Pleasures of the Telescope

By

Garrett Serviss

PREFACE

By the introduction of a complete series of star maps, drawn specially for the use of the amateur and distributed through the body of the work, thus facilitating consultation, it is believed that this book makes a step in advance of its predecessors. The maps show all of the stars visible to the naked eye in the regions of sky represented, and, in addition, some stars that can only be seen with optical aid. The latter have been placed in the maps as guide posts in the telescopic field to assist those who are searching for faint and inconspicuous objects referred to in the text. As the book was not written for those who possess the equipment of an observatory, with telescopes driven by clockwork and provided with graduated circles, right ascensions and declinations are not given. All of the telescopic phenomena described are, however, represented in the maps. Star clusters are indicated by a conventional symbol, and nebulæ by a little white circle; while a small cross serves to mark the places where notable new stars have appeared. The relative magnitudes of the stars are approximately shown by the dimensions of their symbols in the maps, the smaller stars being represented by white dots and the larger by star-shaped figures.

In regard to binary stars, it should be remembered that, in many cases, their distances and angles of position change so rapidly that any statement concerning them remains valid only for a few years at the most. There is also much confusion among the measurements announced by different authorities. In general, the most recent measurements obtainable in 1900 are given in the text, but the observer who wishes to study close and rapid binaries will do well to revise his information about them as frequently as possible. An excellent list of double stars kept up to date, will be found in the annual Companion to the Observatory, published in London.

In the lunar charts the plan of inserting the names of the principal formations has been preferred to that usually followed, of indicating them only by numbers, accompanied by a key list. Even in the most detailed charts of the moon only a part of what is visible with telescopes can be shown, and the representation, at best, must be merely approximate. It is simply a question of what to include and what to omit; and in the present case the probable needs of the amateur observer have governed the selection--readiness and convenience of reference being the chief aim.

It should, perhaps, be said here that the various chapters composing this book--like those of "Astronomy with an Opera-glass"--were, in their original form, with the single exception of Chapter IX, published in Appletons' Popular Science Monthly. The author, it is needless to say, was much gratified by the expressed wish of many readers that these scattered papers should be revised and collected in a more permanent form. As bearing upon the general subject of the book, a chapter has been added, at the end, treating on the question of the existence of planets among the stars. This also first appeared in the periodical above mentioned.

In conclusion, the author wishes for his readers as great a pleasure in the use of the telescope as he himself has enjoyed.

G. P. S.

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PLEASURES OF THE TELESCOPE

CHAPTER I

THE SELECTION AND TESTING OF A GLASS

> "O telescope, instrument of much knowledge, more precious than any scepter! Is not he who holds thee in his hand made king and lord of the works of God?"--JOHN KEPLER.

If the pure and elevated pleasure to be derived from the possession and use of a good telescope of three, four, five, or six inches aperture were generally known, I am certain that no instrument of science would be more commonly found in the homes of intelligent people. The writer, when a boy, discovered unexpected powers in a pocket telescope not more than fourteen inches long when extended, and magnifying ten or twelve times. It became his dream, which was afterward realized, to possess a more powerful telescope, a real astronomical glass, with which he could see the beauties of the double stars, the craters of the moon, the spots on the sun, the belts and satellites of Jupiter, the rings of Saturn, the extraordinary shapes of the nebulæ, the crowds of stars in the Milky Way, and the great stellar clusters. And now he would do what he can to persuade others, who perhaps are not aware how near at hand it lies, to look for themselves into the wonder-world of the astronomers.

There is only one way in which you can be sure of getting a good telescope. First, decide how large a glass you are to have, then go to a maker of established reputation, fix upon the price you are willing to pay--remembering that good work is never cheap--and finally see that the instrument furnished to you answers the proper tests for a telescope of its size. There are telescopes and telescopes. Occasionally a rare combination of perfect homogeneity in the material, complete harmony between the two kinds of glass of which the objective is composed, and lens surfaces whose curves are absolutely right, produces a telescope whose owner would part with his last dollar sooner than with it. Such treasures of the lens-maker's art can not, perhaps, be commanded at will, yet, they are turned out with increasing frequency, and the best artists are generally able, at all times, to approximate so closely to perfection that any shortcoming may be disregarded.

In what is said above I refer, of course, to the refracting telescope, which is the form of instrument that I should recommend to all amateurs in preference to the reflector. But, before proceeding further, it may be well to recall briefly the principal points of difference between these two kinds of telescopes. The purpose of a telescope of either description is, first, to form an image of the object looked at by concentrating at a focus the rays of light proceeding from that object. The refractor achieves this by means of a carefully shaped lens, called the object glass, or objective. The reflector, on the other hand, forms the image at the focus of a concave mirror.

A very pretty little experiment, which illustrates these two methods of forming an optical image, and, by way of corollary, exemplifies the essential difference between refracting and reflecting telescopes, may be performed by any one who possesses a reading glass and a magnifying hand mirror. In a room that is not too brightly illuminated pin a sheet of white paper on the wall opposite to a window that, by preference, should face the north, or away from the position of the sun. Taking first the reading glass, hold it between the window and the wall parallel to the sheet of paper, and a foot or more distant from the latter. By moving it to and fro a little you will be able to find a

distance, corresponding to the focal length of the lens, at which a picture of the window is formed on the paper. This picture, or image, will be upside down, because the rays of light cross at the focus. By moving the glass a little closer to the wall you will cause the picture of the window to become indistinct, while a beautiful image of the houses, trees, or other objects of the outdoor world beyond, will be formed upon the paper. We thus learn that the distance of the image from the lens varies with the distance of the object whose image is formed. In precisely a similar manner an image is formed at the focus of the object glass of a refracting telescope.

Take next your magnifying or concave mirror, and detaching the sheet of paper from the wall, hold it nearly in front of the mirror between the latter and the window. When you have adjusted the distance to the focal length of the mirror, you will see an image of the window projected upon the paper, and by varying the distance, as before, you will be able to produce, at will, pictures of nearer or more remote objects. It is in this way that images are formed at the focus of the mirror of a reflecting telescope.

Now, you will have observed that the chief apparent difference between these two methods of forming an image of distant objects is that in the first case the rays of light, passing through the transparent lens, are brought to a focus on the side opposite to that where the real object is, while in the second case the rays, being reflected from the brilliant surface of the opaque mirror, come to a focus on the same side as that on which the object itself is. From this follows the most striking difference in the method of using refracting and reflecting telescopes. In the refractor the observer looks toward the object; in the reflector he looks away from it. Sir William Herschel made his great discoveries with his back to the sky. He used reflecting telescopes.
This principle, again, can be readily illustrated by means of our simple experiment with a reading glass and a magnifying mirror. Hold the reading glass between the eye and a distant object with one hand, and with the other hand place a smaller lens such as a pocket magnifier, near the eye, and in line with the reading glass. Move the two carefully until they are at a distance apart equal to the sum of the focal lengths of the lenses, and you will see a magnified image of the distant object. In other words, you have constructed a simple refracting telescope. Then take the magnifying mirror, and, turning your back to the object to be looked at, use the small lens as before--that is to say, hold it between

your eye and the mirror, so that its distance from the latter is equal to the sum of the focal lengths of the mirror and the lens, and you will see again a magnified image of the distant object. This time it is a reflecting telescope that you hold in your hands.

The magnification of the image reminds us of the second purpose which is subserved by a telescope. A telescope, whether refracting or reflecting, consists of two essential parts, the first being a lens, or a mirror, to form an image, and the second a microscope, called an eyepiece, to magnify the image. The same eyepieces will serve for either the reflector or the refractor. But in order that the magnification may be effective, and serve to reveal what could not be seen without it, the image itself must be as nearly perfect as possible; this requires that every ray of light that forms the image shall be brought to a point in the image precisely corresponding to that from which it emanates in the real object. In reflectors this is effected by giving a parabolic form to the concave surface of the mirror. In refractors there is a twofold difficulty to be overcome. In the first place, a lens with spherical surfaces does not bend all the rays that pass through it to a focus at precisely the same distance. The rays that pass near the outer edge of the lens have a shorter focus than that of the rays which pass near the center of the lens; this is called spherical aberration. A similar phenomenon occurs with a concave mirror whose surface is spherical. In that case, as we have seen, the difficulty is overcome by giving the mirror a parabolic instead of a spherical form. In an analogous way the spherical aberration of a lens can be corrected by altering its curves, but the second difficulty that arises with a lens is not so easily disposed of: this is what is called chromatic aberration. It is due to the fact that the rays belonging to different parts of the spectrum have different degrees of refrangibility, or, in other words, that they come to a focus at different distances from the lens; and this is independent of the form of the lens. The blue rays come to a focus first, then the yellow, and finally the red. It results from this scattering of the spectral rays along the axis of the lens that there is no single and exact focus where all meet, and that the image of a star, for instance, formed by an ordinary lens, even if the spherical aberration has been corrected, appears blurred and discolored. There is no such difficulty with a mirror, because there is in that case no refraction of the light, and consequently no splitting up of the elements of the spectrum.

In order to get around the obstacle formed by chromatic aberration it is necessary to make the object glass of a refractor consist of two lenses, each composed of a different kind of glass. One of the most interesting facts in the history of the telescope is that Sir Isaac Newton could see no hope that chromatic aberration would be overcome, and accordingly turned his attention to the improvement of the reflecting telescope and devised a form of that instrument which still goes under his name. And even after Chester More Hall in 1729, and John Dollond in 1757, had shown that chromatic aberration could be nearly eliminated by the combination of a flint-glass lens with one of crown glass, William Herschel, who began his observations in 1774, devoted his skill entirely to the making of reflectors, seeing no prospect of much advance in the power of refractors.

A refracting telescope which has been freed from the effects of chromatic aberration is called achromatic. The principle upon which its construction depends is that by combining lenses of different dispersive power the separation of the spectral colors in the image can be corrected while the convergence of the rays of light toward a focus is not destroyed. Flint glass effects a greater dispersion than crown glass nearly in the ratio of three to two. The chromatic combination consists of a convex lens of crown backed by a concave, or plano-concave, lens of flint. When these two lenses are made of focal lengths which are directly proportional to their dispersions, they give a practically colorless image at their common focus. The skill of the telescope-maker and the excellence of his work depend upon the selection of the glasses to be combined and his manipulation of the curves of the lenses.

Now, the reader may ask, "Since reflectors require no correction for color dispersion, while that correction is only approximately effected by the combination of two kinds of lenses and two kinds of glass in a refractor, why is not the reflector preferable to the refractor?"

The answer is, that the refractor gives more light and better definition. It is superior in the first respect because a lens transmits more light than a mirror reflects. Professor Young has remarked that about eighty-two per cent of the light reaches the eye in a good refractor, while "in a Newtonian reflector, in average condition, the percentage seldom exceeds fifty per cent, and more frequently is lower than higher." The superiority of the refractor in regard to definition arises from the fact that any distortion at the surface of a mirror affects the direction of a ray of light three times as much as the same distortion would do at the surface of a lens. And this applies equally both to permanent errors of curvature and to temporary distortions produced by strains and by inequality of temperature. The perfect achromatism of a reflector is, of course, a great advantage, but the chromatic aberration of refractors is now so well corrected that their inferiority in that respect may be disregarded. It must be admitted that reflectors are cheaper and easier to make, but, on the other hand, they require more care, and their mirrors frequently need resilvering, while an object glass with reasonable care never gets seriously out of order, and will last for many a lifetime.

Enough has now, perhaps, been said about the respective properties of object glasses and mirrors, but a word should be added concerning eyepieces. Without a good eyepiece the best telescope will not perform well. The simplest of all eyepieces is a single double-convex lens. With such a lens the magnifying power of the telescope is measured by the ratio of the focal length of the objective to that of the eye lens. Suppose the first is sixty inches and the latter half an inch; then the magnifying power will be a hundred and twenty diameters--i. e., the disk of a planet, for instance, will be enlarged a hundred and twenty times along each diameter, and its area will be enlarged the square of a hundred and twenty, or fourteen thousand four hundred times. But in reckoning magnifying power, diameter, not area, is always considered. For practical use an eyepiece composed of an ordinary single lens is seldom advantageous, because good definition can only be obtained in the center of the field. Lenses made according to special formulæ, however, and called solid eyepieces, give excellent results, and for high powers are often to be preferred to any other. The eyepieces usually furnished with telescopes are, in their essential principles, compound microscopes, and they are of two descriptions, "positive" and "negative." The former generally goes under the name of its inventor, Ramsden, and the latter is named after great Dutch astronomer, Huygens. The Huygens eyepiece consists of two plano-convex lenses whose focal lengths are in the ratio of three to one. The smaller lens is placed next to the eye. Both lenses have their convex surfaces toward the object glass, and their distance apart is equal to half the sum of their focal lengths. In this kind of eyepiece the image is formed between the two lenses, and if the work is properly done such an eyepiece is achromatic. It is therefore generally preferred for mere seeing purposes. In the Ramsden eyepiece two plano-convex lenses are also used, but they are of equal focal length, are placed at a distance apart equal to two thirds of the focal length of either, and have their convex sides facing one another. With such an eyepiece the image viewed is beyond the farther or field lens instead of between the two lenses, and as this fact renders it easier to adjust wires or lines for measuring purposes in the focus of the eyepiece, the Ramsden construction is used when a micrometer is to be employed. In order to ascertain the magnifying power which an eyepiece gives when applied to a telescope it is necessary to know the equivalent, or combined, focal length of the two lenses. Two simple rules, easily remembered, supply the means of ascertaining this. The equivalent focal length of a negative or Huygens eyepiece is equal to half the focal length of the larger or field lens. The equivalent focal length of a positive or Ramsden eyepiece is equal to three fourths of the focal length of either of the lenses. Having ascertained the equivalent focal length of the eyepiece, it is only necessary to divide it into the focal length of the object glass (or mirror) in order to know the magnifying power of your telescope when that particular eyepiece is in use.

A first-class object glass (or mirror) will bear a magnifying power of one hundred to the inch of aperture when the air is in good condition--that is, if you are looking at stars. If you are viewing the moon, or a planet, better results will always be obtained with lower powers--say fifty to the inch at the most. And under ordinary atmospheric conditions a power of from fifty to seventy-five to the inch is far better for stars than a higher power. With a five-inch telescope that would mean from two hundred and fifty to three hundred and seventy-five diameters, and such powers should only be applied for the sake of separating very close double stars. As a general rule, the lowest power that will distinctly show what you desire to see gives the best results. The experienced observer never uses as high powers as the beginner does. The number of eyepieces purchased with a telescope should never be less than three--a very low power--say ten to the inch; a very high power, seventy-five or one hundred to the inch, for occasional use; and a medium power--say forty to the inch--for general use. If you can afford it, get a full battery of eyepieces--six or eight, or a dozen--for experience shows that different objects require different powers in order to be best seen, and, moreover, a slight change of power is frequently a great relief to the eye.

There is one other thing of great importance to be considered in purchasing a telescope--the mounting. If your glass is not well mounted on a steady and easily managed stand, you might better have spent your money for something more useful. I have endured hours of torment while trying to see stars through a telescope that was shivering in the wind and dancing to every motion of the bystanders, to say nothing of the wriggling contortions caused by the application of my own fingers to the focusing screw. The best of all stands is a solid iron pillar firmly fastened into a brick or stone pier, sunk at least four feet in the ground, and surmounted by a well-made equatorial bearing whose polar axis has been carefully placed in the meridian. It can be readily protected from the weather by means of a wooden hood or a rubber sheet, while the tube of the telescope may be kept indoors, being carried out and placed on its bearing only when observations are to be made. With such a mounting you can laugh at the observatories with their cumbersome domes, for the best of all observatories is the open air. But if you dislike the labor of carrying and adjusting the tube every time it is used, and are both fond of and able to procure luxuries, then, after all, perhaps, you had better have the observatory, dome, draughts and all.

The next best thing in the way of a mounting is a portable tripod stand. This may be furnished either with an equatorial bearing for the telescope, or an altazimuth arrangement which permits both up-and-down and horizontal motions. The latter is cheaper than the equatorial and proportionately inferior in usefulness and convenience. The essential principle of the equatorial bearing is motion about two axes placed at right angles to one another. When the polar axis is in the meridian, and inclined at an angle equal to the latitude of the place, the telescope can be moved about the two axes in such a way as to point to any quarter of the sky, and the motion of a star, arising from the earthy rotation, can be followed hour after hour without disturbing the instrument. When thus mounted, the telescope may be driven by clockwork, or by hand with the aid of a screw geared to a handle carrying a universal joint.

And now for testing the telescope. It has already been remarked that the excellence of a telescope depends upon the perfection of the image formed at the focus of the objective. In what follows I have only a refractor in mind, although the same principles would apply to a reflector. With a little practice anybody who has a correct eye can form a fair judgment of the excellence of a telescopic image. Suppose we have our telescope steadily mounted out of doors (if you value your peace of mind you will not try to use a telescope pointed out of a window, especially in winter), and suppose we begin our observations with the pole star, employing a magnifying power of sixty or seventy to the inch. Our first object is to see if the optician has given us a good glass. If the air is not reasonably steady we had better postpone our experiment to another night, because we shall find that the star as seen in the telescope flickers and "boils," and behaves in so extraordinary a fashion that there is no more definition in the image than there is steadiness in a bluebottle buzzing on a window pane. But if the night is a fine one the star image will be quiescent, and then we may note the following particulars: The real image is a minute bright disk, about one second of arc in diameter if we are using a four-and-a-half or five-inch telescope, and surrounded by one very thin ring of light, and the fragments, so to speak, of one or possibly two similar rings a little farther from the disk, and visible, perhaps, only by glimpses. These "diffraction rings" arise from the undulatory nature of light, and their distance apart as well as the diameter of the central disk depend upon the length of the waves of light. If the telescope is a really good one, and both object glass and eyepiece are properly adjusted, the disk will be perfectly round, slightly softer at the edge, but otherwise equally bright throughout; and the ring or rings surrounding it will be exactly concentric, and not brighter on one side than on another. Even if our telescope were only two inches or two inches and a half in aperture we should at once notice a little bluish star, the mere ghost of a star in a small telescope, hovering near the polar star. It is the celebrated "companion," but we shall see it again when we have more time to study it. Now let us put the star out of focus by turning the focusing screw. Suppose we turn it in such a way that the eyepiece moves slightly outside the focus, or away from the object glass. Very beautiful phenomena immediately begin to make their appearance. A slight motion outward causes the little disk to expand perceptibly, and just as this expansion commences, a bright-red point appears at the precise center of the disk. But, the outward motion continuing, this red center disappears, and is replaced by a blue center, which gradually expands into a sort of flare over the middle of the disk. The disk itself has in the mean time enlarged into a series of concentric bright rings, graduated in luminosity with beautiful precision from center toward circumference. The outermost ring is considerably brighter, however, than it would be if the same gradation applied to it as applies to the inner rings, and it is surrounded, moreover, on its outer edge by a slight flare which tends to increase its apparent width. Next let us return to the focus and then move the eyepiece gradually inside the focal point or plane. Once more the star disk expands into a series of circles, and, if we except the color phenomena noticed outside the focus, these circles are precisely like those seen before in arrangement, in size, and in brightness. If they were not the same, we should pronounce the telescope to be imperfect. There is one other difference, however, besides the absence of the blue central flare, and that is a faint reddish edging around the outer ring when the expansion inside the focus is not carried very far. Upon continuing to move the eyepiece inside or outside the focus we observe that the system of rings becomes larger, while the rings themselves rapidly increase in number, becoming at the same time individually thinner and fainter.

By studying the appearance of the star disk when in focus and of the rings when out of focus on either side, an experienced eye can readily detect any fault that a telescope may have. The amateur, of course, can only learn to do this by considerable practice. Any glaring and serious fault, however, will easily make itself manifest. Suppose, for example, we observe that the image of a star instead of being perfectly round is oblong, and that a similar defect appears in the form of the rings when the eyepiece is put out of focus. We know at once that something is wrong; but the trouble may lie either in the object glass, in the eyepiece, in the eye of the observer himself, or in the adjustment of the lenses in the tube. A careful examination of the image and the out-of-focus circles will enable us to determine with which of these sources of error we have to deal. If the star image when in focus has a sort of wing on one side, and if the rings out of focus expand eccentrically, appearing wider and larger on one side than on the other, being at the same time brightest on the least expanded side, then the object glass is probably not at right angles to the axis of the tube and requires readjustment. That part of the object glass on the side where the rings appear most expanded and faintest needs to be pushed slightly inward. This can be effected by means of counterscrews placed for that purpose in or around the cell. But it, after we have got the object glass properly squared to the axis of the tube or the line of sight, the image and the ring system in and out of focus still appear oblong, the fault of astigmatism must exist either in the objective, the eyepiece, or the eye. The chances are very great that it is the eye itself that is at fault. We may be certain of this if we find, on turning the head so as to look into the telescope with the eye in different positions, that the oblong image turns with the head of the observer, keeping its major axis continually in the same relative position with respect to the eye. The remedy then is to consult an oculist and get a pair of cylindrical eyeglasses. If the oblong image does not turn round with the eye, but does turn when the eyepiece is twisted round, then the astigmatism is in the latter. If, finally, it does not follow either the eye or the eyepiece, it is the objective that is at fault.

But instead of being oblong, the image and the rings may be misshapen in some other way. If they are three-cornered, it is probable that the object glass is subjected to undue pressure in its cell. This, if the telescope has been brought out on a cool night from a warm room, may arise from the unequal contraction of the metal work and the glass as they cool off. In fact, no good star image can be got while a telescope is assuming the temperature of the surrounding atmosphere. Even the air inclosed in the tube is capable of making much trouble until its temperature has sunk to the level of that outside. Half an hour at least is required for a telescope to adjust itself to out-of-door temperature, except in the summer time, and it is better to allow an hour or two for such adjustment in cold weather. Any irregularity in the shape of the rings which persists after the lenses have been accurately adjusted and the telescope has properly cooled may be ascribed to imperfections, such as veins or spots of unequal density in the glass forming the objective.

The spherical aberration of an object glass may be undercorrected or overcorrected. In the former case the central rings inside the focus will appear faint and the outer ones unduly strong, while outside the focus the central rings will be too bright and the outer ones too feeble. But if the aberration is overcorrected the central rings will be overbright inside the focus and abnormally faint outside the focus.

Assuming that we have a telescope in which no obvious fault is discernible, the next thing is to test its powers in actual work. In what is to follow I shall endeavor to describe some of the principal objects in the heavens from which the amateur observer may expect to derive pleasure and instruction, and which may at the same time serve as tests of the excellence of his telescope. No one should be deterred or discouraged in the study of celestial objects by the apparent insignificance of his means of observation. The accompanying pictures of the planet Mars may serve as an indication of the fact that a small telescope is frequently capable of doing work that appears by no means contemptible when placed side by side with that of the greater instruments of the observatories.