QUESTAR®
The Optical Innovators

CHOOSING A TELESCOPE

There was a time when the choice among telescopes was simple, even if the instruments themselves were heavy and awkward to use. Today the conflicting claims of the manufacturers of so many different telescopes make it difficult to discriminate among them. In this paper we discuss the chief types of commercially available telescopes and suggest why the Questar® is a unique solution to this opportunity of choice.

REFRACTING TELESCOPES

Refracting optical systems are either achromatic or apochromatic; the first brings two colors to a common focal plane and the second brings three. The major weaknesses of refracting telescopes are the result of their long destabilizing barrel length and their significant chromatic aberration. Both achromatic and apochromatic optical systems have a destructive effect on the ability to create images of high quality. The classic solution is to increase the focal length in order to reduce secondary color. This is a poor solution for the amateur astronomer; it increases the barrel length, which, in turn, demands a heavy and expensive mounting. Therefore, it is difficult to transport and assemble. In the past few years advances in materials technology with the development of low dispersion and fluorite glasses allow manufactures to improve chromatic aberration to about one eighth (⅛th) the aberration of an achromat and, at the same time, reduce the barrel length by about one half (½).

The materials used in a modern apochromat optical system are very fragile. Fluorite has a crystalline structure which is prone to fracture. Such material cannot be heated to the temperatures required to deposit magnesium fluoride or dielectric coatings, and, instead, is "cold-coated" with a far less permanent result or even left uncoated as the interior surfaces often are. Fluorite is also hygroscopic (absorbs moisture) and the surface figure may gradually degrade. A microscope manufactured from fluorite materials is always stored with a desiccant; this precaution is taken even with use under far less hostile conditions than a personal telescope must withstand.

Three further points of interest; first, take a look through an apochromat and notice a glow around the object you are observing. This is longitudinal color, which occurs on-axis and causes the effective focal length of the telescope to change with the wavelength of light. Although these lenses focus three wavelengths of light, the halo which you see is defocused light at wavelengths to which the eye may be less sensitive, but will still see; second, consider the negative effects of the long barrel of a refractor. Its large overhang inevitably results in a less than stable optical system, susceptible to vibration transmitted through the ground and by wind. Each time you touch the telescope, the recovery time is far greater than that of a short barrel instrument; third, as with any telescope the most unstable air you are required to look through is in the telescope itself. A tube length of thirty-two inches (32") may cause four times the internal turbulence of a Questar 3.5 with its eight-inch (8") barrel.

The argument used to counter the presence of these easily observed difficulties in a refractor is the presumed optical effect of the central obscuration in a Catadioptric system. The milky appearance of the background sky sometime associated with Catadioptric telescopes is not the effect of the obscuration. This milky appearance is the result of inadequate baffling and the dispersion of light within the glass of the correcting lens. If you compare the background sky through a Questar and through a good refractor you will see that the background sky of both is black.

The central obscuration causes a light loss to the system of about 10%. This amounts to less than two tenths ($2/10^{ths}$) of a stellar magnitude! Unless the sky transparency conditions are perfect, the difference in overall image quality and contrast is impossible to see.

Even under hypothetically perfect seeing conditions, the loss of *light* energy needs to be considered relative to the secondary color in a refractor which will be present under all seeing conditions. As an article in the March 1992 issue of *SKY and TELESCOPE* puts the matter, "The conventional wisdom about refractors being better than reflectors has definitely been overstated. Perhaps this is because reflectors with marginal optics have been compared unfairly with well made refractors. "From my observations," says Douglas George, author, "the difference between an excellent refractor is very subtle." One must consider this along with the fragility of the optics, the long barrel length, and the chromaticism inherent in the apochromatic design. At the same time, the major effect of the obscuration is that, in fact, it *increases* the fine resolution of the optics, resulting (with a superbly manufactured Catadioptric lens like the Questar) in the easy exceeding of Rayleigh's Criterion and the Dawes Limit for the limiting resolution of a lens. (If the refractor you are comparing with a Catadioptric lens of the same aperture is not significantly better than 1/4 wave total throughout, the loss of energy will be the same or more, but without the increase in resolution).

CATADIOPTRIC TELESCOPES

The Schmidt-Cassegrain telescope is a distinguished design with superb performance characteristics; however, it is a very difficult design to manufacture. The correcting lens of the Schmidt is designed with a complex fourth order curve that must be painstakingly and very accurately ground. Deviations from the prescribed curve cause a falloff in the wavefront accuracy of the optic with very little room for error. One of the highly significant breakthroughs in Maksutov's design was his achievement of the correction for spherical aberration using a spherical curve, which is far easier to grind. The thinness of the meniscus of the Schmidt, on the other hand, compounds the difficulty since grinding on one side of the corrector warps the already completed figure on the other. It is no surprise that one very rarely sees Schmidt's fabricated by amateur telescope makers.

Why can numerous manufacturers offer Schmidt telescopes at low prices? Ignoring the issue of mechanical quality which becomes apparent when you compare Questar with any other commercially available telescope, the chief economy introduced results from approximating the fourth order curve of the true Schmidt by drawing the corrector with a vacuum, which, in effect, reduces the complex curve to a sphere. This major compromise makes telescopes of reasonable quality available to many people. The economy is further suspect, however, since the secondary mirror, which is a part of the curve of the corrector in a Maksutov, is a separate component in the Schmidt, and must be ground and figured separately. The collimation of the telescope also requires the additional step of collimating the secondary, an additional cost to the manufacturer. (Incidentally, the presence of a separate secondary causes Schmidt to go out of collimation, and require frequent re-collimation by the owner. The Questar is *permanently collimated*). Considering the fact that a professional quality Schmidt is significantly more difficult to manufacture than a Maksutov, and that a commercial grade Schmidt can still be purchased for less with more than twice the aperture, there has clearly been a relaxation of the optical and mechanical tolerances.

Manufacturers of Schmidt have made claims such as "defraction-limited one-tenth ($1/10^{th}$) wave optics." This claim should not be made for *system* performance but for *component* performance. Questar components test individually and typically at one-twentieth ($1/20^{th}$) or better wave, in order to produce one-eighth ($1/8^{th}$) wave front system we strive to achieve for each telescope. A Schmidt telescope with tenth (10^{th}) wave optical components can produce a system performance of close to one-half (1/2) or better wave.

Commercial manufacturers of Schmidt have marketed the great advantage of a larger aperture, and have gone so far as to suggest that a larger aperture in itself will produce better resolution than smaller. That assumption is open to serious question. When you observe you are, in effect, looking through cells in the atmosphere. Their turbulent effects are largely invisible as long as the cone of light entering the telescope is smaller than the physical dimensions of the cell; the 3.5 inch aperture of the Questar was determined with this fact firmly in mind. With mediocre viewing conditions, the larger aperture can become a liability to good seeing; this is one reason most owners of the Questar Seven® also own a Questar 3.5® for their regular use. When you compare the larger aperture instruments offered by commercial Schmidt manufacturers, the argument about resolution and aperture size is thoroughly discredited. We do not make comparisons with specific brands of telescopes, but we encourage you to compare performance. We regularly receive comparisons of the Questar 3.5 with eight-inch (8") aperture Schmidt. Questar telescopes routinely outresolve them for all the reasons, which we have mentioned.

One way in which the larger aperture does outperform the smaller is in its ability to grasp light. Yet, if you compare a larger Schmidt with the Questar 3.5, the image although brighter in the larger telescope exhibits less contrast. This is the result of a poorly baffled and less precise optical system with additional light scatter from the corrector lens. Light outside the focussed light cone of the image has entered the telescope and washes out the light-to-dark transitions. When you observe a planet, the details of the subtle striations of color are lost, and when you observe an object against the background of deep space the subtle features are reduced to a fog. The last word in this argument about aperture comes when we compare the image of the Questar Seven with that of an eight inch (8") Schmidt. In spite of the slightly smaller aperture of the Questar, the eight inch (8") Schmidt does not remotely compare to the Seven Inch Questar in contrast, brightness and resolution.

Over and above these discussions of difference in design, there are numerous mechanical and design features of the Questar, which make it more than just a Maksutov. They are the reason why Questar telescopes go into outerspace, why they are used in every major industry and government agency. A Questar telescope is on permanent display in the Eastern Museum, as well as the Museum of Science and Industry. We hope that the information in this paper puts you in a better position to make a critical evaluation of what is available to you and that most of all you make the ultimate test and compare a Questar carefully with any other telescope in the market.

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