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A Buyer's and User's Guide to Astronomical Telescopes & Binoculars

James Mullaney, F.R.A.S.

Springer

James Mullaney
Rehoboth Beach
Delaware
USA

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Preface

In Robert Frost's famous poem *The Star-Splitter*, he states that someone in every town owes it to the town to keep a telescope. I would take that a step further and say that someone in *every home* should have one! For without these wondrous instruments, we are out of touch with the awesome universe in which we live. I have no doubt that Frost himself would have agreed with me, for he was an avid stargazer throughout his long life.

The book you're holding in your hands will make it possible for you to be that someone who has the vision and curiosity to own a telescope. It will help answer such questions as: "Should I buy a new or used telescope?" "Can I make one myself?", "Which type is best?", "What size should I get and how much should I spend?", "How much power do I need?", "What can I see with it once I get it?", and "Do I really need a telescope or will binoculars suffice?" These are all important concerns – and ones that should be addressed before plunging into the purchase of any instrument intended for stargazing.

This book contains two main themes. One deals with the different kinds of astronomical telescopes and binoculars, and recommended sources for them. The other tells you how to use them once you possess them and what to look at in the sky.

Perhaps this is as good a place as any to explain what we mean when we describe an instrument as "astronomical." This term relates to its optical quality. While just about any telescope will show the features of the Moon's alien landscape, the four bright jewel-like satellites of Jupiter, and perhaps even the majestic ice-rings of Saturn, there's an amazing difference in the views seen of these and a host of other celestial wonders through a precision optical system compared with those in one of poor or mediocre quality. Most binoculars and low-end "spotting grade" telescopes are designed with terrestrial use in mind rather than celestial. The optical precision needed to produce razor-sharp views of the Moon and planets and pinpoint images of stars is an order of magnitude above that required for ground-based observing. Since binoculars are normally used at very low magnifications (typically 10× or less), optical aberrations are not nearly as critical an issue for them as they are for a telescope with its correspondingly greater magnifications (typically 50× and higher).

For many readers – particularly those who are already somewhat familiar with telescopes and binoculars, as well as with their use – the greatest value of this book may well prove to be the extensive compilations in Chapter 8 and Chapter 9 that provide handy references to the principal manufacturers and sources for these instruments. Here you'll find standard mail and Internet web-site addresses, telephone numbers (in most cases), and an overview of types and models offered. Since new or upgraded instruments are constantly being added to many manufacturers' lines, you'll be able to get information and specifications on the very latest available models, current prices, and delivery times through their catalogs and other literature (both on-line and printed copies).

Distilled in this volume is the author's more than 50 years of experience in making, designing, selecting, testing – and especially using – literally thousands of different sizes, types, and makes of telescopes. These have included refractors from 2- to 30-inch (!) in aperture, reflectors from 3- to 60-inch, and compound catadioptric scopes from 3.5- to 22-inch in size, employed both for casual personal observing and (in the case of the larger apertures) for research work as well. And after all those instruments and all those years, I'm as excited about telescopes and stargazing as ever!

It should be mentioned here that this present book is *not* intended to be a comprehensive treatise on all the intricate technical aspects of telescope and binocular optics – nor is it intended to be an all-encompassing guidebook on their use in astronomy. (References are given throughout for those who do wish to dig deeper into these areas.) Its purpose, instead, is to offer readers a condensed, trustworthy treatment of these topics that is sufficient to make informed decisions on the selection and use of these instruments – but general enough to not overwhelm them. And although I discuss telescopes costing many thousands of dollars, I also cover ones priced at around a hundred dollars. Stargazing can indeed be a very affordable pastime! If you are new to the field, it's best to start with a basic instrument of good quality (especially optically) and then in time graduate to a larger and/or more sophisticated one if desired. Despite all the varied types and sizes of instruments I've used over the years, my most pleasurable observing experiences still continue to be those with a 3-inch short-focus refractor at 30× and a 5-inch catadioptric telescope at magnifications of 40× to 100×. Each of them, used on an interchangeable, lightweight but sturdy altazimuth mounting with smooth slow-motion controls and wooden tripod, weighs in at less than a dozen pounds. Another long-time favorite instrument is a very portable 6-inch reflector on a basic Dobsonian mounting.

It's my sincere wish that, whatever level your present familiarity and experience with telescopes and binoculars may be, if you read this book carefully you will be able to select a quality optical instrument ideally suited to your particular needs and intended purposes. And more importantly, that it will also lead you to the ultimate use of these marvelous devices – whether binocular or telescope, new or used, large or small, inexpensive and basic, or costly and sophisticated – viewing the wonders of the heavens in a way that will excite, enrich, and ennoble your life, as well as that of others!

James Mullaney
Rehoboth Beach, Delaware
USA

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There are many people in the astronomical and telescope manufacturing community who have helped to make this book possible. The companies listed in the tables in Chapters 8–9 have kindly supplied the resource information given there on their products, as well as images of selected instruments in many cases. Special thanks must go to Orion Telescopes & Binoculars, which has generously supplied me with images of many telescopes, binoculars, and accessories typical of those widely used by amateur astronomers today.

I am also indebted to Dennis di Cicco, a Senior Editor at *Sky & Telescope* magazine and long recognized as one of the world's most experienced astrophotographers, for the use of previously unpublished images from his private collection. And California astroimager Steve Peters also kindly supplied many of his personal images for use in this book.

Dr John Watson, FRAS, Dr. Mike Inglis, FRAS, and my editors at Springer – Nicholas Wilson in the London office; Dr Harry Blom, Louise Farkas, and Christopher Coughlin in their New York office – have all been most helpful and a sincere pleasure to work with on this, my second volume for this truly world-class publisher.

And finally, I wish to thank my dear wife, Sharon McDonald Mullaney, for her encouragement and continued support of my ongoing mission of "celestial evangelism."

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Part I

Buying Astronomical Telescopes and Binoculars

CHAPTER ONE

Introduction

More Than Meets the Eye

This book is offered as a no-nonsense practical guide to the selection and use of telescopes and binoculars for stargazing. But these devices should not be looked upon as yet more gadgets to add to our collection of modern technical possessions. Rightly viewed, they are truly magical instruments, for they are literally "spaceships of the mind," "time machines," and "windows on creation" that allow their users to roam the universe in what is surely the next best thing to actually being there!

These lines from William Wordsworth convey something of the excitement that seeing a telescope aimed skyward typically evokes:

> What crowd is this? what have we here! we must not pass it by;
> A Telescope upon its frame, and pointed to the sky.

As you work your way through the many specifications and recommendations contained in the following pages, keep foremost in your mind the wonder of what you're ultimately dealing with in the selection and use of these wonderful devices. To help maintain this perspective, you may want to turn to the concluding chapter from time to time and reflect upon its contents.

New Versus Used Equipment

While this volume focuses on the selection and use of commercially made and available telescopes and binoculars, something should be said about used equipment. Often, a telescope or pair of binoculars can be found on the second-hand used market for a fraction of its original cost new, making it possible to own an instrument that you might otherwise not be able to afford. But the down-side of this is that you have no guarantee of its optical or mechanical condition unless you can actually see and use it before making the purchase. For items bought online over the Internet or by mail, this is not normally possible. In such cases, a substantial deposit should be offered the seller, with the balance to be paid after receiving and inspecting the instrument (and with the clear understanding that the deposit will be refunded and the instrument returned should any problems be found). The ideal situation is to purchase used equipment within easy driving distance – and preferably from a member of a local astronomy club – where you can inspect and use it before buying. Aside from examin-

Figure 1.1. Given good optics, even a small telescope can provide a lifetime of celestial viewing pleasure for people of all ages. Shown here is the ubiquitous 2.4-inch (60 mm) refractor, which has long been (and continues to be) the most common telescope in the world. Courtesy of Edmund Scientifics.

ing the tube assembly and mounting for any mechanical damage, you must also carefully check the optical performance using a test like that described later in this chapter.

Among the most sought-after used telescopes are:

pre-1980 model Unitron refractors (especially the 2.4- and 3-inch)
Criterion Dynascope reflectors (especially the 6-inch)
Cave Astrola reflectors (all models)
Optical Craftsmen reflectors (especially the 8-inch)
Fecker Celestar (4-inch reflector)
early models of Questar's 3.5-inch Maksutov-Cassegrain

Mention should also be made of the legendary classic "antique" refractors by such optical masters of the past as Alvan Clark, John Brashear, and Carl Zeiss. With the exception of Unitron and Questar, these firms have been out of the telescope manufacturing business for years, making their instruments true collector's items. If you happen to own one of these gems already – or have an opportunity to purchase one used and in good condition – consider yourself extremely fortunate!

Making Your Own

As with purchasing used equipment, something also needs to be said about the alternative of making a telescope yourself. (Binoculars are not considered here, for their prices are typically so much lower than that of a telescope and their assembly from scratch so much more involved that it's scarcely worth the time and effort to attempt doing this.) And here we need to differentiate between *making* a telescope and *assembling* one. The former involves the time-honored but equally time-consuming art of fabricating the optical components (typically the primary mirror for a reflector and the objective lenses for a refractor). With quality optics mass-produced by machine widely available and reasonably priced today, most "telescope makers" opt for the latter, purchasing the optical components and building the rest of the instrument. This is especially true in the case of the immensely popular, large-aperture Dobsonian reflectors covered in Chapter 5. (A great resource here is Richard Berry's *Build Your Own Telescope*, Willmann-Bell, 2001.) But as a former telescope maker myself, I can attest that there is no thrill quite like viewing the heavens through an instrument that has optics made entirely with your own hands! If you want to go this route, there are many excellent books on grinding, polishing, and testing the mirror for a reflecting telescope. An old standby is *Making Your Own Telescope* by Allyn Thompson, which was reissued by Dover Publications in 2003.

Figure 1.2. The author shown at the age of sixteen with his 6-inch equatorially mounted Newtonian reflector, entirely home-made (including its parabolic primary mirror). Today, most "telescope makers" opt for purchasing commercial optics and mounting them in an instrument of their own construction (typically as a Dobsonian reflector, especially for larger apertures). Photo by the author.

Optical Testing

Whether you purchase a telescope new or used, or make one yourself, you simply *must* know how to test its optical performance! Many sophisticated methods of doing this have been developed over the years by both astronomers and telescope opticians – including Foucault, Ronchi, Hartmann, and interferometric laser testing. But there is one very simple, convenient, and sensitive test that's easy to perform almost anywhere and at any time – even in broad daylight. Known as the *extrafocal image* or *star test*, it uses the image of a star as the test source. This can be either a real one in the night sky or an artificial one produced by shining light through a small pinhole. The latter is especially useful for testing optics in the daytime. (An alternative here is to use the specular reflection of the Sun off the chrome bumper of a car in the distance, or off a glass insulator on a power line; this produces a bright beam of light that is essentially a point source.)

The test is simplicity itself. If you're working with a real star, choose one that's neither too bright nor too faint. An ideal choice is Polaris (α Ursae Minoris), the Pole Star. Not only is it of an ideal brightness but it also offers the great advantage of not moving due to the diurnal rotation of the Earth during testing – a real plus if you're using a telescope without a motor drive! Using a medium-magnification eyepiece (one giving about 20× per inch of aperture), first place the star at the center of the eyepiece field and bring it into sharp focus. Next defocus the star, by going either inside of focus or outside of it, and examine the image. You should see a circular disk within which are concentric rings of equal brightness. (If using a reflector or compound telescope, you will also see the dark silhouette of the secondary mirror at the center of the disk.) Now move an equal distance on the other side of focus. Should you see an identical-looking disk and ring pattern in both positions, congratulations – your telescope has essentially perfect optics! (The technical term for this is *diffraction limited*, meaning that performance is limited solely by the wave nature of light itself rather than the quality of the optical system.)

If optical defects are present, they will readily reveal themselves in the extrafocal image. For example, should the image be triangularly shaped on either side of focus, you have pinched optics. This usually means that either the primary mirror of a reflector or the objective lens of a refractor is mounted too tightly in its cell. This can typically be remedied by loosening the mirror clips in the former case or backing off on the retaining ring in the latter one. If you see an elliptically shaped image that turns 90 degrees as you reverse focus, you have a serious condition known as *astigmatism*. However, before putting the blame on your primary optics, make sure that this isn't in the eyepiece or your own eye! Simply turning the eyepiece in its focusing tube will show if it's the former, while rotating your head will show if it's the latter – in either case, as evidenced by the turning of the ellipse with it.

Figure 1.3. The out-of-focus (extrafocal) image of a star can reveal many things about a telescope's optics (as well as about its thermal environment and the state of the atmosphere) – in this case, the alignment of the optical components. The image in the left-hand panel reveals gross misalignment. That in the middle panel shows moderate misalignment (still enough to degrade image quality), while the image in the right-hand panel indicates perfectly collimated optics.

There are other symptoms to look for. Concentric rings that have a jagged or shaggy appearance to them indicate that the optical surface is rough (typically resulting from rapid machine polishing) rather than smooth. Rings that vary in thickness and brightness rather than being uniform in appearance indicate zones (high ridges and low valleys) in the optical surface. Rings that are bunched together and skewed into a comma-shaped image indicate that the optics are misaligned. The extrafocal image can also tell you something about the state of the atmosphere (a rapid rippling across the disk being seen on turbulent nights), the cooling of the optical components (eerie, snake-like plumes moving across the image until the optics reach equilibrium with the night-time air temperature), and the thermal environment of your observing site (waves seen like those rising from a pavement on a warm day).

You should perform this test not only when you buy an instrument but also frequently afterward, in particular to check the optical alignment, or *collimation*. This is especially critical in reflectors and Schmidt-Cassegrains, which can often be thrown out of collimation simply by moving them from place to place. With the exception of well-made refractors and Maksutov-Cassegrain systems (both of which are essentially permanently aligned, owing to the way the optics are mounted in their cells), shipping a telescope is often enough to throw the collimation out. Once learned, the adjustments are relatively simple to perform (especially for a Newtonian reflector) and will make a significant difference in the image quality that you see at the eyepiece.

The finest reference ever written on the subject of extrafocal image testing is Harold Richard Suiter's *Star Testing Astronomical Telescopes* (Willmann-Bell, 1994). It offers an exhaustive treatment of the subject and contains a wonderful array of extrafocal images showing various optical conditions that may be seen at the eyepiece of a telescope. (It should be mentioned here that once binoculars become out of collimation – as evidenced by seeing double images! – they require the services of a professional optician and special alignment jigs to correct, owing to the complex light paths through several trains of prisms.)

CHAPTER TWO

Binoculars

Seeing Double

It's commonly recommended that, before you buy a telescope, you should first get a pair of binoculars. And with very good reason! Not only are such glasses much less expensive, very portable, and always ready for immediate use, but they can also provide views of the heavens unmatched by any telescope. This results primarily from their incredibly wide fields of view – typically 5 or 6 degrees (or 10 to 12 full-Moon diameters) in extent compared with the 1-degree fields of most telescopes, even used at their lowest magnifications. There are also ultra-wide-field models that take in a staggering 10 degrees of sky. Binoculars are ideal for learning your way around the heavens and for exploring what lurks beyond the naked-eye star patterns.

But there's another aspect of "seeing double" (as binocular observing is sometimes referred to) that makes these optical gems unsurpassed for stargazing. And that's the remarkable illusion of depth or three-dimensionality that results from viewing with both eyes. This is perhaps most striking when observing the Moon, which through binoculars looks like a huge globe suspended against the starry background – especially during an occultation, when it passes in front of a big, bright star cluster such as the Pleiades or Hyades. See also the discussion in Chapter 13 about apparent depth perception when viewing the Milky Way's massed starclouds with binoculars (or with the unaided eye). Finally, aesthetics aside, it's been repeatedly shown that using both eyes to view celestial objects improves image contrast, resolution, and sensitivity to low light levels by as much as 40%!

Specifications

A binocular consists essentially of two small refracting telescopes mounted side-by-side and in precise parallel optical alignment with each other. Between each of the objective lenses and eyepieces are internal prism assemblies that serve not only to fold and shorten the light path, but also to provide erect images. (Inexpensive "imitation binoculars" such as opera and field glasses use negative eyepiece lenses instead of prisms to give an erect image, resulting in very small fields of view and inferior image quality.)

The spacing between the optical axes of the two halves of a binocular (known as the *interpupilary distance*) can be adjusted for different observers' eyes by rotating the tubes about the supporting connection between them. If this spacing isn't properly set to match the separation between your eyes, you will see two overlapping images. In this same area is a *central focusing* knob that changes the eyepiece focus for both eyes simultaneously. An additional *diopter focus* is provided on most binoculars (typically on the right-side eyepiece) to compensate for any differences in focus between the two eyes. Once this adjustment has been made, you need only use the main focus to get equally sharp images for both. Some lower-grade binoculars offer a rapid-focusing lever; although this allows for quick changes in focus, the adjustment is too coarse for the critical focusing required when viewing celestial objects.

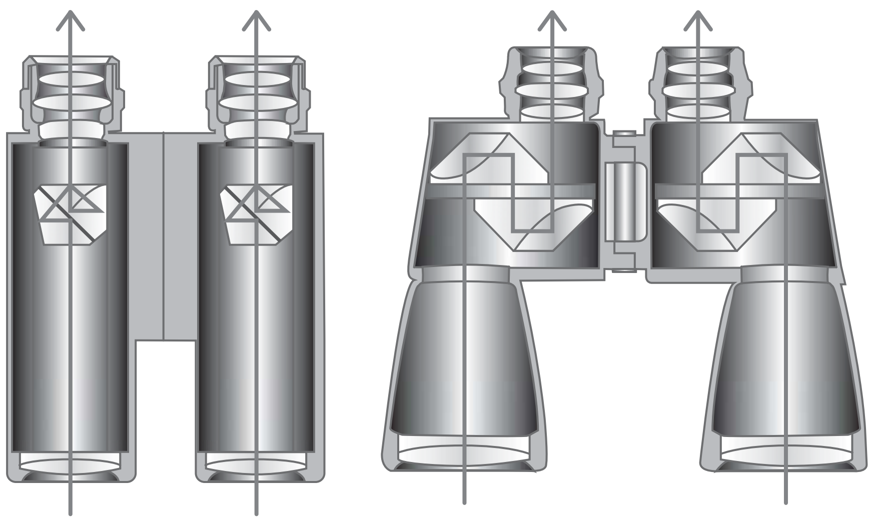
Two numbers are used for the specification of a binocular. The first is the *magnification* or power (×), followed by the *aperture* or size of the objective lenses in millimeters (mm). Thus, a 7 × 50 glass magnifies the image 7 times and has objectives 50 mm (or 2 inches) in diameter. Another important parameter is the size of the *exit pupil* produced by a binocular, which is easily found by dividing the aperture by the magnification. This means that 7 × 50 binoculars produce bundles of light exiting the eyepieces that are just over 7 mm across. (These bundles can be seen by holding a binocular against the daytime sky at arm's length. You'll find two circles of light seemingly floating in the air before you.)

The pupil of a fully dark-adapted human eye dilates or opens to about 7 mm, and so in theory all the light a 7 × 50 collects can fit inside the eye. (This binocular is the famed Navy "night glass" developed long ago by the military for optimum night vision.) But in practice, not only does the eye's ability to open fully decrease with age, but light pollution and/or any surrounding sources of illumination reduce dilation as well. Only under optimum conditions can the full light grasp of a 7 × 50 be utilized. Thus, a better choice for astronomical use is the 10 × 50, which gives a 5-mm exit pupil and slightly higher magnification, improving the amount of detail you can see.

A 7 × 35 or 6 × 30 binocular also provides a 5-mm pupil, but these smaller sizes have less light-gathering power and resolution than does a larger glass.

Another feature of a binocular to look for is its *eye relief*. This is the distance you need to hold your eyes from the eyepieces to see a fully illuminated field of view. It ranges from less than 12 mm for some models to over 24 mm for others. If the relief is too short, you'll have to "hug" the eyepieces to get a full field of view, and if too long you may have difficulty centering the binoculars over your eyes. A good value is around 15 mm to 20 mm, especially if you wear glasses – if you do, longer eye reliefs are preferred over shorter ones. Note that if you wear glasses simply to correct for near- or far-sightedness (rather than for astigmatism), you can remove them and adjust the focus to compensate. Most binoculars today have fold-down rubber eyecups to enable you to get closer to the eyepieces if necessary; these also keep your eyes from touching the glass surfaces and (depending on style) help keep out stray light.

While just about any size of binocular can be and has been used for stargazing, the 7×50 and 10×50 are the most popular choices among observers. (See also the section on giant binoculars later in the chapter.) Moreover, 10× and 50 mm are about the highest magnification and largest aperture that can be conveniently held by hand; more power and/or bigger sizes require mounting the binocular on a tripod in order to hold it steady. (It should be mentioned here that *zoom binoculars* are also widely available today. While offering a range of magnifications with the flick of a lever, these generally have inferior image quality and fields of view that change as the power changes.) Good stargazing binoculars in the size range above are available for under $100 from a number of companies, including Bushnell, Celestron, Eagle Optics, Nikon, Oberwerk, Orion, Pentax, and Swift. (See Chapter 8 for contact information on these and many other manufacturers.) Prices for premium astronomical glasses typically run between two and three times this amount.



Roof prism binocular *Porro prism binocular*

Figure 2.1. Optical light path through a roof prism binocular (left) and a Porro prism binocular (right). Although bulkier than the former, the latter is preferred for astronomical viewing because of its superior image quality.