large feature. Dr H. P. Wilkins studied the Mare Humboldtianum and published special charts.[2] Later drawings made by the present writer were published in *The Moon*.[3]

The north-eastern portion of the mare is seen only with favourable libration, when the true nature of the damaged crater in the centre is also apparent. An obscure ring on the western floor of the mare has been recorded during several observations. The walls of the mare are breached by many passes, valleys and craters. The smaller features on the floor require confirmation. The published photographs are generally inadequate in this region.

References

1 Kuiper, G. P., *Photographic Lunar Atlas*, B.1-c.
2 "Memoirs of the B.A.A.", Ninth Report of the Lunar Section, *The Journal of the B.A.A.*, Vol. 48, No. 9, July 1938. Also the "300" Map Charts of the Libratory Regions.
3 "The Moon", Vol. 1, No. 1, June 1950; "The Moon", Vol. 5, No. 2, December 1956; "The Moon", Vol. 8, No. 2, January 1960.

COMMUNICATIONS TO THE ASSOCIATION

VISUAL ASTRONOMY IN THE ULTRA-VIOLET

H. E. Dall

The title appears to be a contradiction in terms. How can one carry out visual observation by means of light from the invisible part of the spectrum? The answer to this question depends on whose vision we are dealing with, also with the intensity of the light.

Authors of text books on light are in the habit of copying one another and it is usual to find a statement that the sensitivity curve of the eye in good light extends from 4 000 Angström Units in the far violet to 7 000 Å in the deep red. However, it is generally recognized that the curve has a longer asymptote at the red end, and if a high intensity source is examined spectroscopically the eye can see light up to and even beyond 8 000 Å.

At the other end of the spectrum the fade-off of the sensitivity curve (see Fig. 1) is more abrupt, but with considerable dependence on the individual and his age. Some young people I have tested can see (very faintly) the ultra violet line at about 3 655 Å in the spectrum of Mercury vapour either in fluorescent lamps or in street lamps. However, most prism-type direct vision or non-direct vision spectroscopes of high dispersion do not show this ultra-violet line because the dense lead glass in them cuts out this part of the spectrum.

Even if the spectroscope is capable of showing the ultra-violet, very few adults can see appreciably beyond the Mercury violet line at 4 047 Å.

I happen to be one of those adults and can now see right into the ultra violet to a wavelength of about 3 300 Å or one-third of a micron because the so-called crystalline lenses of my eyes have been removed in normal cataract operations.

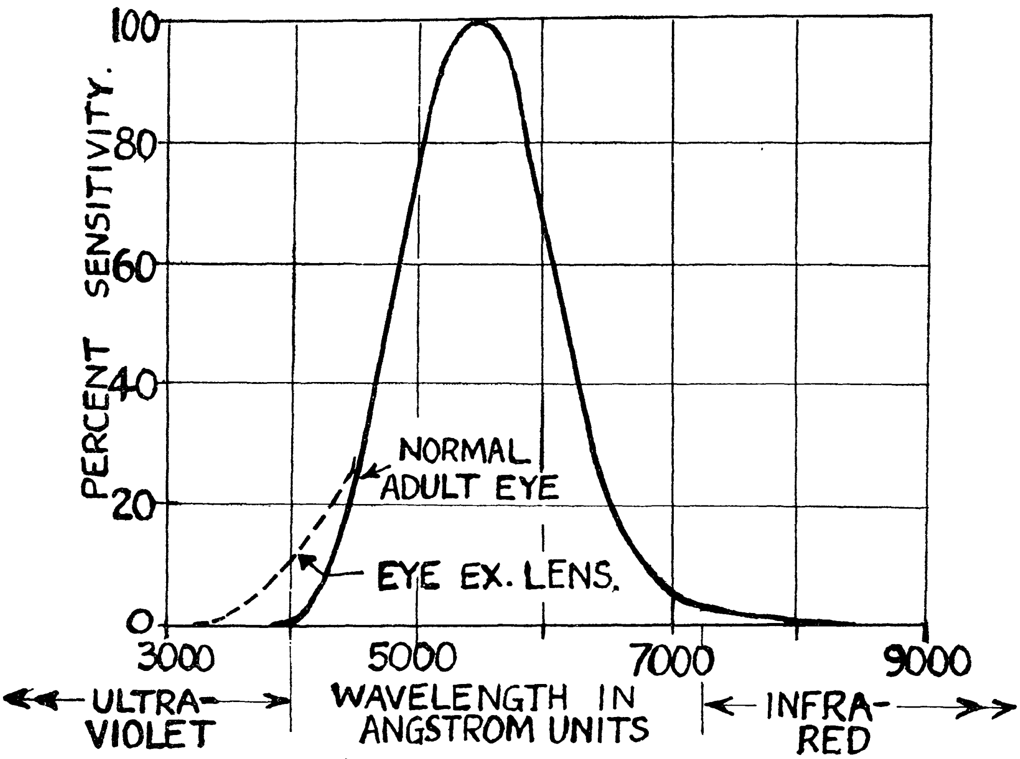


FIG. 1. SENSITIVITY OF EYE.

In consequence, I can see relatively well through a Wood's glass filter which substantially cuts out the usual visual spectrum while being fairly transparent in the ultra-violet down to about 3 000 Å. Not only so but I can see with good clarity and in extra high resolution through a microscope illuminated only by a 'black' lamp of the type used for fluorescence effects. This type of lamp has a Wood's glass envelope. The characteristic transmission curve of Wood's glass, e.g. Ilford filter No. 828, shows two regions of transparency. The greater one, with a peak of about 73 per cent (in 2 mm thickness) centred at 3 600 Å and extended from 2 900 Å to 4 200 Å.

The lesser one with a peak of about 25 per cent centred at 7 500 Å and extended from 6 800 Å to 7 600 Å. Figure 2 shows these two peaks in relation to the sensitivity curve of the normal eye (dotted).

The two widely separated peaks provide an excellent means of testing one's eyes for sensitivity in the ultra-violet. If, for instance, a naked filament lamp or one with a 'pearl' envelope is viewed through such a filter it will appear quite red to a person having no ultra-violet sensitivity because only red light gets through to the retina, and red sensitivity is high in young and old alike over a wide range of intensities. I see the lamp as blue and young adults see it as a purple mixture. Very young people will see it as a bluer purple. Incidentally, although the violet line at 4 047 Å appears to me as a vivid violet, the ultra-violet line of Mercury vapour at 3 655 Å appears as blue rather than as violet, indicating an unsuspected kind of fold in colour vision sequence.

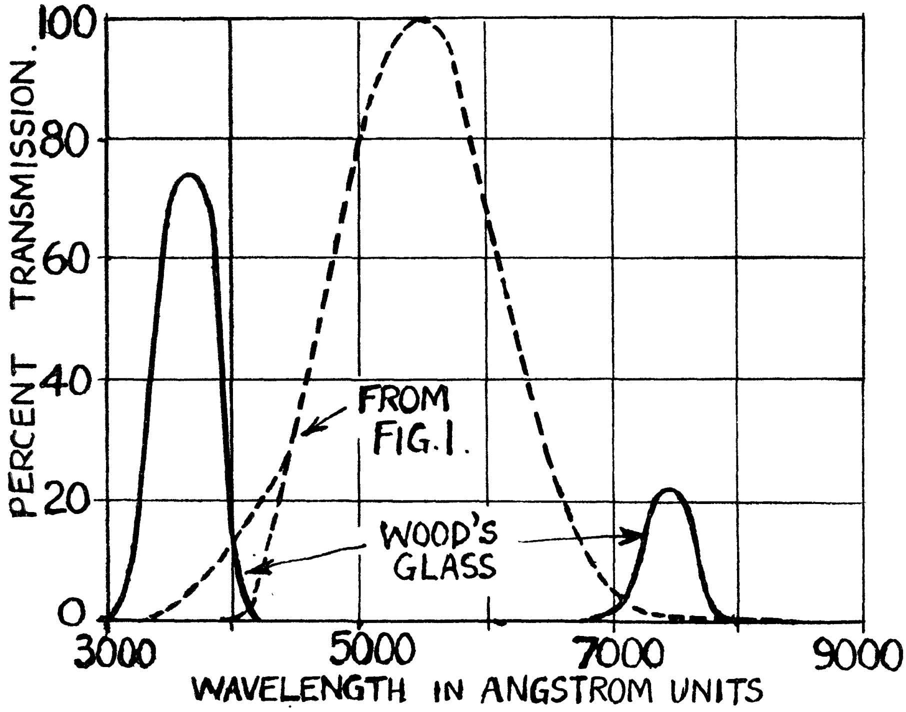


FIG 2 TRANSMISSION OF WOOD'S GLASS.

Following the cataract operations I quickly noticed that blues were much more vivid than before the operation. For instance a bunsen burner flame became a rich blue colour instead of the greyish blue to which I had been accustomed. Further tests with spectroscopes revealed that I could see abnormally far into the ultra-violet—making possible new fields of visual observation. The new field on the astronomical side developed when I made a pair of Wood's glass spectacles to see what changes of view occurred with stars and planets both visually and through the telescope. We have in this Association heard a great deal about the use of filters in planetary observation and the subject arouses considerable interest and discussion; thus an extension into the ultra-violet field is a useful gain of experience, and one in which there must be a number of members, both young and old, capable of partaking.

The eye is a non-achromatic organ and I find that the focal power is $1\frac{1}{2}$ dioptres greater in the ultra-violet—hence I ground and polished the Wood's glass spectacles as negative lenses of this strength. When the crystalline lens of the eye is removed in a cataract operation, rather high strength spectacle lenses (e.g. positive lenses 3-inch to 4-inch focus) are necessary to replace the focussing power removed, and to supplement the power of the transparent cornea, etc.

The first trials were plain visual views of stars and planets through the spectacles. Mars was so weak in ultra-violet that it was only just visible, e.g. equivalent to about sixth magnitude. Jupiter was much brighter; probably 4·2 magnitudes, a difference of 1·8 magnitudes when the *Handbook* gave only 0·8 magnitudes difference in white light. This was not an unexpected result, neither was the observed weakness of the redder stars. For example, Betelgeuse, Aldebaran and even Arcturus were invisible, or practically so, whereas the much fainter three stars of Orion's belt were all plainly visible.

Familiar constellations change their character. Only two stars (Eta and Epsilon) are visible in Ursa Major.

Using the same ultra-violet filter spectacles in views through the $15\frac{1}{2}$-inch reflecting telescope, Mars was still remarkably faint and no features were visible on the disk at the same sky conditions that permitted two belts of Jupiter to be just seen. Again there is nothing surprising about these observations, but as opportunities occur I hope to examine other objects in U.V., particularly the brilliant surface of Venus. It will be remembered that various photographs of Venus taken through a similar U.V filter have been published showing slabs of shading near the terminator, though never near the limb.

In my own efforts at photography of Venus in ultra-violet, none of this shading has appeared, probably because I aimed at negatives of the same density as those taken in white or orange light. My theory, which I would like to see proven or disproved, is that the slab shading is spurious and due to underexposure of the emulsion near the terminator, which means working at the foot of the characteristic curve of the emulsion. The limb is so much brighter that the exposure point is well up the curve. The foot of the curve is notoriously unstable and unsuitable for useful work, but can be avoided only by rather lengthy exposure through the dense U.V. filter. With U.V. sensitive eyes I hope to be able to see the surface of Venus sufficiently brightly through the filter spectacles to detect the presence or absence of the shading by the simple visual process using the telescope.

Ultra-violet light is somewhat harmful to the retina in heavy doses, e.g. from the direct or indirect solar rays, and the adult's eye protects itself at this end of the spectrum by developing a yellowish colour in the lens. This protection is absent in the U.V. sensitive eyes and suitable precautions should be taken. There will be a number of amateur or professional astronomers in a similar situation and this short note may serve to encourage similar experiments. Wood's glass filters are obtainable from several manufacturers and, as already mentioned, the Ilford product is Filter No. 828, while in America suitable filters are available from well-known surplus suppliers specializing in scientific and optical items. For filters used with the telescope, there is of course no need to work a curve on the surface to correct for chromatism of the eye, though some change of focus of the eyepiece will be necessary. Youthful eyes have sufficient accommodation not to need correction in many cases.

THE NIGHT SKY AT GLASGOW, 1959–64

R. J. LIVESEY

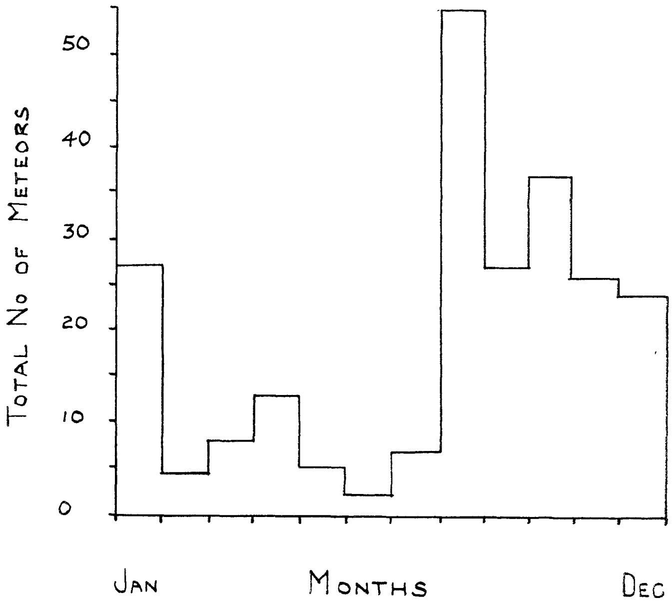
The night sky is scanned at least once per evening for the detection of auroral or other activity. When the sky conditions are satisfactory various observations are carried out for a period of about one and a half hours. As the result of the sky scanning procedure the following information has been collected.

The mean percentage of nights per month in the period 1960–64 on which cloud prohibited the observation of stellar background were as follows:

Month	Jan.	Feb.	Mar.	Apr.	May	June
Per cent	59	57	67	62	69	65
Month	July	Aug.	Sept.	Oct.	Nov.	Dec.
Per cent	71	62	59	63	56	50

The best months for observing were November to February inclusive, the most inconsistent month June, and the worst months March, May and July.

Observed Sporadic Meteors - Glasgow - 1959 - 64.



The totals of sporadic meteors per month for the period 1959–64 were as follows:—

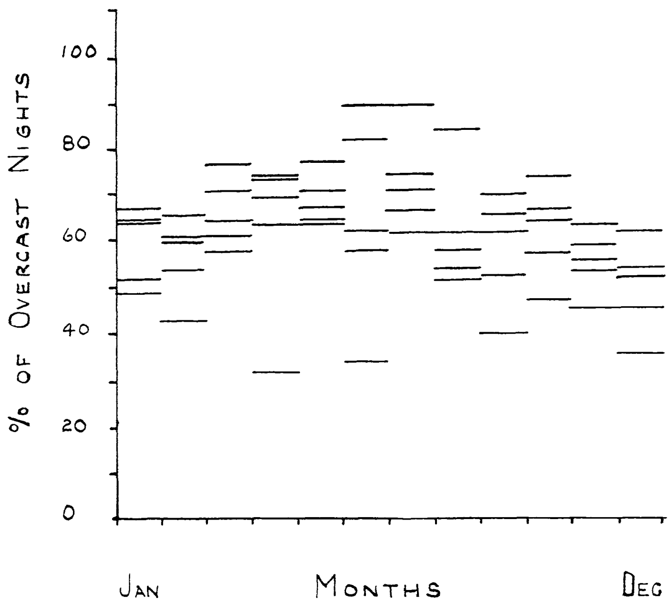
Month	Jan.	Feb.	Mar.	Apr.	May	June
Meteors	27	4	8	13	5	2
Month	July	Aug.	Sept.	Oct.	Nov.	Dec.
Meteors	7	55	27	37	26	24

The above figures specifically omit meteors recorded during long period watches at the peaks of meteor showers. The results clearly confirm the well-established annual distribution of meteoric activity.

The number of nights on which a telescope could be used were indicated by the total observations of W. Cygni per month for the period 1959–64 during the patrol of variable stars, as under:

Month	Jan.	Feb.	Mar.	Apr.	May	June
Observations	56	39	29	39	40	19
Month	July	Aug.	Sept.	Oct.	Nov.	Dec.
Observations	36	38	40	48	50	47

PERCENTAGE OVERCAST NIGHTS PER MONTH- GLASGOW - 1960-64.



The low value in June indicated that the telescope was out of action due to holidays. The late sunsets and night twilight found at this latitude likewise affected observing rates in June and July. The general level of observing frequency outwith the midsummer period was reasonably consistent so that the coverage of sporadic meteor activity could be considered a true sample of the real activity.

The observatory from which the above data were obtained is situated at 450 feet above sea level on the Renfrewshire Escarpment seven miles south and to windward of the city.

TESTING A HYPERBOLOIDAL MIRROR FOR A CASSEGRAINIAN TELESCOPE

A. THOM

In the course of constructing a 12-inch Cassegrainian telescope I experienced the usual difficulties in figuring and testing the secondary mirror. This has to be a convex hyperboloid and so has no real focus. Hence indirect methods of testing have to be used. It may be that the professional can work and finish a concave mirror and then figure the convex to fit it everywhere as judged by interference fringes, but this may be too difficult for others. In this case the following methods may prove useful.

When figuring the mirror, test it by viewing from the back with the usual slit-cum-knife-edge arrangement. The back of the mirror must first be made optically flat, as any deviation from flatness will cause a distortion in the face being worked.

It is shown in the appendix that the measured longitudinal aberration ϵ' is given by

$$\epsilon' = \frac{\epsilon}{\mu} - \frac{\mu^2 - 1}{2\mu}\frac{y^2}{R}\left(1 + \frac{t}{R}\right)$$

where ϵ is the actual aberration of the face,
t is the thickness of the mirror,
R is the radius of curvature,
y is the radial distance from the axis to the ray, measured at the back of the mirror where the Coudé screens would be placed.

The difficulties of the method are:

(1) The glass must be free from striae or other faults which might deviate the rays.

(2) The observed aberration is less than the actual.

(3) The light source must be nearly monochromatic.

(4) Care has to be taken not to scratch the back of the mirror when working on the front.

(5) Any turned edge on the flat face shows up and prevents a true estimate of the conditions of the edge of the front face.

In making the measurements adopt the arrangement shown in Fig. 1 for the slit-cum-knife-edge arrangement. Taking readings on both knife-edges mitigates to some extent the effect of non-uniform illumination. Using Coudé screens with two sets of openings at right angles (Fig. 2) one can make sure that the eye is at the correct level by watching the top and bottom openings; do not attempt to see the left and right slits simultaneously but move the eye so that cut-off occurs equally for each.

As a completely independent check on the mirror was required, the method used is now described. It is necessary to find a lens or combination of lenses having a focal length about half the radius of curvature of the mirror. The diameter must be as large as the mirror diameter and for preference slightly larger: the longitudinal aberrations of the lens should be small.

The arrangement is as shown in Fig. 3. With the mirror in position a slit-cum-knife-edge unit is placed at B and aberrations are measured in the usual way with Coudé screens placed as shown. Then the mirror is removed and, with the knife-edge still at B, an illuminated slit is placed at the conjugate focus A. With the screens in the same position the lens aberrations are now measured. The mirror aberrations can be calculated from the difference between the two sets of measurements.

The explanation is as follows—with the mirror absent the ray AC focusses at B. Now suppose that the mirror is spherical and that it is placed in position with its centre of curvature at A, then a ray from B will be reflected from the surface at C and return on its own path to B just as if it had originated at A. So any deviation it receives is due to the aberration in the mirror. If the lens has been so chosen that A and B are equidistant from the lens then the

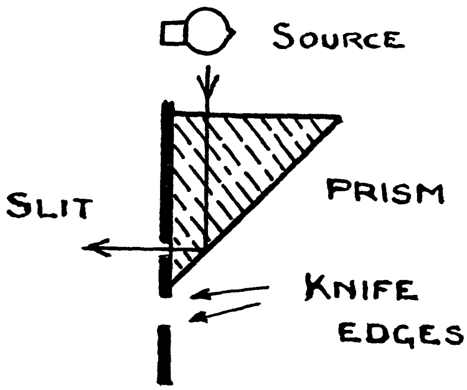


FIGURE I

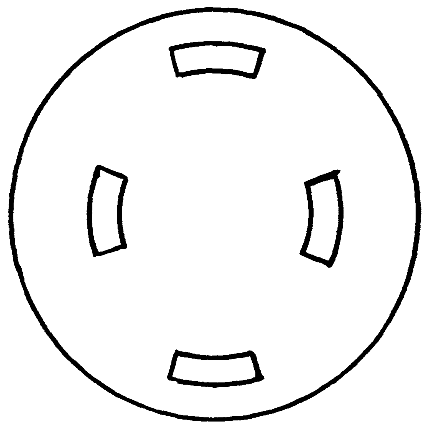


FIGURE 2

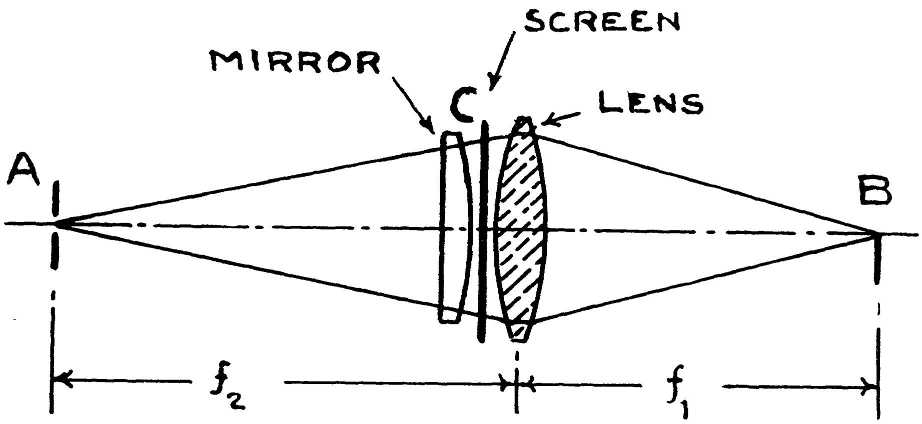


FIGURE 3

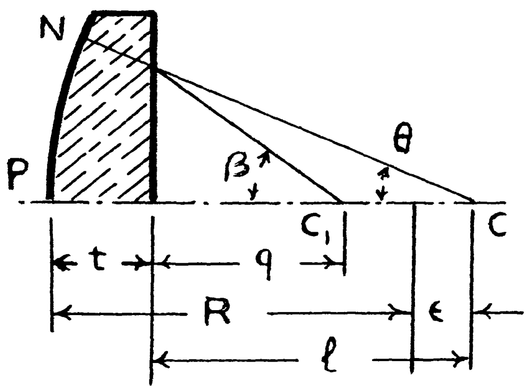


FIGURE 5

difference between the observed lens aberration (slit at A) and the aberration with the mirror in place is the required mirror aberration. In general, lens theory shows that the observed difference must be multiplied by $(f_2/f_1)^2$.

The reason for having the lens of focal length half the radius of curvature is now apparent. If this condition is not fulfilled then f_1 and f_2 will not be equal. If f_2 is substantially greater than f_1, the observed aberrations may be too small for convenient measurement. If f_1 is greater than f_2 the eye may be too far from the mirror for convenient observation of the screens.

Care is needed in setting up the apparatus. The three components must be rigidly connected. A small lathe mounted on a heavy wooden beam could be used and the lathe controls allow accurate setting of the knife-edge and correct measurement of its movement. The lens axis must be made to pass near the knife-edges. This is done in the first place by looking at the reflections of the slit in the various surfaces of the lens and getting them in line. When everything is so nearly in position that the mirror can be seen brightly illuminated in the usual Foucault manner two edges of the mirror should be bright with an inclined dark band between. Tilting the lens very slightly about the horizontal diameter makes the dark band vertical and rotation about the vertical diameter will make the side bands vanish. They would not vanish for both knife-edges simultaneously, but there is no need to worry about a small lack of uniformity. The Coudé screen method of measurement automatically ignores any mal-illumination which is symmetrical about a vertical axis. However, one cannot expect to see the typical 'doughnut' appearance unless the illumination is otherwise uniform.

In the above it will be seen that a combination of lenses was found which gave the correct focal length and small aberrations (Fig. 4a). An achromatic combination might be an advantage and although in this experiment a deep red filter was used a truly monochromatic source of light would be more helpful. The hole in the screen appears a deeper red than the other; since this reverses with the knife-edge any effect produced will not cancel out in the mean.

In Fig. 4a the raw observations are given for the lens and mirror. Each point is the mean of the left and right knife-edge reading. The deduced aberrations are shown, to a larger scale, at Fig. 4b where they are compared with the earlier measurements taken through the back of the mirror. The required aberration $e^2y/2R$ is also shown where e is the eccentricity required in the hyperbola.

The mirror particulars are $R = 40{\cdot}3$ inches, diameter 3 inches, $e^2 = 2{\cdot}89$. So at a radius of $y = 1{\cdot}4$ inches the difference between the sphere and the hyperboloid is $e^2y^4/8R^3 = 21 \times 10^{-6}$ inches, or almost exactly one wavelength. Considering that the portion of the mirror to be used lies between $y = 0{\cdot}3$ and $y = 1{\cdot}4$ it appears that the mirror is within a small fraction of a wavelength of perfection.

For the benefit of the beginner it may be mentioned that in taking and plotting these measurements the zero is quite unimportant. In fact, different runs can be made with different zeros and combined. The mean values are

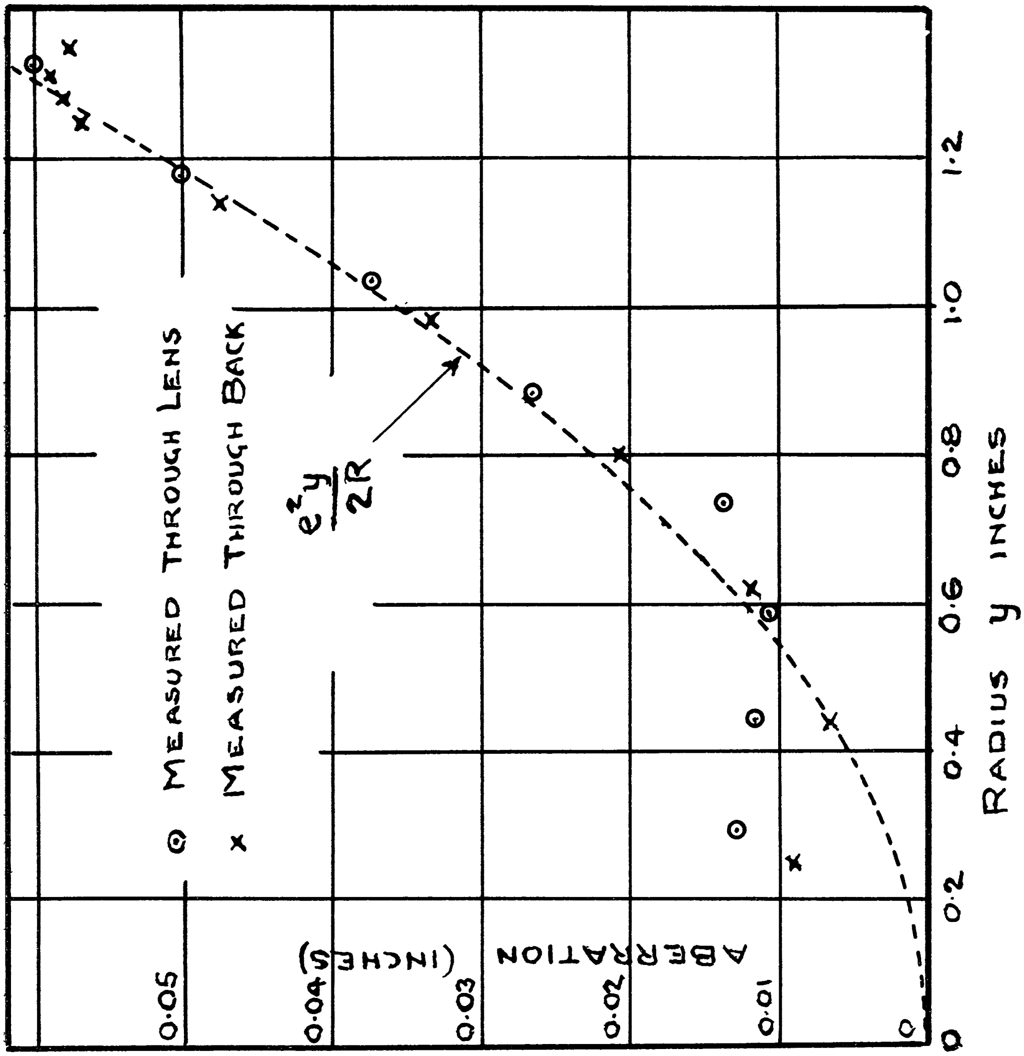


FIGURE 4b

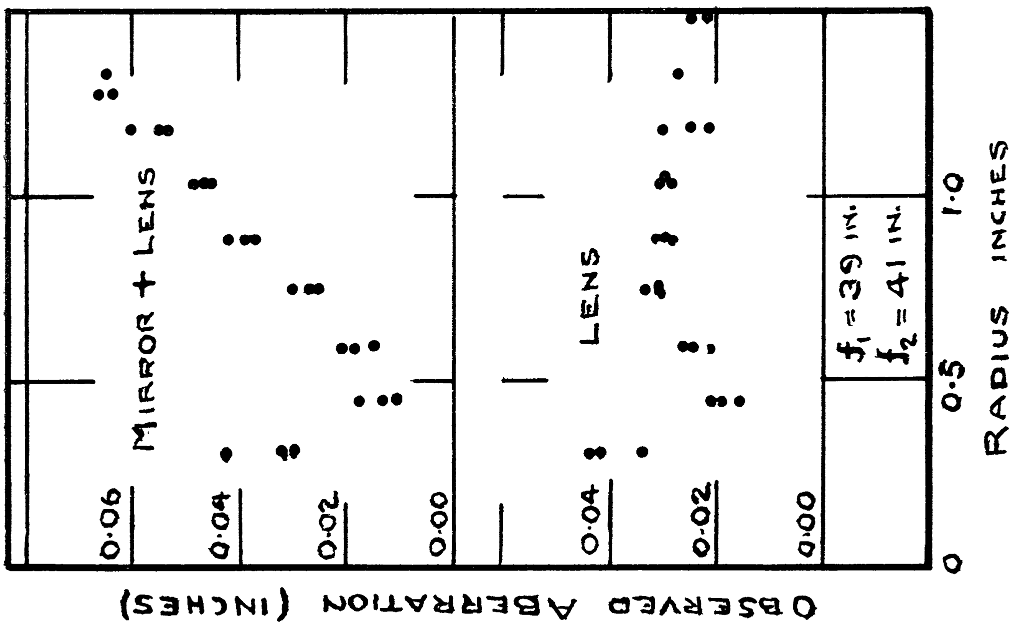


FIGURE 4a

found for the two arrangements (Fig. 4a) and subtracted. The differences are, of course, again to an unknown arbitrary zero. Finally, a zero is chosen which will give the best agreements with the required curve $e^2y/2R$. This corresponds to focussing the telescope.

If the final aberrations are multiplied by y/R^2 and integrated once, the curve so obtained shows the deviation of the surface from the sphere; the radius of the sphere depends on the zero chosen. If the difference between the measured aberrations and $e^2y/2R$ is treated in the same way the deviation of the surface from the required hyperbola will appear. The zero is best chosen so that the curve starts and ends near zero. Treated in this way the above results do not show any deviation larger than 1×10^{-6} inches.

When figuring the mirror a rough calculation of this kind is performed after every test. This is well worth while. The test may take an hour or more but the calculations only a few minutes. One sees immediately the high zones and where one should concentrate the very light stroking required to reduce these.

APPENDIX

Derivation of the relation between the observed and the actual aberration when the mirror is viewed from the back. In Fig. 5 NC is normal to the mirror surface at N but due to refraction instead of viewing from C it must be viewed from C_1 where C is specified by the relation

$$\sin\beta = \mu \sin\theta$$

Using second order ray theory we find

$$q = \frac{l}{\mu}\left(1-\frac{1}{2}\right)\left(\mu^2-1\right)\frac{y^2}{1^2}$$

But the surface is not spherical so C is displaced from the centre of the sphere osculating at P by an amount ϵ the longitudinal aberration. Hence

$$l = R+\epsilon-t$$

Neglecting unimportant small terms we find after some manipulation

$$\mu q = R+\epsilon-t-y^2\,(1+t/R)(\mu^2-1)/2R$$

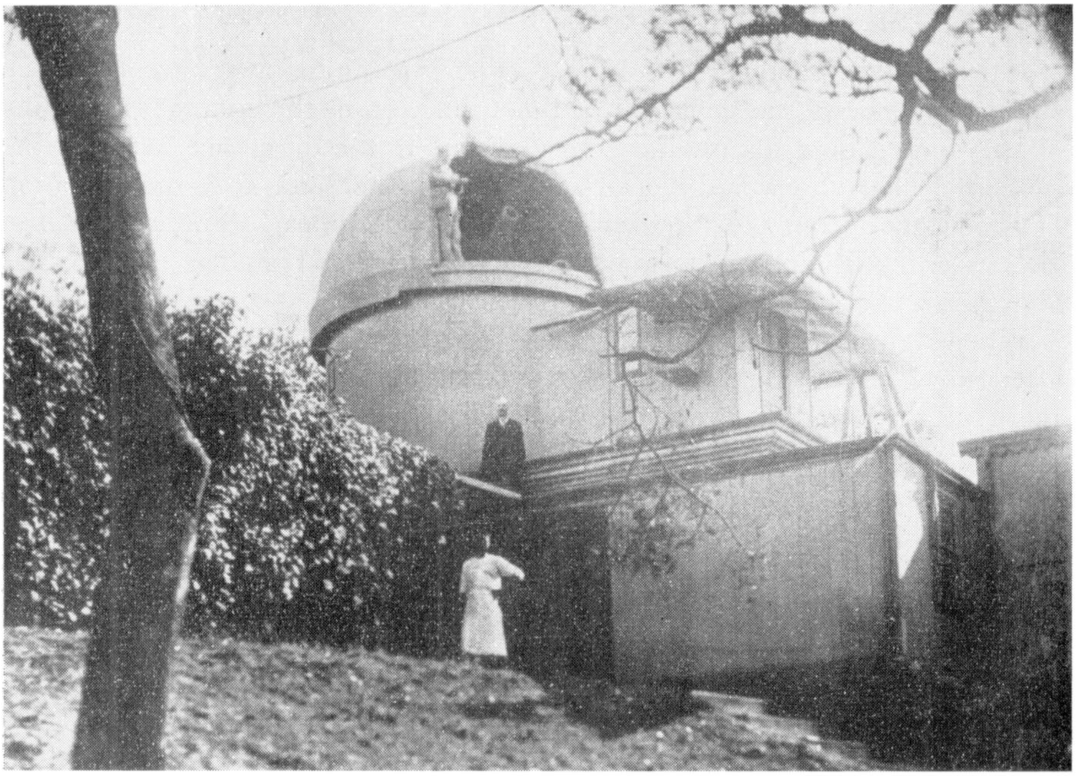
but when $y = 0$, $q = q_0$ and $\epsilon = 0$
so

$$\mu q_0 = R-t$$

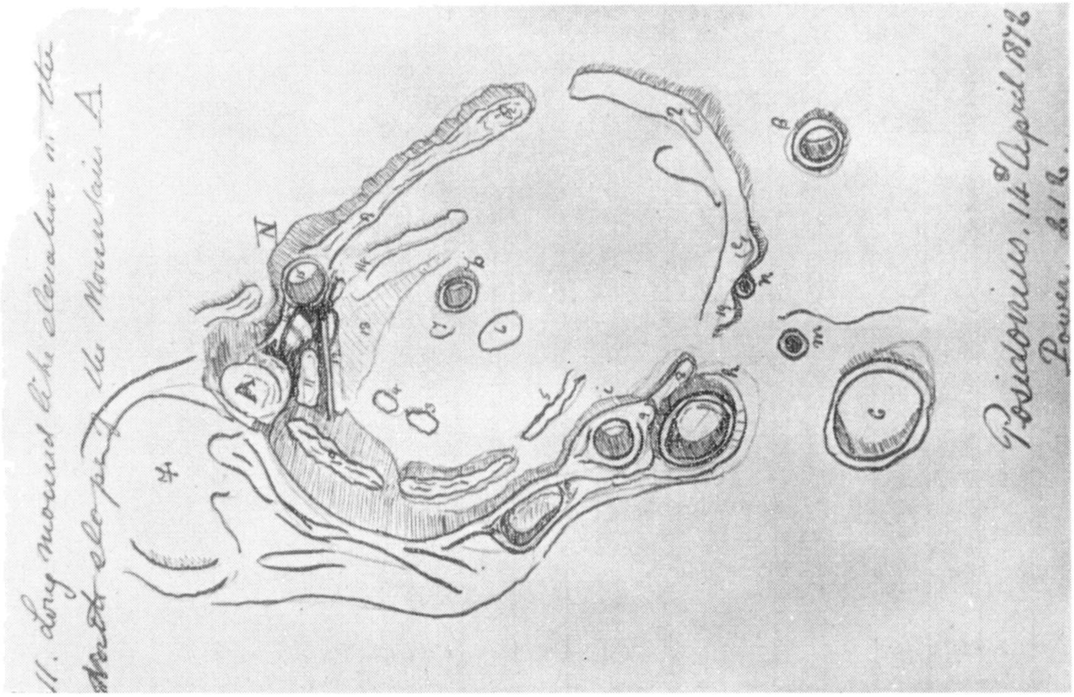
Hence the aberration which appears at C_1 is

$$\epsilon' = q-q_0 = \frac{\epsilon}{\mu} - \frac{\mu^2-1}{2\mu}\frac{y^2}{R}\left(1+\frac{t}{R}\right)$$

The second term is by no means negligible.

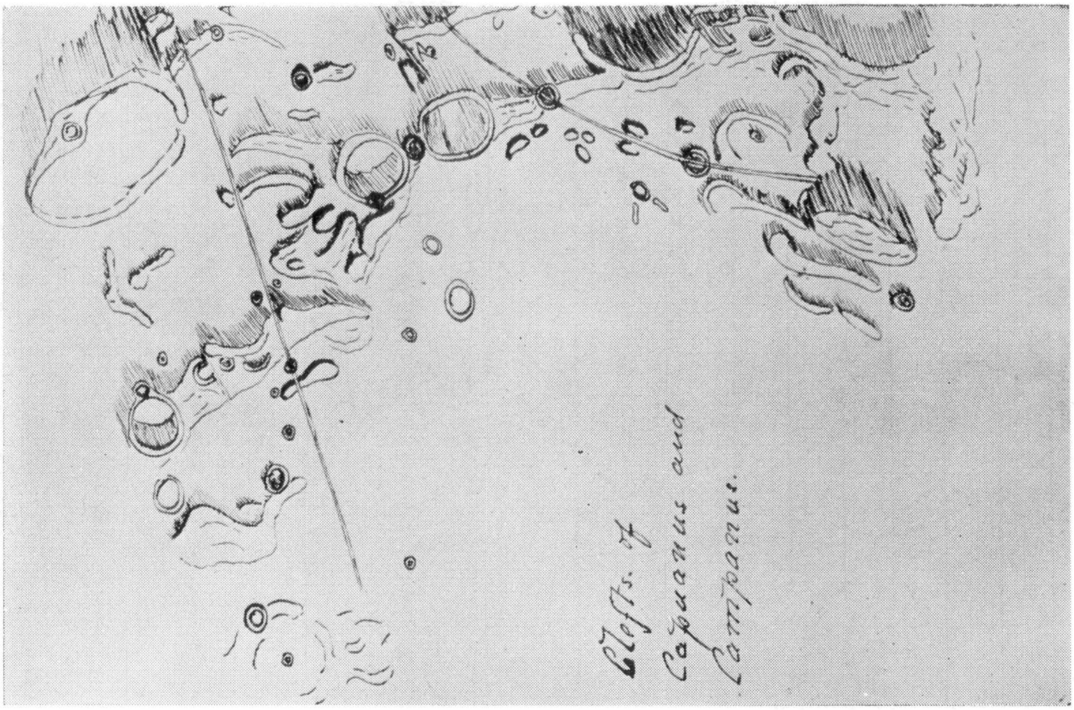


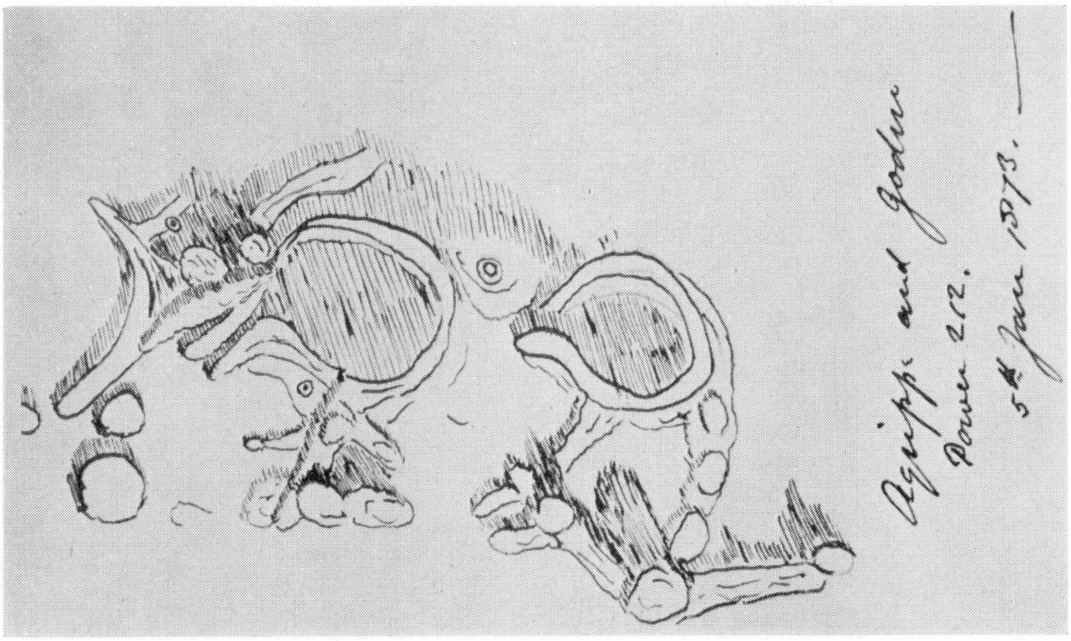
The photographs on this and the next two pages, which have been specially produced, by the Ronan Picture Library, refer to the talk by Patrick Moore regarding 'Edmund Neison' Vol. 75.4 p. 223.

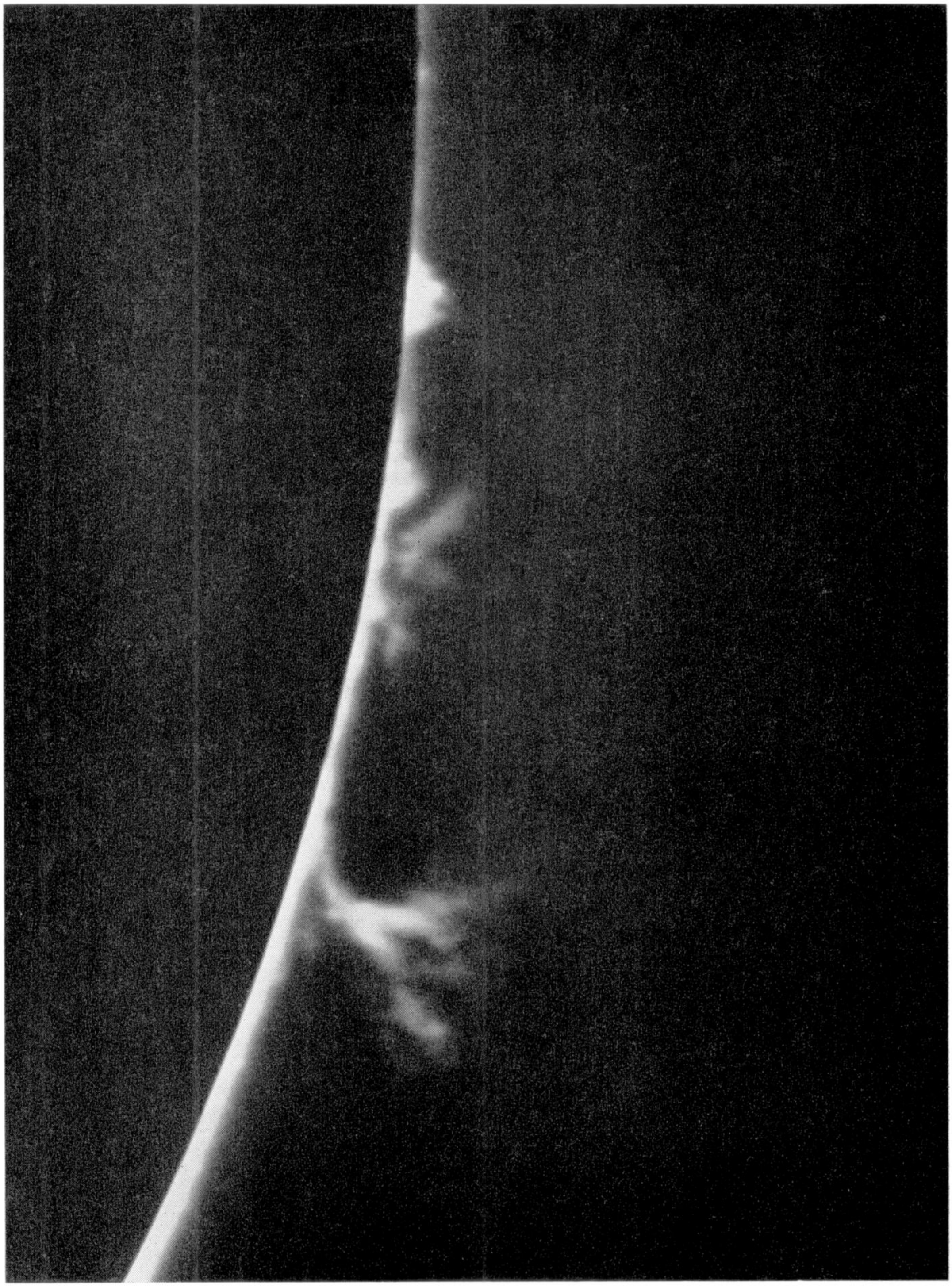


Posidonius, 14th April 1878
Power 218.

April 13th 1878.
Examined Moon 7 to 8 pm.
Posidonius
Power 212.
Definition fair


Clefts of
Capuanus and
Campanus.


Agrippa and Godin
Power 212.
5th Jan 1873.



Prominence Photograph 1965, May 9, 11·00 U.T. 3 inch Promscope with 4°A all dielectric filter, exposure 1 second on Duplo-Pan Rapid 35 mm film. H. E. Dall.