THE POSSIBILITIES OF THE TELESCOPE.

By A. B. Biggs.

Up to about the end of the 15th century mankind was in a condition of helpless ignorance with regard to the nature, the distances, and the dimensions or (except two) the form of the various bodies which constitute the visible universe. No human eye had ever beheld either stars or planets as other than dimensionless points. Their motions and positions had been carefully observed, systematised and theorised upon; but they were unapproachable. What a wonderful revelation then must that have been which *Galileo's telescope* opened up! practically diminishing the distance some 20 or 30 times. True, his was a very simple affair, and feeble in its infancy; but it revealed some most important facts. It served to show that the planets at least were globes, some of them of vast bulk: it opened up to human vision for the first time the wonderful mountainous scenery of the Moon. But perhaps its most important service was to establish beyond question the Copernican theory of astronomy by revealing the phases of the inner planets—also the moons of Jupiter—a Copernican system in miniature.

The Rings of Saturn constituted an inscrutable riddle, reserved for further development of this new power of vision.

Since Galileo's time, the effort has been constant and unwearying to develop to the utmost the power of the instrument. There were difficulties inseparable from the principle on which the instrument is constructed, which it was long thought never could be overcome, the chief of which was (briefly stated) that a ray of light, when bent out of its course, as by a prism, or a lens, is separated into its different component colours, each having a different focus. The discovery and utilisation of the fact that different kinds of glass have different separating or prismatic effect, led to the construction of the *achromatic* object glass. This gave a new start to the powers of the instrument, so that we have reached from Galileo's power of 30, and imperfect at that, to a power ot about 3,000 in the Lick Telescope.

Well, now the question arises:—If we have from the time of Galileo been enabled by the gradual improvement of the telescope to stretch our gaze farther and farther into space, why should we not still go on enlarging its scope. As we now see clearly the configuration of the lunar mountains, why should we not, in time, come to see the trees growing upon there sides, if there be any? Why not discover signs of organised existence, if such exist? Is there any limit to which the instrument is capable of being developed. This is the question which it is natural to ask, and which I have been asked repeatedly. On this account I have thought it might be deemed an interesting question to discuss.

I may state at starting that doubtless there *is* a limit, and moreover, I believe that limit is already nearly, if not quite, attained. To prepare the ground for a clear understanding of my reasons, I must very briefly refer to the fundamental principles of the telescope. A luminous body, such as a star, emits rays diverging in all directions in straight lines. Of course the greater the distance the more these rays are spread ; that is, the light is diminished in intensity, and that in proportion to the *square of the distance.* Of the total light emitted that received by the eye is that fraction which the pupil bears to the whole sphere of which the radius equals the distance. These rays may be so enfeebled by distance that the object ceases to be visible. Now, if we can gather a sheaf of these rays that would otherwise pass by us unperceived, and bend them inwards until they enter the pupil of the eye, we evidently increase the visible luminosity in that proportion. This is the function of the object glass—*i.e.*, the large glass at the outer end of the telescope—or the speculum of the reflecting telescope (See Fig 1).

Of course, the larger the glass the more it can gather. As the rays from every point of the object are brought to a corresponding point at the focus of the lens, a small image of the object is formed. This image is magnified by the eyepiece, which is really a *microscope.* But whether we magnify this image less or more, we have only the same amount of light to deal with, viz., that which is grasped by the object glass ; and the more this light is spread out by magnification the more it is enfeebled. This magnification is therefore limited by the capacity or size of the object class—(other things being equal). In this respect the Telescope and the Microscope stand on a very different footing. We cannot, of course, increase the actual luminosity of a celestial object in the smallest degree. All we can do is to grasp as much as possible of the light actually emitted. With the microscope, on the other hand, we can, by means of condensers, and the employment of suitable sources of light, increase the illumination of the object indefinitely up to the required amount of amplification. Hence it is evident that increase of *telescopic power* is to be sought in the *enlargement of the light gatherer*—the object glass. But this is where the trouble comes in. The difficulty of accurately figuring a large object glass, or speculum, increases enormously out of proportion to its dimensions. If every point of its active surface does not refract or reflect its ray to its exact point in the focus, such defective part is worse than useless. To give some idea of the nicety of manipulation required, I may state that a speculum is ground and finished up to the finishing touch of fine grinding, as a portion of the surface of a *perfect sphere.* But this figure would not do at all for the telescope. The marginal rays would be reflected to a different, that is, a *shorter* focus than the central ones. The radius of curvature needs to increase as it approaches the margin. The figure needs to be *parabolic*, answering nearly to the end of a long ellipse. But so little does this parabolic figure differ from the spherical, that it is all *done in the polishing.* And this is especially where the highest skill of the manipulator is called for. An extra rub with the palm of the hand may be sufficient to distort its figure

Then another trouble comes in, increasing enormously with the size. We cannot get size without an immense increase of *weight*, and then comes the difficulty of supporting in their tubes these heavy masses without flexure or straining, the least degree of which is fatal to definition.

But now, supposing all these difficulties successfully overcome, there remains yet another obstacle, which is utterly beyond man's power or skill to contend with. We live at the bottom of an ocean of air; and we could not exist even if we could surmount it, any more than a fish could live out of water. And this ocean is in a state of ceaseless agitation, more or less. Through this medium must pass the rays which go to form the telescopic image. Some idea of the effect of this may be formed by trying to read the inscription on a coin lying at the bottom of a clear pool that is agitated by the breeze. I have viewed the planet *Saturn* in the telescope, when, from this cause, it presented the appearance of a fire-ball; huge tongues of flame apparently blazing all round it, flickering and dancing; precisely like those *kerosene fire-balls* which the boys throw up into the air with such magnificent effect on Queen's birth-nights. It was, to all appearance, a *world in a blaze.* It is not then to be supposed that we can, whenever we please, obtain a clear and distinct view of any celestial object we may wish to inspect. Favourable occasions for this are few and far between. Sometimes a lull in the atmospheric waves permits of a momentary glimpse of the object clearly and sharply defined; just as, in the case of the coin in the pool, a brief lull in the breeze allows you to begin to read the inscription; but before you get half-way through another puff comes up and blurrs it all over.

Now this difficulty increases with the size of the telescope, inasmuch as that the larger diameter takes in a greater number of these disturbing atmospheric waves; for which reason the observer has often temporarily to reduce the effective aperture, that is, the *power* of his telescope.

The only possible amelioration of the obstacle referred to is to leave as much as possible of this disturbing medium below the observer. This is just what is done in the case of the great *Lick Telescope*, which is erected on a mountain in San Francisco at an elevation of 4,300 feet, or about the height of the top of Mount Wellington. This, coupled with its vast size and perfect finish, places this instrument in the advance post of telescopic power. It has lately been proposed in France to erect an Observatory on one of the Alps, at an elevation of 15,000 feet. Owing to the compressibility of the atmosphere by the superincumbent weight of the upper strata the half of the entire mass lies somewhat below an elevation of three miles, although the rarer air probably extends considerably over 100 miles. But the necessity of air and warmth places a limit not far to reach in this direction. The most daring of balloonists ventured up to an elevation of about seven miles (I speak from memory), when one of the occupants became insensible, and his companion had only strength left to release the gas with his teeth, having lost the use of hands, and descend into a denser atmosphere.

Assuming that I have fairly stated the case, it would appear then that the smallest advance in telescopic power is necessarily to be obtained only at a cost enormously out of proportion to the gain, or, as it is commonly expressed, "the game is not worth the candle."

One word with reference to the announcement of a new optical glass for the manufacture of telescopic lenses, about which a deal of tall talk has been indulged, and probably not a few hoaxes, with more yet to come. This sort of talk springs from an entire ignorance of the function of any such glass and a supposition that some magical magnifying power is inherent in the glass itself instead of in the skill required to shape it. The function of such glass is simply to combine more accurately the different coloured rays, which existing combinations fail, to some extent, to bring to a common focus, the result being more perfect definition.

A brief explanation will, I think, serve to make this clear. *Light* passes in *straight* lines through a uniform medium. On entering a denser transparent body the ray is bent towards the substance of that body (See Fig. 2).

But what we see as *white* light is really composed of the blending of all the colours of the rainbow, together with some other rays, viz., the actnic or chemical rays and the heat rays. Now, these latter, together with all the different colours, are unequally "refracted" or bent. The light is, in fact, decomposed. Of the *light* rays the *violet* is the most bent, the *red* least. They are thus spread out into a band, along which the different colours are distributed. A simple lens, such as that of the primitive telescope, is *prismatic*. The effect is that the red rays are brought to focus at R, and the voilet to a shorter focus at V, the other tints lying between. Thus there is no definite focus (See Fig. 3).

We have, then, two effects from the passage of a ray through a *prism*—the *bending* or *refraction*, and the *decomposing* or *dispersion*. But the grand discovery was made that different kinds of glass *disperse* or spread the colours in different degrees with a given amount of refraction, thus :— If the former prism had been of *flint* glass instead of *plate*, and made to give the same amount of bending, we should have had the different colours spread over, perhaps, double the space. To produce an equal spreading of the colours we shall require a *flint* glass prism that will bend or refract *less*. We shall require to bend the ray only to B instead of to A (Fig. 2) ; that is, we shall require a thinner or less angular prism. Now, place these two prisms together in reverse positions, and what will be the effect ? The ray will be partially brought back towards the straight, viz., to C instead of to A (See Fig. 2 b), leaving still an amount of deviation, from the greater thickness of the *plate* glass. But the dispersion of the colours is in *reverse* order in consequence of the inversion of the prisms, but in equal degree. The complimentary colours are therefore superimposed, and are re-composed into *white light*. This is the secret of the vast advance in telescopic power since the days of Galileo.

Now to apply this to the telescope. The lens (*P*) of *plate* glass (see Figure 4) is backed by a concave of *flint* glass (*C*) of less refraction power, thus leaving a surplus of refraction to the convex, the effect being that we get a focus at *F* instead of at *f*, with all the different coloured rays brought to a common focus.

Now, there is one trouble that has not yet been surmounted. Although the *general* prismatic dispersion may be equalised and neutralised, the colours are *unequally* distributed by the two kinds of glass. Consequently one particular coloured ray does not meet its exact complimentary in the reversed spectrum, and as a result we have a fringe of outstanding colour. This is called the "irrationality" of the spectrum. This is what opticians are endeavouring to get rid of by the invention of a glass that will locate the different colours in the same relative position as does the plate glass of the convex, and this is all the *magic* there is about it.

Possible Power of the Telescope.

I think many persons entertain very exaggerated ideas of what the telescope in its present stage can really accomplish. Theoretically it is assumed that the utmost available power of the most perfect instrument, and under the most favourable circumstances as to the state of the air, etc., is 100 to the inch of aperture. This is the *extreme*, rarely reached. The Lick Telescope has an object glass 36 inches in diameter. Considering the necessarily immense thickness of glass through which the light has to pass, we may assume 3,000 at the utmost of its power. This should, if definition were perfect, give us a view of the moon as at a distance of 80 miles. Of course this is a vast approach. But what could we see of the details of a terrestrial mountain, supposing we could discern it at 80 miles distance? This estimate is, of course, on the supposition that we could eliminate all optical imperfection and atmospheric disturbance, both of which are impracticable. In connection with this question I made the following experiment the other day:—I approached a handbill, of the subject of which I was ignorant, until I could just make out the boldest type. I found the distance 16 yards. The letters were bold block letters, 1 inch in height. Reckoning from this, similar letters on the moon's face, to be seen by natural unassisted vision, should measure 417 miles. There would be room across her face for a word of five letters. With a telescopic power of 3,000, and no imperfection introduced, such letters, to be readable, would have to be 244 yards. Each letter would thus cover a space of about 12 acres. Allowing for imperfection, I think this would be the smallest patch that would be discernible at all as to shape. At the distance of Jupiter this object would need to be about four million times larger in surface, or, say, three times the size of Tasmania.

Photography.

There is one direction, however, in which the powers of the telescope are in process of development to a considerable extent, that is, by its association with photography. I have so far dealt with the telescope as a *seeing* instrument. Whatever is to be seen is seen at once. We cannot increase its vividness or distinctness by prolonged gaze. If a faint star, *e.g.*, is not at once visible when the eye is directed to its position, any amount of staring at it will not bring it into view. Not so with *photography*. The more it looks the more it sees. In this way it has been arranged to explore the entire heavens to depths far beyond the limits of telescopic vision by combined effort of all the principal Observatories in the world. Already vast numbers of minute stars have impressed themselves upon the photographic plate that would probably for ever have remained beyond the power of actual vision. To accomplish this something more is necessary than merely focussing the object upon the photo plate. It has to be kept there accurately during the whole time of the exposure—a needle's point to a spider line—and that for hours, against the diurnal motion of the earth. To give the proper motion to the telescope the most accurately constructed driving clock-work is necessary. For planetary detail, however, I much question if photography will ever render much service. There is no getting over the blurring caused by atmospheric disturbances, superadded to instrumental imperfection. The photo of moon from the great Melbourne telescope is generally accounted one of the most successful ever produced. But in this, minute details that are distinctly visible in either of my comparatively small telescopes are totally absent.

A few remarks on the necessity of *caution* in rightly interpreting telescopic appearances may fittingly conclude this paper. A novice on taking his first peep at the planets, we will suppose, will probably feel quite disappointed that the object he sees exhibits very little of the detail or appearance of that same object as depicted and described by experienced observers, and after long and diligent observation. The eye requires considerable training for this kind of seeing. Moreover, considerable judgment is necessary in rightly interpreting what we see.

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"In Fig. 2 *b* add a dotted line (A) from prism, above C."

Figures for
Page 3 "Possibilities of the Telescope.

Fig. 1

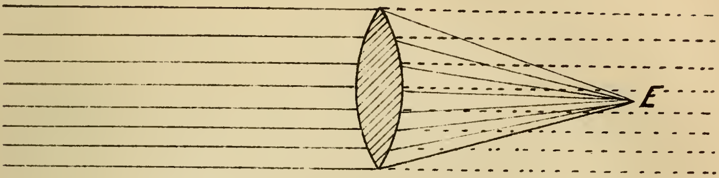


Fig 2,
Page A.

Fig 2b
Page A.

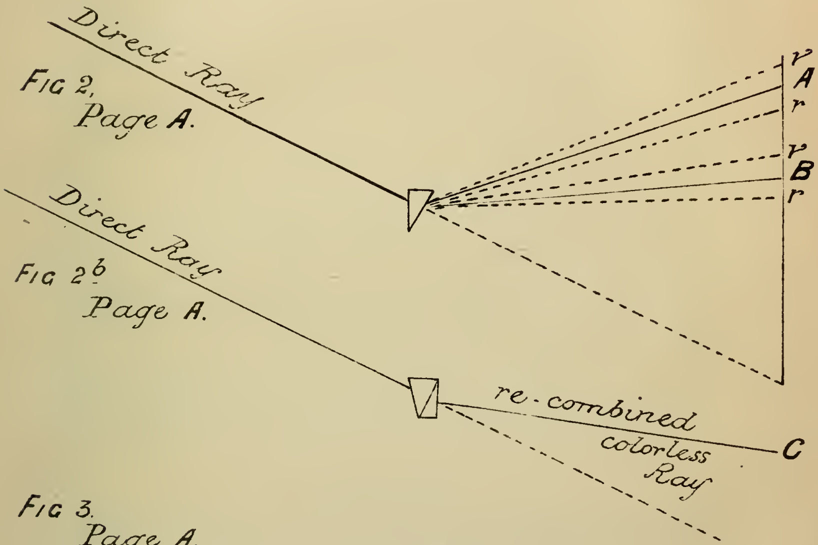


Fig 3.
Page A.

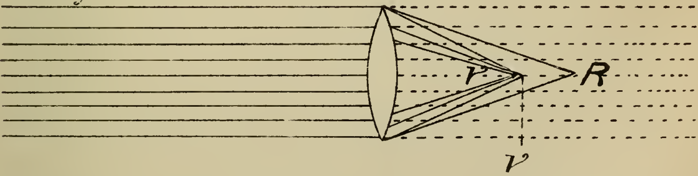
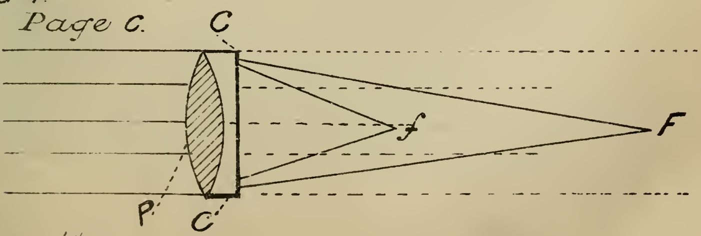


Fig 4.
Page C.



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