needed a fair bit of paint (Fig. 3.11).

I initially planned on using the mirror mount on a table, but a tripod seemed more practical when observing at remote locations. Since the surveyor tripod that I was using was a little high for use with the mirror mount I shorted it. I recently updated the mirror mount with a lazy susan bearing, so I could dispense with the tripod when traveling. Both the tripod en tablet top configuration are used and are equally effective. For aiming the mount I use a quick finder or laser pointer. The first views with the new mount were fantastic, its like rediscovering the night sky. Merging the images is a matter of seconds and observing with binoculars has never been this comfortable. The only downside to the mirror mount is that some objects look a different because of the flipped image. This is especially apparent when viewing the North America nebula. Personally I find that an advantage to this is that I seem to see new details in objects that I have seen many times before (Figs. 3.12 and 3.13).





**Fig. 3.12** Here is Carl’s drawing of his binocular mirror mount showing the dual mirror system (Image credit: Carl Vehmeyer)



**Fig. 3.13** (Cartoon credit: Jack Kramer)

Carl Vehmeyer  
The Netherlands

Adapted from “Binocular Mirror Mount” with permission from Carl Vehmeyer (<http://vehmeyer.net>)

## Downward Looking Binocular Mount

### *Why Build One?*

By Rob Nabholz

I have found binocular astronomy to be a lot of fun. It is a great test of observing skills and can be a way to do some observing at times or places where a more involved setup of equipment is not possible (Figs. 3.6 and 3.7).



**Fig. 3.14** A very nice, stable binocular mirror mount with a simple design (Image credit: Rob Nobholtz)

In observing with binoculars, I have found the experience much more rewarding if I can mount the binoculars. There are various methods of doing that, and I have played around with many of them. I came across the idea of a downward-looking mount using mirrors and liked the idea of comfort that looking down versus up would afford (Fig. 3.14).

I found a source for inexpensive first surface mirrors on the net and decided to build a mount.

There seem to be a couple of popular approaches to this type of mount. One uses a large mirror on a tilting platform. The advantage of that design is that the binocular eyepiece remains in a static position. The disadvantage is that it requires a rather large mirror to make it work, and “large” in this case also means expensive.

The second approach involves tilting the mount and binoculars together, allowing the use of the smaller, less expensive mirror. That is the path I took (Fig. 3.15).

### Construction

Main beam at a 45° angle and is also three pieces, but the center piece, extends up through the main beam and is secured by glue and the construction is quite simple. Most of the unit is constructed from ½" maple. The main beam is made from multiple pieces of maple glued and screwed together (mostly all of the screws are



**Fig. 3.15** This simple wooden binocular mirror mount setup looks good from all angles (Image credit: Rob Nabholz)

from the backside and are not visible in these photos). The downstalk joins the screws. The binocular mounting stalk is a single piece glued and secured between the outer pieces.

The mirror rests on a platform of plywood and is secured with multiple dabs of silicone adhesive. The platform is attached to the beam at a 45° angle by a short piece of maple that, like the bino mount stalk, is sandwiched between the outer pieces. It is secured in place by a ¼" removable bolt that allows removal of the platform, making it easier to store and pack.

The entire unit attaches to the tripod using ¼" 20 threaded insert in the bottom of the down stalk. It attaches to a pan and tilt head providing the movement necessary to scan the skies.

### Using the Mount: First Light

Out under the stars for First Light, things did not go as smoothly as I had planned. My favorite astro binoculars are Fujinon 16×70s, so I mounted them up and anxiously moved into the eyepieces. My first view was a jumble of fuzzy elongated stars. Quick check of the focus maybe a little better, but not even close to the tight pinpoint stars I was used to seeing with these binoculars. After some experimentation using different methods, including checking the binocular's collimation, I began to suspect that the mirror might not be optically "up to snuff." To check that theory, I

took off the 16× binoculars and mounted my Fuji 7×50s, and sure enough, the view was perfect. The mirror simply was not smooth enough to support the higher magnification of the 16×70s.

Since then I have mounted the 10× binoculars and enjoyed a very nice view, but I believe that magnification is about the limit for this mirror. A few months later, I noticed that the supplier (who was responsive and accommodating) has added some new products to his offering, mirrors rated to support higher magnifications (at a higher cost, as you would certainly reasonably expect).

### Other Considerations

Using this mount, I have found two points regarding tripod features that I consider essential for maximum enjoyment. First is a nice damped tripod head. A damped head makes scanning with the mount a real pleasure. The second essential feature is a tripod with an adjustable center post. Tilting the mount changes the eyepiece height. Having it mounted on an adjustable center post makes adjusting to the new eyepiece much easier.

One other point: using this kind of mount where I live means having to deal with dew. As you might expect, the mirror can accumulate dew quickly on some of our Iowa summer nights. Be aware of this and cover the mirror when not in use, or the other favorite dew fighting tactics like blowers or maybe a heating system.

Aiming the mount is a bit of a trick and takes some getting used to. I have recently been experimenting with a green laser pointer as an aiming device. Mounted parallel to the binocular's optical axis, when adjusted, the laser hits the mirror and points out the current center of the view, much easier than trying to "eyeball" it.

### Conclusions

I do enjoy using this mount. The downward look is quite a comfortable viewing. The mirror sometimes makes high magnifications impossible, so this is wide field, casual scanning—more of a "type b" behavior, just what the doctor ordered some nights when you feel like getting lost for a while (Figs. 3.8 and 3.16).

Rob Nobholz

Adapted from "Downward Looking Binocular Mount" with permission from Rob Nabholz (<http://www.homebuiltastronomy.com>)



“The Universe Before the Big Bang”

**Fig. 3.16** (Cartoon credit: the Author)

## Making of *Voyager*

By Wayne Schmidt

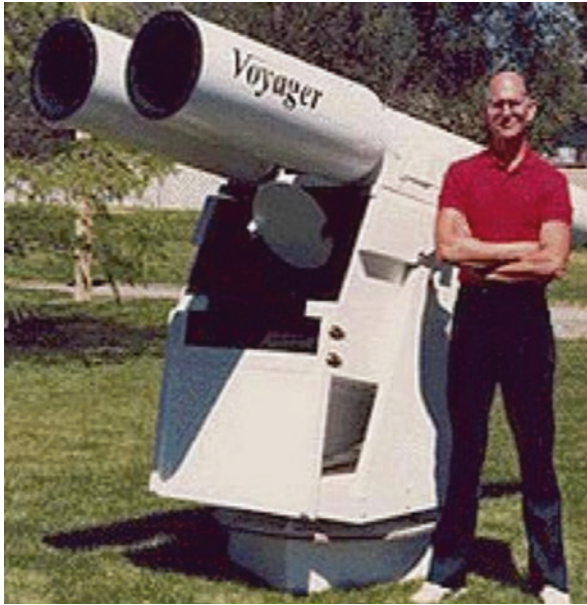
The design and construction of Wayne Schmidt’s motorized binocular chair for a pair of 8-in. diameter aperture binoculars.

Telescopes are great...as long as you don’t have to use them. Flat, one-dimensional views, straining to reach the eyepiece and fighting the cold all conspire to challenge even the most stalwart astronomy enthusiast. My solution to these problems was to mount a pair of large binoculars on a motorized chair complete with electrical heaters. I named it *Voyager* (Fig. 3.17).

I used large binoculars because they reduce eyestrain, increase light sensitivity by 40%, color sensitivity 25%, and most importantly provide beautiful three-dimensional appearing images.

The following photo image of Wayne Schmidt’s remarkable motorized binocular chair was taken at the 1995 Riverside Telescope Makers Conference (RTMC) at Camp Oakes. (Author’s note: It should be mentioned that Wayne won a merit award at the 1991 RTMC for “Interesting Concepts In Motorized Observer’s Chair”).

I used f/8.0 mirrors because they provided optimum compromise between light capturing capability, ease of fabrication, and image quality. By using a longer focal length than the usual 4.0–6.0 seen on most reflective binoculars, I was able to use smaller secondary mirrors and thinner spider vanes to reduce diffraction effects. Here’s what the optical path looks like: can look down into the observing area of the chair (Fig. 3.25).



**Fig. 3.17** Wayne Schmidt standing next to his 8-in. f/8 binocular telescope (image credit: Wayne Schmidt)

Unfortunately, one of the negatives of this design is that the image rotates as the tubes rotate. This means that the simple method of tube rotation for adjusting the interocular distance can't be used. Instead, right-hand tube is mounted on a cradle equipped with sideways push-pull screw pairs front and back to adjust eyepiece separation. For merging the images in both scopes, the left-hand tube was mounted on a cradle whose rear end could be moved left and right and the right-hand tube with a cradle that moves its end up and down by turning adjustment knobs located in the front of the chair. This way the observer can set the alignment while using the binoculars in the actual viewing position. This is important because unavoidable flexure resulting from tilting the 350-lb chair with a 170-lb rider can throw the alignment off. The ability of adjusting on the fly makes tuning up the alignment easy at any time. The pivot points for the tubes are set at the eyepiece positions so alignment doesn't affect the interocular distance. By removing the opaque overhead light cover, you can look down into the observing area of the chair (Fig. 3.18).

The eyepieces in the top set are 50 mm Plossls that provide 32.5 power with a  $1.4^\circ$  field of view. They are mounted on sliding carriages that allow the focus to be quickly adjusted for higher powers using a pair of 2.0 $\times$  Barlow lenses stretched to 2.8 $\times$  to provide 90 $\times$ . The eyepieces themselves lock into focusers made from flush valves. The smaller eyepieces are to a pair of very fine Adlerblick 7 $\times$ 50 binoculars. Their large field of view and erect image make them ideal finderscopes. Below that is a circular metal disk, which uses magnets to hold star charts in any desired



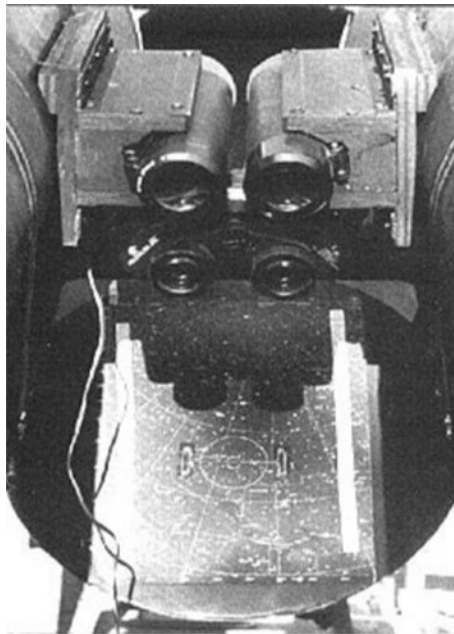
**Fig. 3.18** Wayne Schmidt standing next to his motorized 8-in.  $f/8$  binocular telescope at the 1995 RTMC (Image credit: Robert Stephens—RTMC)

position. In the middle of the star chart is a finder gauge consisting of two wire rings. The outer one corresponds to the field of view of the Adlerblicks, while the smaller inner circle matches the field of view of the 8-in.  $f8.0$  binoculars. The wire hanging down on the left is a low power resistive heater for both pairs of eyepieces to prevent dew formation. (Speaking of heaters, the chair has an electrically heated vest and boots to make sure the rider stays comfortable on even the coldest nights.) (Figs. 3.19 and 3.20)

To move the binoculars forward and backward or up and down to use different eyepieces or reach the finder binoculars, the frame that holds the binoculars is equipped with two motors. One, mounted on the back of the rider’s chair, moves the entire binocular assembly up and down using an electric motor driving a threaded rod through a captured nut. The 100+ lb weight of this assembly tended to grind down the nut and rod so it’s important to keep both of them heavily greased and protected from dust. For moving the binoculars back and forth, they were mounted on a pair of linear bearings, and a second motor/captured nut drive pushed or pulled them as needed (Fig. 3.21).

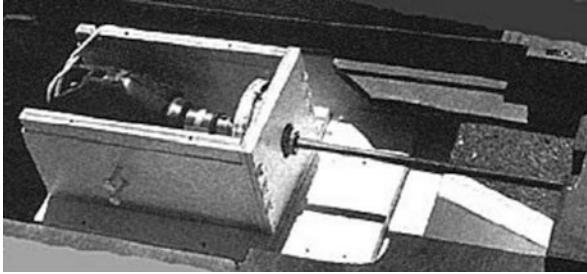


**Fig. 3.19** Wayne sitting at the controls of 8-in.  $f/8$  motorized binocular telescope at the 1995 RTMC (Image credit: Robert Stephens—RTMC)



**Fig. 3.20** Photo showing the dual eyepiece system of Wayne’s 8-in.  $f/8$  binocular telescope (Image credit: Wayne Schmidt)





**Fig. 3.21** Photo showing the motor drive unit that powers Wayne's 8-in. f/8 binocular telescope (Image credit: Wayne Schmidt)

The motor drive that moves the binocular carriage forward and backward is a cheap rechargeable drill with its handle cutoff. Three similar motors drive the other chair motions.

At this point, it's necessary to make a comment about safety. When the chair is tilted back so that the observer is looking straight up, if the binoculars broke loose, all 100+ lb of them would come crushing down into the observer's eyes. For this reason, it's necessary to have multiple safety measures in place to insure that if this ever happens, fail-safe mechanical locks prevent the observer from being injured. The same thing applies to all aspects of such chairs. When being ridden, the observer is essentially imprisoned, and every aspect of safety must be carefully considered and addressed.

The chair's frame was made of 3/4-in. plywood strengthened where needed with 2×4-in. lumber. Straight-grained, kiln-dried wood was used through to avoid warping. The altitude bearings are 2-in. diameter metal casters. I found they produced less drag and ran smoother than traditional Teflon bearing. The altitude drive consists of a rubber roller pressing against a sector arc covered with 30-grit sand paper. The rubber wheel is driven by an electric motor. (Note that because this was a friction drive, it is essential to keep the center of weight the same or the drive could slip. I found this to be the chair's biggest weakness because if a 170-lb rider shifts his position by only 2 in., he's creating 340-in. pound of additional torque, enough to cause the altitude drive to slip. I tried a bent-bolt drive, but it slipped even easier.) For this reason, it's difficult for other people much different in size to myself to use the chair. I have counterbalancing weights that can be used to compensate for this problem, but they are awkward to use.

Seating area of the chair is padded with a 5-in. thick layer of contoured foam to provide uncompromised comfort. The rotating part of the chair rests on a 12-in. diameter Lazy Susan bearing stabilized with four casters mounted near the edge of the circular base. A similar drive system rotates the chair, except the entire disk of the base is used so the chair can turn 360°.

Ordinary toggle switches on the right-hand armrest turn the motors on, off and control the direction of slewing. Additionally, there's a switch that puts a 1- $\Omega$ , 20-W resistor into the power circuit to reduce the slew rate from 3° per second to 0.5° per second. Power is provided by a 6-V, 140-Ah deep discharge battery that has enough stored energy to run the chair for five nights, even in sub-zero weather.

I made the mirrors myself. They both pass six-point Millies-Lacroix diffraction limit test and have smooth surfaces and good edges. The final focal lengths were 64 in. and 64.37 in., well within the 1% agreement needed for good binocular image merging. It took an extra 5 h of work to get the second mirror to match the first, but then these were the first mirrors I'd ever made. A more experienced mirror making could certainly do it in less.

I used three 2-square-inch pads of foam mounting tape to secure each mirror to its cell. These mounts have held for years and never shown any sign of straining the mirrors or coming loose. The mirror cells themselves were simply two disks of 3/4-in. plywood with push-pull adjusting screws set at 90°, rather than the usual 60°, for easier collimation.

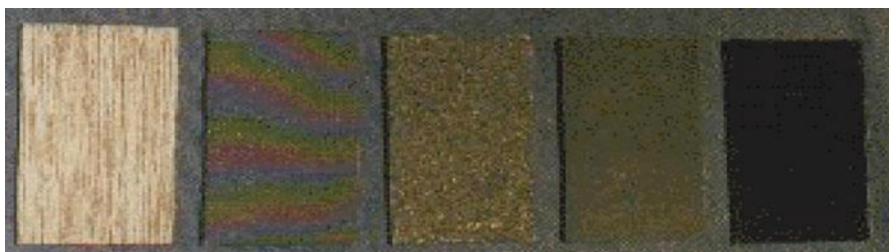
The secondary mirrors are 1.5 in. across and provide a 100% illumination field 20 min in diameter. Surveying 1866 astronomical objects indicated that this field would be large enough for 100% illumination of 95% of them. The illumination drop-off near the edge is unnoticeable. By using such a tight optical path, I was able to employ a better baffling system that increased the scope's contrast. In the end, using the smaller diagonals actually provided brighter, sharper images.

All three mirrors in each tube were coated with enhanced aluminum. This increased the overall reflection efficiency from 68% of normal coatings to 86%.

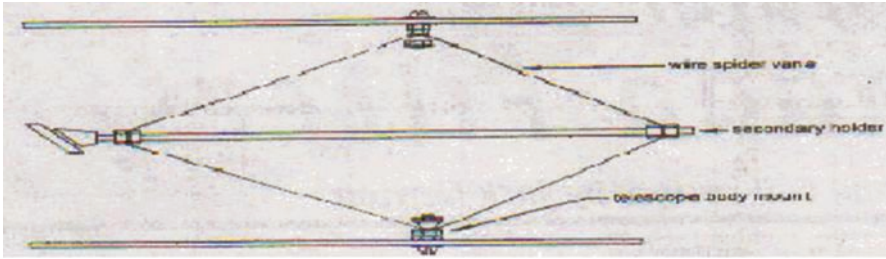
The tubes for each telescope were cut from 11-in. diameter concrete forming tubes purchased from Home Depot. Mounted on front of them are 15-in. diameter, 40-in. long baffling tubes used to reduce stray light from reaching the focal plane and reducing contrast (Fig. 3.18).

To decide how to coat the insides of the tubes, I conducted an experiment to see which surface treatment absorbed the most light. Above, from left to right, is flat black paint, black flocking paper, and sawdust sprayed with flat black paint, black cloth, and finally black velvet. The velvet was clearly the best so that's what I used (Fig. 3.22).

The four 0.02-in. thick spider vanes used in most telescopes produce very large diffraction spikes. To reduce this, I used a set of three vanes, which avoids spike reinforcement from in-line vanes, made of 0.008-in. music wire. The combined effect was to reduce the brightness of the diffraction spikes by 65%. While these



**Fig. 3.22** Photo showing the different colors/materials that Wayne chose from to reduce reflections inside of the telescope tubes (Image credit: Wayne Schmidt)



**Fig. 3.23** Drawing showing Wayne’s secondary holder design for his 8-in. f/8 binocular telescope (Image credit: Wayne Schmidt)



**Fig. 3.24** Photo showing what the actual secondary mirror system looks like (Image credit: Wayne Schmidt)

spikes are easily seen in normal scopes when looking at second magnitude stars, *Voyager’s* wire spiders don’t show them until you’re looking at first magnitude stars, and even then they are barely discernible. Here’s a cross section of what they look like (Fig. 3.23).

A jig was used to make each wire loop (This is necessary so the nylon nut and nut cap that holds the wire firmly to the side of the telescope tube yet with enough slip so it can be adjusted and a close-up of the end of the central diagonal bar showing how two nuts tighten on the wire’s end loops. The secondary position is adjusted closer or further from the primary mirror by sliding the wires through the nylon capture nuts mounted on the telescope’s tube. The secondary itself is foam tape mounted on a wooden block and can be rotated by turning it on the threaded rod screwed into it that forms the central spar of the diagonal. Finally, the entire wire assembly can be angled by sliding one wire through its nylon nut further than the other two. Collimation using this system isn’t easy, but the reduced diffraction losses are worth it, that they are all the same length (Fig. 3.24).

A word of warning: I found collimating a three-mirror optical path very difficult. There are so many rings within rings that have to all be concentric that I had a hard time keeping them straight and remembering what adjustment affected which ring. Fortunately, once the scopes were collimated, they tended to remain that way even after transporting them hundreds of miles in a car.

Originally the chair broke down into 10 manageable pieces. Assembly on-site took half an hour. However, it was a tight fit to pack it into my station wagon so after a year I rebuilt it onto a small trailer. Everything except the telescope cradle and telescope tubes was permanently fixed to it. This reduced setup time to less than 5 min. During transport I used wood wedges to raise the main chair off the Lazy Susan bearing so heavy bounces wouldn't flatten it. A white vinyl cover sewed to fit the chair protected it from weather. The only drawback to this was that it made the chair look like a construction site port-a-potty (Fig. 3.18).

So, how does it work? Outstanding! Besides the already mentioned advantages of binocular viewing, there is a very real psychological pleasure from physically looking in the same direction the telescopes are looking. One additional benefit I hadn't expected was the fact that when seated in the chair, the observer's head lays on a head rest. This immobilizes his head and therefore his eyes. By eliminating the small eye movements unavoidable when looking through a normal telescope, I found that images looked brighter, sharper, and much more concrete. I estimate that this increased the scope's limiting magnitude by at least half a magnitude (Fig. 3.19).

Large binoculars breathe life into astronomical views that must be seen to be appreciated, and riding a motorized chair in warmth and comfort enormously increases the joy of observing, creating a sense of identity with the objects inhabiting the night sky unattainable any other way. The Orion nebula becomes a huge glowing cloud ripped by valleys of stygian blackness. The Triffid's color can be clearly seen, and the swan looks so solid and three-dimensional it's hard to take your eyes off it. When riding *Voyager*, the universe comes alive, inviting exploration (Figs. 3.25, 3.26, and 3.27).

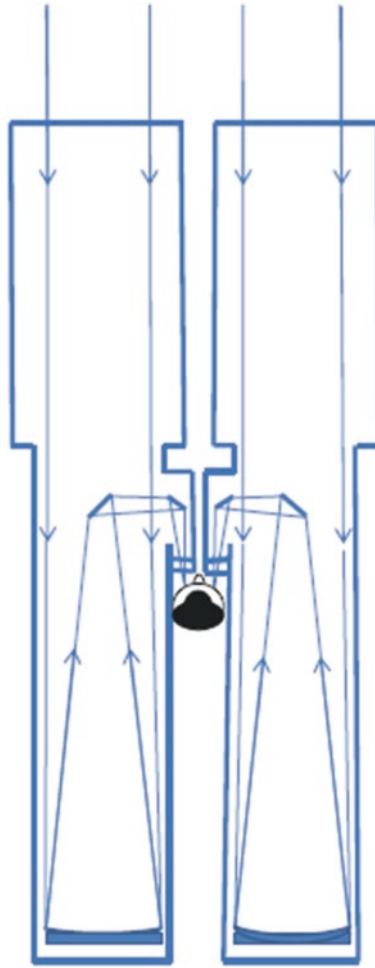
Wayne Schmidt

Adapted from "The Making of Voyager" with permission from Wayne Schmidt (<http://www.waynesthisandthat.com>)

## A GOTO Binocular Chair

By Norm Butler

Made from an old discarded IKEA semi-reclining chair, the author's homemade GOTO binocular chair has a pair of servomotors located on each axis, which enables the observer, while holding a Celestron hand controller, to select each object in the 40 K object database via NexStar 4SE software. With just a touch of the Celestron hand controller's button, the servomotor-powered binocular chair



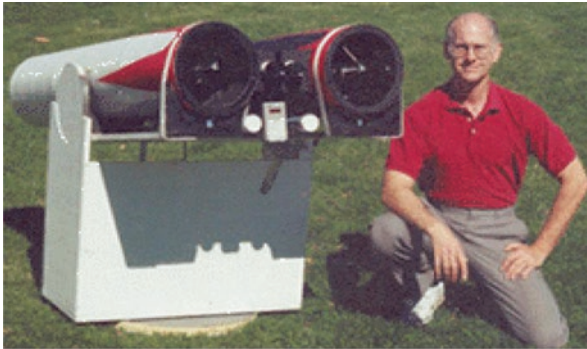
**Fig. 3.25** A diagram illustrating the optical path that coming light takes through Wayne’s dual 8 in.  $f/8$  motorized binocular telescope (Image credit: the Author)

moves to each selected celestial object that the observer chooses to observe sitting in complete comfort (Fig. 3.28).

The idea of a GOTO binocular chair had never occurred to me, much less the prospect of actually building one, until a gentleman at the RTMC a couple of years ago who was a wheel-chair-bound binocular astronomy enthusiast mentioned to me during a brief conversation that it would be nice to sit in a comfortable computerized GOTO binocular chair and push some buttons on a hand controller to aim the chair, user, and binoculars to desired objects. As challenging as the project would be, it was a fascinating idea of comfortably observing the heavens with no more effort than pushing buttons on a hand controller.



**Fig. 3.26** Photo showing how Wayne transports his motorized binocular telescope (Image credit: Wayne Schmidt)



**Fig. 3.27** This is what the newer version of Wayne’s original motorized binocular telescope looks like today (Image credit: Wayne Schmidt)

Having designed and built some pretty interesting telescopes in the past had pushed my electro-optical, and mechanical skills to the limit, but this one would probably be the most challenging of all of them. Still, once an idea takes hold, there’s no going back. While working at Haleakala Observatory on Maui for AVCO Everett Research Laboratory in the early 1980s gave me some great engineering experience, especially with then the state-of-the-art computerized systems that ran



**Fig. 3.28** The author's homemade GOTO servomotor-powered binocular chair (Image credit: the Author)

the big telescopes, at the same time I knew that even with today's advanced GOTO systems, it would be difficult to design and build a totally computerized GOTO bino chair. In considering the options, it was decided to not use big DC motors and chain or belt drives typical of motorized observing chairs, preferring instead to use small but powerful DC servomotors (torque monsters) wired in series to drive each axis, compact motors that can still produce enough torque to easily move a 200-lb person in both azimuth and altitude. The real challenge would be in finding the right kind of chair (reclining or otherwise) to do the job and thus eliminating first the typical "pitch-and-tilt" bino chair design with the observer's entire body being tilted forward and backward, often with feet raised overhead and head well below heart when the binoculars are pointed near zenith. This arrangement is familiar on some motorized bino chairs, and given the fact that the chair would be used to observe various assortment of celestial objects for extended periods of time, the feet-above-head arrangement just didn't appeal to me. I had searched for a while for a chair that could be easily modified and make it move with the same mechanical motion(s) as a typical Altazimuth GOTO telescope, where my body would be somewhat horizontal (at least leg and feet wise) while observing the heavens with my big binoculars (Fig. 3.28).

While dumping the trash one day, an old discarded IKEA chair was leaning next to the local trash bin. It's condition, even though a few years old, still appeared to be excellent. It was in good mechanical condition and worked splendidly as a semi-reclining chair. To make it into a fully reclining binocular chair, it would have to be



**Fig. 3.29** The GOTO binocular chair in the early stages of construction (Image credit: Astronomy Technology Today)

stripped down to its bare frame and remove some of the existing mechanical components (the semi-reclining slide bars on the bottom sides of the seat, for starters) and modify others to allow the backrest to recline fully, without tilting the seat portion. The first build step was to mount the chair on a rotating platform. After searching the Internet for swivel bearings, I found a 17.5-in. diameter ball-bearing swivel (Lazy Susan bearing) rated for a 500-lb load on eBay, ordered it and then found two 23.5-in. round wood tops at Home Depot. After purchasing them, I mounted the IKEA chair on top of a round wooden top with the big swivel bearing centered, sandwiched, and secured in place between the two wooden tops and then tested the assembly against my 200 lb. body, and it rotated a full 360° with very little effort (see Fig. 3.29).

After performing the initial rotation tests, it was the right time to replace the original 23.5-in. bottom plate for one that had a greater diameter for additional stability. Fortunately, there was an old 30-in. diameter 5/8-in. thick wooden table top that was not in use at the time, so it became the new bottom plate. It was important to be able to level the base, so three 3-in. diameter pipe flanges were secured in place on the bottom of the 30-in. diameter wooden table top, bolting them in place approximately 120° apart, each combined with a 1/2-in. diameter 2.5-in. long threaded pipe with a 3-in. diameter pipe flange mounted on the bottom of each one. A simple turn or two of the pipe flange(s) is all that's needed to level the chair assembly at most viewing locations. There is a metal handle mounted on each side on top of the bottom wooden base for lifting the assembly (see Fig. 3.31). After it was mounted, the IKEA chair was stripped down to its bare frame and removed all of the mechanical components that prevented the back from reclining fully to start rebuilding it from "scratch." As in any project, it's easier to do some of the more simple





**Fig. 3.30** The 17.5-in. dia. swivel bearing for the rotational base for the GOTO binocular chair (image credit: the Author)

things first, like modifying a portion of an ironing board leg stand to serve as a footrest frame and then attaching it at the four pivot points of the original chair frame. The next modification to the original chair frame was to remove the side slide rails that were bolted to the bottom side sections of the seat, replacing them instead with nylon wheels salvaged from a skateboard found at a local swap-meet (Fig. 3.30).

The next important thing on my “to do” list was to make a strong stable system for supporting a pair of big binoculars securely in front of the observer. Ironically, a few days later, when once again emptying the trash in our local trash container, a square-tubed rectangular metal frame with the right proportions was spotted next to the trash container. Looking upward and thinking, the “Gods” are with me on this project and to be honest, the author wasn’t even sure what the metal frame was originally designed for, but it looked like it could work just fine for the binocular support frame in terms of length and width. A few drilled holes and  $\frac{1}{4}$ –20 bolts were all needed to mount it securely to back of the chair in the position shown in Fig. 3.31. The use of a standard  $\frac{3}{4}$ -in. steel pipe and a four-way steel pipe connector for the rest of the binocular support system simplified the project without having to machine anything—to form a connector for the holder of the binocular support shaft, an 8-in. long  $\frac{3}{8}$ -in. diameter threaded steel bolt and the use of a big plastic knob on the top end to mount the binocular holder (see Fig. 3.34). The resulting binocular support system can be adjusted to accommodate the observer’s most comfortable head and eye position. The “U”-shaped support frame can be moved up or down by the observer no matter what position the back of the chair is in. It has a  $\frac{3}{4}$ -in. spring-loaded pipe lever with a handle on the observer’s right side that the observer can lift up or down to move the binoculars out of the way for entry into or out of the chair, aided by a counterbalance system on the rear section of the of

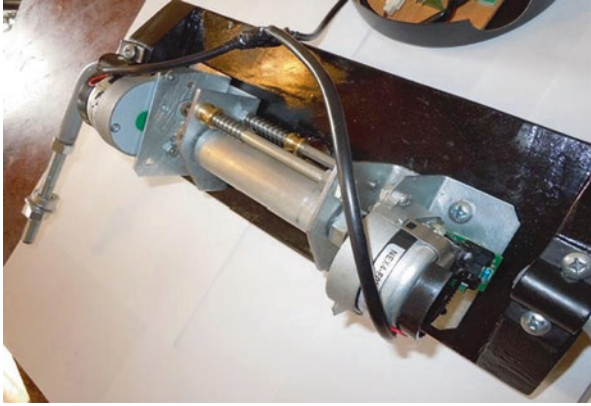


**Fig. 3.31** The IKEA chair stripped down and ready to reassemble into a GOTO Binocular Chair (Image credit: Astronomy Technology Today)

the support frame. It can accommodate up to three round weights of 6 lb each; weight can be easily added or removed to accommodate for the weight of small or large binos. With the back of the chair tilting forward and backward during slewing or in the full go-to mode, with the observer's weight pressing the front of the chair, a counterbalance system was made to accommodate for this weight shift, to make it easier for the two altitude servomotors to move the back of the chair via a steel cable drive. For this, a set of barbell plates mounted on each side was used and secured at the end of two 20-in. long by 3/4-in. diameter support bars, totaling approximately 30 lb (more can be added or removed if needed). The weight system support bar is attached to the bottom rear of the of the bino chair and can be easily removed for transport via two 3/4-in. male/female pipe inserts.

For the altitude drive, two NexStar 4SE servomotors were used combined with the Celestron Sky Align software and NexStar hand controller (see Fig. 3.35). The two altitude servomotors are wired in series/tandem (see Fig. 3.32) and together provide plenty of torque to move the back of the bino chair and the observer it supports to just about any position. From the beginning, I wanted to make the altitude mechanical drive system as simple as possible. For me, simplicity makes a much smoother, problem-free system to operate and maintain, and after it was completed, I did not want to have to go back and change it later if it became a problem to operate or if it performed inconsistently (Figs. 3.33 and 3.34).

The altitude drive system consists of an 11-in. tangent arm (equivalent to a 22-in. diameter drive gear) that pulls the back of the bino chair forward and backward via a 1/8-in. diameter stainless-steel plastic-coated steel cable that wraps/unwraps approximately 3.6 times (11.938 in. total length) around a 1.0-in. diameter steel roller via 36-tooth gears located on each end of the steel roller that in turn mates



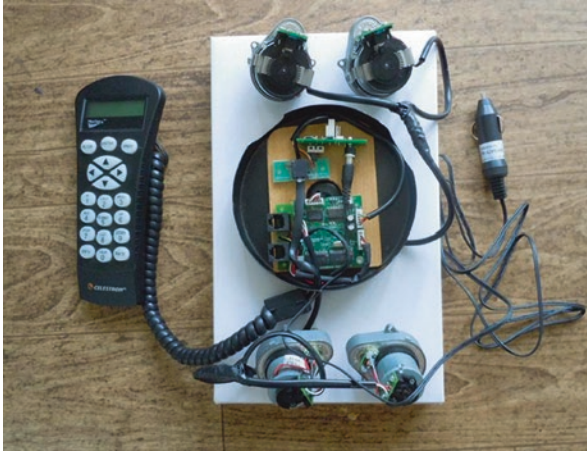
**Fig. 3.32** The dual altitude servomotor steel cable roller drive system for the GOTO Binocular Chair (Image credit: Astronomy Technology Today)



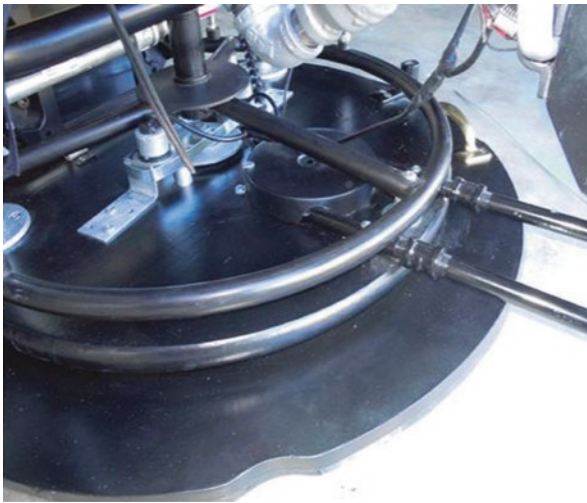
**Fig. 3.33** The rear of the GOTO Binocular Chair with the altitude dual servomotor drive system in place (Image credit: Astronomy Technology Today)



**Fig. 3.34** The binocular mounting and adjusting system for the GOTO Binocular Chair (Image credit: Astronomy Technology Today)



**Fig. 3.35** NexStar 4SE electronics, servomotors, and controller for the GOTO Binocular Chair (Image credit: Astronomy Technology Today)



**Fig. 3.36** The NexStar 4SE electronics package and azimuth drive for the GOTO Binocular Chair (Image credit: Astronomy Technology Today)

with the 16-tooth NexStar 4SE servomotor gear. The azimuth drive also uses two NexStar 4SE servomotors. Just like the altitude drive, the azimuth drive has both servomotors wired in series/tandem (see Fig. 3.35). The azimuth motors are coupled to 200-tooth 3.8-in. diameter gears (Fig. 3.36).

The NexStar 4SE Electronics Package. The entire GOTO electronics are housed in a small 6-in. diameter by 3/4-in. tall housing that fits neatly under the bino chair's

rear support arm and is secured with two metal clips (see Fig. 3.35). The servomotor connectors, the hand controller, and the power cord plug into the PCB electronic board are located inside of this housing, and the housing is made water proof thanks to a rubber seal that surrounds its base (see Fig. 3.36). Shown is the NexStar hand controller, two NexStar 4SE azimuth servomotors wired in series (bottom), two NexStar 4SE altitude servomotors wired in series (top), NexStar 4SE electronics package (middle) and remote 12-V plug for the Celestron Power Tank (top). The housing design permits easy access to the sealed electronics package when needed.

To better handle the torque produced by the twin servomotors, the mounting brackets were reinforced by using a couple of steel 1/8-in. thick right-angle brackets and a 7-in. hose clamp that wraps around both servomotors. Adding the big hose clamp really kept the servomotors tightly engaged in the 3.8-in. diameter azimuth drive gears. The altitude drive cable is secured at the back of the bino chair with a 1/2-in. thick aluminum plate secured in place on a U-shaped 1/2-in. pipe bracket and a 3/8-in. bolt that has a lengthwise hole through which the steel cable passes. The cable is secured with a strong spring and lock ring. The spring takes up any slop in the cable while it wraps/unwraps during go-to and slewing.

Using the GOTO Bino Chair for the first time was great fun. It takes all the work out of searching for objects of interest to view with your big binoculars. With the touch of a button, the chair slews you and your binoculars to the desired object and then keeps it centered and tracks while you view it from a comfortable, natural sitting position. A motorized bino chair is great, but a GOTO bino chair is even more fun, especially if you build it yourself. Any creative, resourceful ATM can design and build a similar system. All parts used in mine are readily available and affordable.

To set up the GOTO Binocular Chair for observing, the observer levels the binocular chair via the three leveling pads and then levels the binoculars and making sure the back of the binocular chair's seat is in 90° position and then makes sure that front (foot rest) of the binocular chair is pointed in the north direction. Using the Celestron hand controller, one can input the time, date, and location and then select the appropriate Sky Align program (e.g., One Star Align). Then it's just a touch of a button on the NexStar hand controller, and the binocular chair will GOTO to the selected celestial object of interest that is within the 15×80-mm binoculars 3.5° field of view. The observer is always sitting in a comfortable position, while the binocular chair tracks the celestial object(s) at the appropriate tracking rate. Other times one can just enjoy scanning the skies while slewing or "slowing" in the "azimuth" mode using just the hand controller. Also, just hang a thermos of coffee on one of the arm rests, pausing briefly for a sip or two every now and then to keep you going through a night's observing session.

Any creative and resourceful ATM can build a GOTO Binocular Chair because the parts to build one are out there and you can find most if not all of the major pieces of hardware at your local Home Depot or a hardware store. A motorized binocular chair with a joystick is great, but a "GOTO" Binocular Chair can be even more fun, especially if you build one yourself. All parts used in mine are readily available and affordable. So, why not give it a try?

Norm Butler  
Northern Marianas Islands

## The StarChair3000

The StarChair3000 is a commercial motorized binocular chair that can move the observer about both in the vertical and horizontal axis in complete comfort via a joy stick controller. This kind of chair would provide the observer with the ultimate kind of observing experience, especially with a big pair of Fujinon 150 mm×25 binoculars mounted in front of you (Fig. 3.37).

For the binocular astronomer who enjoys viewing the heavens in complete comfort in a motorized binocular chair, then the Sky Rover StarChair™ is for you. The author wanted to include the following information about this remarkable motorized binocular chair because it offers the binocular astronomer an excellent opportunity to enjoy sitting in a completely motorized binocular chair and moving to all parts of the binocular sky using a joystick controller sitting in complete comfort.

Being a binocular astronomer to some degree myself, I was fortunate enough to have seen and used the StarChair3000 on more than occasion, and each time I was more than impressed with its capabilities and operation. Consider the following



**Fig. 3.37** The StarChair3000 is a commercial motorized binocular chair manufactured in Australia. Note: STARCHAIR NOW is temporarily in suspension. A new improved model underway. If all goes well (Image credit: [www.starchair.com](http://www.starchair.com))

“Noted” comments on my part, an informative review about an exciting product for binocular astronomy.

The Sky Rover StarChair™ is a very well-designed robust portable motorized binocular chair that allows the observer to view the night sky through a variety of front-mounted binoculars of different sizes and magnifications.

Using a simple joystick, the observer can rotate the chair on its base through a full 360° and at the same time move the chair from the horizon to zenith in a smooth fashion. As a result, the binocular observer can view the entire heavens in seated comfort with the use of the hand-held joystick controller. The addition of optional computer Sky Vector hardware allows the StarChair™ binocular observer to quickly and easily position any one of several thousand celestial objects in the binocular field of view. The StarChair™ revolutionizes the use of binoculars for viewing the night sky.

The Sky Rover StarChair™ is powered by a standard 12-V motorbike battery or car battery. The binocular observer uses a joystick to control the motion of the chair. The motorized chair has a variable speed, low power motor that rotates a central worm gear and a unique altitude actuator that act together to move the chair in the desired direction. There is no slippage while traversing, nor directional backlash or flexing on halting. As a result, binocular images always remain steady.

The design ensures the electronic wiring does not suffer umbilical cord fouling. This allows base rotation beyond 360°. Binoculars are held rigidly in place as part of the chair, but remain fully adjustable to allow an observer to tailor the position of the eyepieces to their individual body height and size. The Sky Rover StarChair™ is constructed from high-quality materials and components. It is designed for outdoor use and will not deteriorate if left outdoors for extended periods of time. User safety has been a paramount goal from the initial design stage. The resulting StarChair™ design puts safety first and instills user piece of mind. The construction is very strong—will not break—and easily supports 1000 lb of weight! StarChair™ 3000 model is basically composed of three easily manageable components that fit together in around 3 min ready for use. The main base section is only 26 in. wide and can be conveniently carried through any standard doorway.

The StarChair™ weighs only 45 lb and can be lifted by most average users. The seat section is light weight and is quickly inserted into the main base. The material of the specially designed seat is made from laser cut 6-mm thick extremely strong aluminum plate and quite rigid, yet light weight. It can easily support 1000 lb! The inside width of the seat is 20 in.

The plush thick upholstery is ergonomically contoured and covered with appealing UV-treated navy blue velour material. The front posterior upholstery is so “obtusely rounded,” there is now no need for a foot rest. “Under-the-knee section” is now just so comfortable. The third section is the new heavy-duty back hook bar and binocular head attachment. This new designed section is now capable of supporting all large binoculars from 70-mm up to the giant 150-mm Fujinons, totally adjustable to cater to all sized stature observers. A hand-held supplied joystick will control the speed and direction to all points of the celestial dome. Maximum speed is around 8° per second! Minimum speed is around 1 min of arc per second! Both axes can be

activated simultaneously! That is, chasing and centralizing fast moving satellites is possible and exhilarating. So are fast moving aircraft. Sky divers and Glider aircraft are also suitable for close observation, using the variable speed joystick and StarChair™ combination in complete steady reclined luxury comfort.

When it comes to computer control, the StarChair™ has very accurate inbuilt fittings in its design, so that standard optical encoders will quickly snap on to StarChair™. The optical encoders will give a full read out of positions of the celestial dome as well as feedback to most PC programs that will show where the StarChair™ is pointing. Deep-sky objects can then be accessed by using the “Guide To” or “Identify” function mode. When it comes to its portability, the StarChair™ will fit into any small sedan and be driven to any dark sky site. The StarChair™ setup time is approximately 3 min! And packing it up after an observing session is also about the same amount of time. The StarChair™ has extensively field tested this factor many times and finds this as one of the most favorable features of the motorized chair, especially, in cold weather climates, which makes it a great plus for deep-sky observing! StarChair’s power supply is curtailed by the need to have a “safe and secure” simple use of a 12-V dc car battery. This low power requirement using a 12-V dc power supply is a nice comfort to have when observing with temperatures hovering around 5° or less and at a “remote” dark sky site! A simple 9 A per hour dc battery will easily control the StarChair™ all night, and even the next night! And even the third night before recharging the battery, which only takes about 3 h. This is a very nice situation for the users. StarChair™ is advanced in this situation. In fact, at extreme locations, a small “solar power” cell can recharge during the day!

Note: Star Chair is temporarily in suspension. A new improved model underway. If all goes well ([www.starchair.com](http://www.starchair.com)).

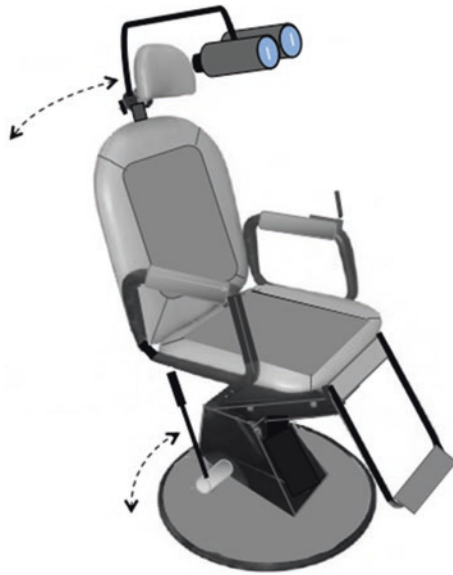
## A Motorized Binocular Chair

For those who enjoy observing the heavens in complete comfort while using a big pair of 100 mm or even larger big binoculars, consider the use of a motorized exam chair that can be converted and modified into a motorized binocular chair. A new, used or refurbished exam (or ophthalmic chair) could become your dream motorized binocular chair project (Fig. 3.38). There are also many resources on the internet where you can purchase a reasonably priced one.

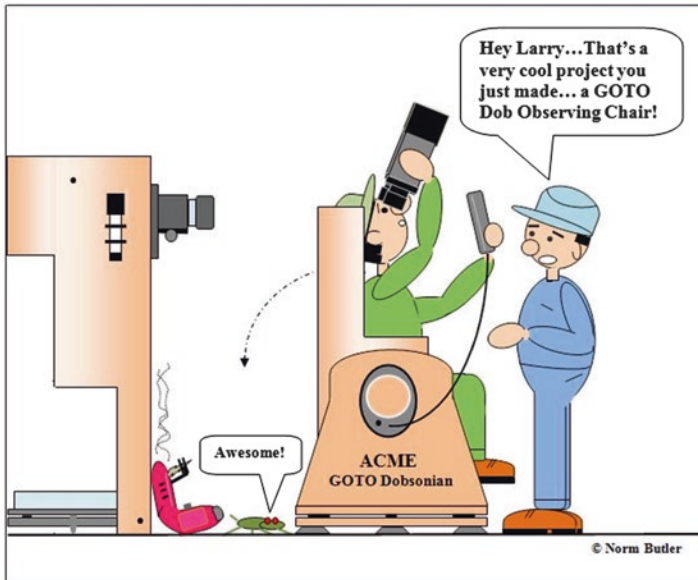
One additional component that could be added to your chair is a “Joy Stick” that is wired into the original existing electronics of the motorized binocular chair. The “Joy Stick” can normally be found at any electronic store or website. Even the use of a foot pedal electrically attached to the foot rest would serve as a convenient way to move the motorized binocular chair in the desired direction. If you are thinking about progressing to a new level of binocular astronomy, consider a refurbished exam or ophthalmic chair for your next ATM astronomy project.

Let’s see what kind of project our two favorite ATMs Larry and Gordon are working on these days (see Figs. 3.39, 3.40, 3.41, 3.42, 3.43, 3.44, 3.45, 3.46, 3.47, 3.48, and 3.49).



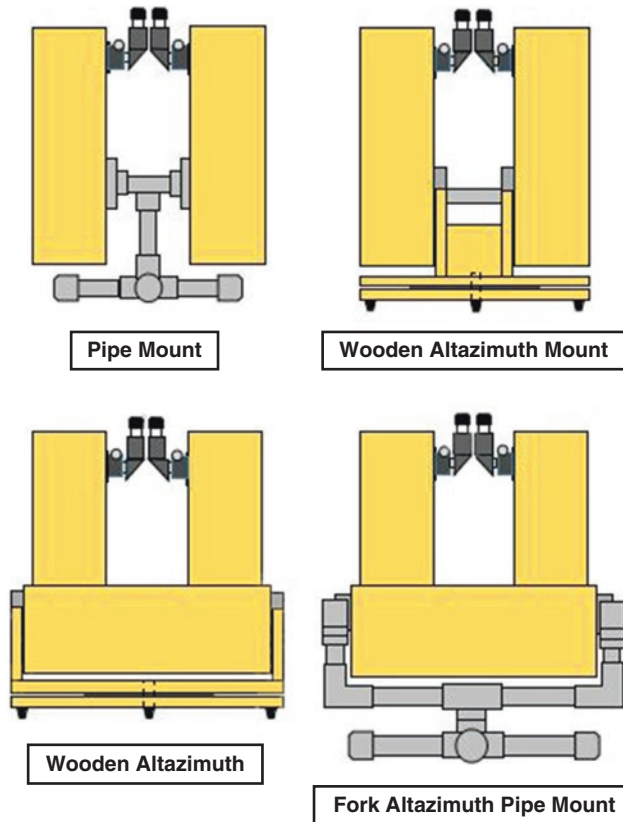


**Fig. 3.38** An illustration of an exam chair converted into a motorized binocular chair (Image credit: the Author)



**Fig. 3.39** (Cartoon credit: the Author)

### Simple Altazimuth Mounts for Binocular Telescopes



**Fig. 3.40** Four examples of wooden and Altazimuth pipe mounts that can be simply made for a homemade binocular telescope. Note: Drawings are not to scale and are presented in this chapter for illustration only. (Image credit: the Author)



**Fig. 3.41** Rollei 7×42 fixed-focus binoculars were based on the British AVIMO 7×42 mm made in a rubber-armored form during the 1980s for British troops, police and NATO forces. The Rollei version was intended for civilian use (hence the attractive silver finish) although they still have the military graticule. Today, the Russian BELMO factory in St. Petersburg makes copies of this fine binocular. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.42** A rare Carl Zeiss 5+10×24 mm “Marine-Glas m.Revolver” dual power turret binocular (circa 1896–1904). It was known as the “Admiral Togo Glass” because the commander of the Japanese in the Russo-Japanese war of 1904–1905 used this particular binocular. The construction of the body, objective lens cells and the method of securing the prisms are all similar to those used in the famous single power ‘Feldstecher’ binoculars. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.43** A Carl Zeiss 12–20–40×80 mm turret binoculars (Asembi) was used in WW1 and WW2 by the Kriegs marine. The design remained unchanged with one of the few changes being that the air-spaced objective lenses were eventually replaced with cemented ones in the later models. The prism housings can be swiveled to change the IPD and also be swung outwards to allow two observers to use it as two separate telescopes observing the same target. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



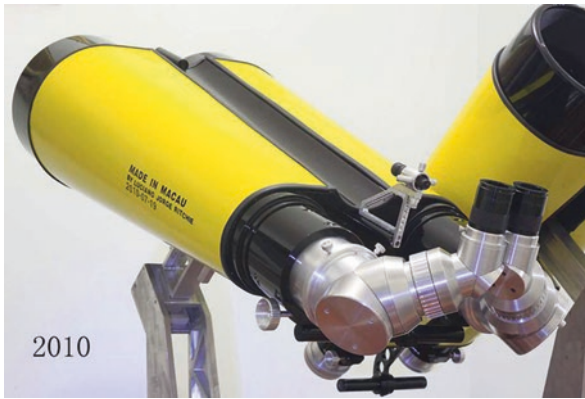
**Fig. 3.44** A British AVIMO warship binocular, type G389/1 fitted with electrical heaters and internal filters. These binoculars, which have many unusual features along with the smaller G386/3, were the last types designed by AVIMO before the company was drawn in by Thales. This type of binocular is used by the Royal Navy and the navies of many other countries. (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.45** A tiny Carl Zeiss 3.5×15 mm prismatic “pocket” binocular (Image credit: Antony Kay—OptRep—[www.opticalrepairs.com](http://www.opticalrepairs.com))



**Fig. 3.46** Folding opera glasses made out of brass and Mother of Pearl (Image credit: Public Domain—Wikimedia Commons)



**Fig. 3.47** A splendid looking giant pair of homemade 203 mm giant binoculars (Image credit: Luciano Jorge Ritchie of Macau)



**Fig. 3.48** NGC 7635, which is often called the “Bubble nebula”, in the constellation Cassiopeia (Image credit: Sara Wager—[www.swagastro.com](http://www.swagastro.com))

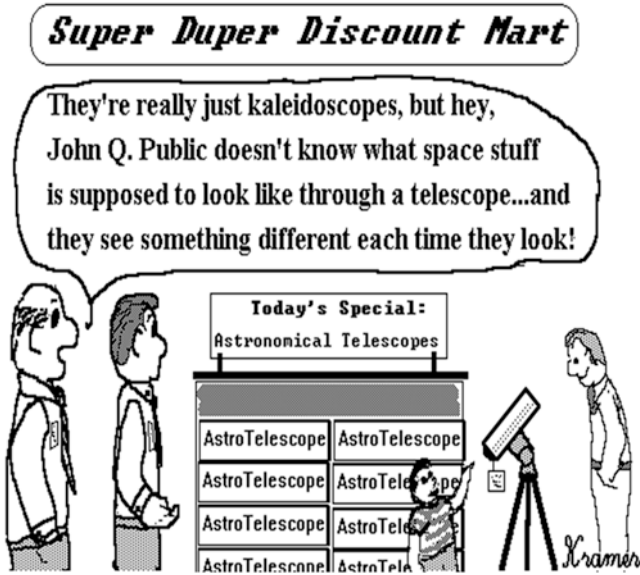


Fig. 3.49 (Cartoon credit: Jack Kramer)

## Further Reading

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