WILLIAM HERSCHEL'S SOLAR OBSERVATION TECHNIQUES

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William Herschel (1738-1822), a German-born British astronomer is considered the founder of sideral astronomy. Herschel discovered the planet Uranus in 1781, hypothesized that nebulae are composed of stars and developed a theory of stellar evolution. His thoughts about the "construction of the heavens" were revolutionary and influenced many 19th-century astronomers. Herschel also built the largest reflecting telescope of its time.

William Herschel's lifework was published in 1912, 90 years after his death in 1822, by John Louis Emil Dreyer, Director of Armagh Observatory, and author of the famous New General Catalogue[1]. The Scientific papers of Sir William Herschel filled two large-format volumes with a total of 1441 pages[2].

Dryer compiled many papers that were spread over forty volumes of the *Philosophical Transactions of the Royal Society*. These include Herschel's three catalogues of nebulae and star clusters, published in 1786, 1789 and 1802; his observations of double stars; the discovery of Uranus; the later discovery of the sixth and seventh satellites of Saturn; the papers on the "construction of the heavens", including the analysis of the Sun's proper motion and a graphic presentation of the Milky Way (based on extensive star counts); and reports about the construction of large telescopes. Unpublished material was also included[3].

The first volume includes a 56-page scientific bibliography of W. Herschel compiled by Dreyer, followed by a few "unpublished papers" The appendix of Volume II includes an unpublished collection of Herschel observations of Messier objects with 27 figures.

Volume 1 include Herschel's investigations on the infrared region of the electromagnetic spectrum. Herschel discovered this form of radiation in 1800 by exploring, with the aid of a thermometer, sunlight dispersed into its colours by a glass prism[4].

"In a variety of experiments, I have occasionally made, relating to the method of viewing the sun, with large telescopes, to the best advantage, I used various combinations of differently coloured darkening glasses. What appeared remarkable was, that when I used some of them, I felt a sensation of heat, though I had but little light; while others gave me much light, with scarce any sensation of heat. Now, as in these different combinations the sun's image was also differently coloured, it occurred to me, that the prismatic rays might have the power of heating bodies very unequally distributed among them; and, as I judged it right in this respect to entertain a doubt, it appeared equally proper to admit the same

[1] John Herschel (1792-1871), William Herschel's, son tried to publish his fathers' papers but was unsuccessful due to financial reasons
[2] Dreyer, J.L.E. (1912). *The Scientific Papers of Sir William Herschel, 2 Volumes* (Royal Society, London)
Vol. 1 http://tinyurl.com/herschelv1
Vol. 2 http://tinyurl.com/herschelv2
[3] Mainly observing journals covering many years of work in Bath, Datchet, Old Windsor and Slough
[4] Investigation of the Powers of the prismatic Colours to heat and illuminate Objects; with Remarks, that prove the different Refrangibility of radiant Heat. To which is added, an Inquiry into the Method of viewing the Sun advantageously, with Telescopes of large Apertures and high magnifying Powers. *Phil. Trans.* 1800 pp 255-283.

with regard to light. If certain colours should be more apt to occasion heat, others might, on the contrary, be more fit for vision, by possessing a superior illuminating power. At all events, it would be proper to recur to experiments for a decision."

Application of the Result of the foregoing Observations, to the Method of viewing the Sun advantageously, with Telescopes of large Apertures and high magnifying Powers.

Sometime before the late transit of Mercury over the disk of the sun, I prepared my 7-feet telescope, in order to see it to the best advantage. As I wished to keep the whole aperture of the mirror open, I soon cracked every one of the darkening slips of wedged glasses, which are generally used with achromatic telescopes: none of them could withstand the accumulated heat in the focus of pencils, where these glasses are generally placed. Being thus left without resource, I made use of red glasses; but was by no means satisfied with their performance. My not being better prepared, as it happened, was of no consequence; the weather proving totally unfavourable for viewing the sun at the time of the transit. However, as I was fully aware of the necessity of providing an apparatus for this purpose, since no method that was in use could be applied to my telescopes, I took the first opportunity of beginning my trials. The instrument I wished to adapt for solar inspection, was a Newtonian reflector, with 9 inches aperture; and my aim was, to use the whole of it open. I began with a red glass; and, not finding it to stop light enough, took two of them together. These intercepted full as much light as was necessary; but I soon found that the eye could not bear the irritation, from a sensation of heat, which it appeared these glasses did not stop. I now took two green glasses; but found that they did not intercept light enough. I therefore smoked one of them; and it appeared that, notwithstanding they now still transmitted considerably more light than the red glasses, they remedied the former inconvenience of an irritation arising from heat. Repeating these trials several times, I constantly found the same result; and the sun in the first case being of a deep red colour, I surmised that the red-making rays, transmitted through red glasses, were more efficacious in raising a sensation of heat, than those which passed through green, and which caused the sun to look greenish. In consequence of this surmise, I undertook the investigations which have been delivered under the two first heads As soon as I was convinced that the red light of the sun ought to be intercepted on account of the heat it occasions, and that it might also be safely set aside, since it was now proved that pale green light excels in illumination, the method which ought to be pursued in the construction of a darkening apparatus was sufficiently pointed out ; and nothing remained but to find such materials as would give us the colour of the sun, viewed in a telescope, of a pale green light, sufficiently tempered for the eye to bear its lustre. To determine what glasses would most effectually stop the red rays, I procured some of all colours, and tried them in the following manner. I placed a prism in the upper part of a window and received its coloured spectrum upon a sheet of white paper. Then I intercepted the colours, just before they came to the paper, successively, by the glasses, and found the result as follows. A deep red glass intercepted all the rays. A paler red did the same. From this, we ought not to conclude that red glasses will stop the red rays; but rather, that none of the sun's light, after its dispersion by the prism, remains intense enough to pass through red glasses, in sufficient quantity to be perceptible, when it comes to the paper. By looking through them directly at the sun, or even at day objects, it is sufficiently evident that they transmit chiefly red rays. An orange glass transmitted nearly all the red, the orange, and the yellow. It intercepted some of the green; much of the blue; and very little of the indigo and violet. A yellow glass intercepted hardly any light, of any one of the colours. A dark green glass intercepted nearly all the red, and partly also the orange and yellow. It transmitted the green; intercepted much of the blue; but none of the indigo and violet. A darker green glass intercepted nearly all the red; much of the orange; and a little of the yellow. It transmitted the green; stopped some of the blue; but transmitted the indigo and violet. A blue glass intercepted much of the red and orange; some of the yellow; hardly any of the green; none of the blue, indigo, or violet. A purple glass transmitted some of the red; a very little of the orange and yellow: it also transmitted a little of the green and blue; but more of the indigo and violet. From these experiments we see that dark green glasses are most efficacious for intercepting red light and will therefore answer one of the intended *purposes; but since, in viewing the sun, we have also its splendour to contend with, I proceeded to the following additional trials. White glass, lightly smoked, apparently intercepted an equal share of all the colours; and, when the smoke was laid on thicker, it permitted none of them to pass. Hard pitch, melted between two white glasses, intercepted much light; and, when put on sufficiently thick, transmitted none. Many differently coloured fluids, that were also tried, I found were not sufficiently pure to be used, when dense enough to stop light. Now, red glasses, and the two last-mentioned resources of smoke, and pitch, any one of which, it has been seen, will stop as much light as may be required, had still a remaining trial to undergo, relating to distinctness; but this I was convinced could only be decided by actual observations of the sun. As an easy way of smoking glasses uniformly is of some consequence to distinct vision, it may be of service here to give the proper directions, how to proceed in the operation. With a pair of warm pliers, take hold of the glass, and place it over a candle, at a sufficient distance not to contract smoke. When it is heated, but no more than still to permit a finger to touch the edges of it, bring down the glass, at the side of the flame, as low as the wick will permit, which must not be touched. Then, with a quick vibratory motion, agitate it in the flame from side to side; at the same time advancing and retiring it gently all the while. By this method, you may proceed to lay on smoke to any required darkness. It ought to be viewed from time to time, not only to see whether it be sufficiently dark, but whether any inequality may be perceived; for, if that should happen, it will not be proper to go on. The smoke of sealing-wax is bad: that of pitch is worse. A wax candle gives a good smoke; but that of a tallow candle is better. As good as any I have hitherto met with, is the smoke of spermaceti oil. In using a lamp, you may also have the advantage of an even flame extended to any length.*

Telescopic Experiments

No. 1. *By way of putting my theory to the trial, I used two red glasses, and found that the heat which passed through them could not be suffered a moment; but I was now also convinced that distinctness of vision is capitally injured, by the colouring matter of these glasses.*
No. 2*. I smoked a white glass, till it stopped light enough to permit the eye to bear the sun. This destroyed all distinctness; and also permitted some heat to come to the eye, by transmitting chiefly red rays.*
No. 3. *I applied two white glasses, with pitch between them, to the telescope; and found that it made the sun appear of a scarlet colour. They transmitted some heat; and distinctness was greatly injured.*
No. 4. *I used a very dark green glass, to stop heat; and behind it, or towards the eye, I placed a red glass, to stop light. The first glimpse I had of the sun, was accompanied with a sensation of heat; distinctness also was materially injured.*
No. 5. *I used a dark green and a pale red; but the sun not being sufficiently darkened, I smoked the red glass, and, putting a small partition between the two, placed the smoke towards the green glass. This took off the exuberance of light; but did not remedy the inconvenience arising from heat.*
No. 6*. I used two pale green glasses, smoking that next to the eye, and placing it as in No. 5, so that the smoke might be enclosed between the two. This acted incomparably well; but, in a very short time, the heat which passed the firs glass, (though not the second, for I felt no sensation of it in the eye,) disordered the smoke, by drawing it up into little blisters or stars, which let through light; and this composition, therefore, soon became useless.*
No. 7. *I used two dark green glasses, one of them smoked, as in No. 5. These also acted well; but became useless, for the reason assigned in No. 6, though somewhat less smoke had been required than in the former composition. I felt no heat.*
No. 8. *I used one pale green, with a dark green smoked glass upon it, as in No. 5. It bore an aperture of 4 inches very well, and the smoke was not disordered; but, when all the tube was open, the pale green glass cracked in a few minutes.*
No. 9. *Placing now a dark green before a smoked green, I saw the sun remarkably well. In this experiment, I had made a difference in the arrangement of the apparatus. The cracking of the glasses,*

I supposed, might be owing to their receiving heat in the middle, while the outside remained cold, which would occasion a partial dilatation. I therefore cut them into pieces about a quarter of an inch square, and set three of them in a slider, so that I could move them behind the smoked glass, without disturbing it. After looking about three or four minutes through one of them, I moved the slider to the second, and then to the third. This kept the glasses sufficiently cool; but the disturbance of the alterations proved hurtful to vision, which requires repose; and, if perchance I stopped a little longer than the proper time, the glass cracked, with a very disagreeable explosion, that endangered the eye.

No. 10. *Two dark green glasses, both smoked, that a thinner coat might be on each, but the smoke still contracted blisters, though less dense than before. No. II. To get rid of smoke entirely, I used two dark green glasses, two very dark green, two pale blue, and one pale green glass, together. Distinctness was wanting; nor was light sufficiently intercepted.*

No. 12. *A dark green and a pale blue glass, smoked. The green glass cracked.*

No. 13. *A pale blue and a dark green glass, smoked. The blue glass cracked. The eye felt no sensation of heat.*

No. 14. *Two pale blue glasses, one smoked. The first glass cracked. It was now sufficiently evident, that no glass which stops heat, and therefore receives it, could be preserved from cracking, when exposed to the focus of pencils. This induced me to try an application of the darkening apparatus to another part of the telescope. The place where the rays are least condensed, without interfering with the reflections of the mirrors, is immediately close to the small one. I therefore screwed an apparatus to the speculum arm, into which any glass might be placed.*

No. 15. *A dark green glass close to the small speculum, and smoked pale green in the focus of pencils, as before. I saw remarkably well.*

No. 16. *The dark green as before; but that more light might be admitted, a white smoked glass near the eye. Better than No. 15; but the green glass cracked.*

No. 17. *A very dark green and white smoked glass, as before. Very distinct, but the green glass cracked in about six or seven minutes.*

No. 18. *A dark blue glass, as in No. 15, and white smoked. This was distinct; and no heat came to the eye. The sun appeared ruddy.*

No. 19. *A dark blue and a yellow glass, close together, as in No. 15, and a white smoked one, as before. This was not distinct.*

No. 20. *A purple glass, as in No. 15, with a white smoked one. This gave the sun of a deep orange colour, approaching to scarlet. It was not distinct.*

No. 21. *An orange glass, as in No. 15, with a white smoked one. The colour of the sun was too red.*

No. 22, *A white smoked glass, as in No. 15, without any other at the eye. This gave the sun of a beautiful orange colour; but distinctness was totally destroyed.*

No. 23. *The heat near the small speculum being still too powerful for the glasses, I had a bluish dark green glass made of a proper diameter to be enclosed between the two eyeglasses of a double eyepiece. All glass I knew would stop some heat; and was therefore in hopes that the interposition of this eyeglass would temper the rays, so as in some measure to protect the coloured glass. In the usual place near the eye, I put two white glasses, with a thin coat of pitch between them. These glasses, when looked through by the natural eye, give the sun of a red colour; I therefore entertained no great hopes of their application to the telescope. They darkened the sun not sufficiently; and, when the pitch was thickened, distinctness was wanting.*

No. 24. *The same glass between the eyeglasses, and a dark green smoked glass at the eye. Very distinct. This arrangement is preferable to that of No. 15; after some considerable time, however, this glass also cracked.*

No. 25. *I placed a very dark green glass behind the second eyeglass, that it might be sheltered by both glasses, which in my double eyepiece are close together, and of an equal focal length. Here, as the rays are not much concentrated, the coloured glass receives them on a large surface, and stops light and heat, in the proportion of the squares of its diameter now used, to that on which the rays would have fallen, had it been placed in the focus of pencils. And, for the same reason, I now also placed a dark* *green smoked glass close upon the former, with the smoked side towards the eye, that the smoke might likewise be protected against heat, by a passage of the rays through two surfaces of coloured glass. This position had moreover the advantage of leaving the telescope, with its mirrors and glasses, completely to perform its operation, before the application of the darkening apparatus; and thus, to prevent the injury which must be occasioned, by the interposition of the heterogeneous colouring matter of the glasses and of the smoke.*

No. 26. *I placed a deep blue glass with a bluish green smoked one upon it, as in No. 25, and found the sun of a whiter colour than with the former composition. There was no disagreeable sensation of heat, though a little warmth might be felt.*

No. 27*. I used two black glasses, placed as in No. 25. Here there was no occasion for smoke; but the sun appeared of a bright scarlet colour, and an intolerable sensation of heat took place immediately. I rather suspect that these are very deep red glasses, though their outward appearance is black. In order to have a more sure criterion of heat, I applied Dr. Wilson's thermometer. No. 2, to the end of the eyepiece, where the eye is generally placed. With No. 25, it rose from 34 to 37 degrees. With No. 26, it rose from 35 to 46; and, with No. 27, it rose, very quickly, from 36 to 95 degrees. I am pretty sure it would have mounted up still higher; but the scale extending only to 100, 1 was not willing to run the risk of breaking the thermometer by a longer exposure. It remains now only to be added, that with No. 25 and 26 I have seen uncommonly well; and that, in a long series of very interesting observations upon the sun, which will soon be communicated, the glasses have met with no accident. However, when the sun is at a considerable altitude, it will be advisable to lessen the aperture a little, in telescopes that have so much light as my lo-feet reflector ; or, which will give us more distinctness, to view the sun earlier in the morning, and later in the afternoon ; for, the light intercepted by the atmosphere in lower altitudes will reduce its brilliancy much more uniformly than we can soften it, by laying on more smoke upon our darkening glasses. Now, as few instruments in common use are so large as that to which this method of darkening has been adapted, we may hope that it will be of general utility in solar observations.*

In 1801, Herschel viewed the sun through a mixture of ink diluted with water and filtered through paper. It gave an image of the sun ' as white as snow '. An eyepiece was then filled with a solution of ferrous sulphate with ' tincture of galls '. This gave a dark blue solar image which changed, on adding more ferrous sulphate to the solution, to an image 'of a deep red colour.' Herschel expressed no surprise at this interesting case of dichromatism and failed to appreciate its significance.

Additional Observations tending to investigate the Symptoms of the variable Emission of the Light and Heat of the Sun; with Trials to set aside darkening Glasses, by transmitting the Solar Rays through Liquids; and a few Remarks to remove Objections that might be made against some of the Arguments contained in the former Paper.

Having brought up the solar observations, relating to the symptoms of a copious emission of the light and heat of the sun, to the 2d of March, I give them continued in this Paper to the 3d of May. It will be seen that my expectations of the continuance of the symptoms which I supposed favourable to such emissions, have hitherto been sufficiently verified; and, by comparing the phaenomena I have reported, with the corresponding mildness of the season, my arguments will receive a considerable support. I have given the following observations without delay, as containing an outline of the method we ought to pursue, in order to establish the principles which have been pointed out in my former Paper. But we need not in future be at a loss how to come at the truth of the current temperature of this climate, as the thermometrical observations, which are now regularly published in the Philosophical Transactions, can furnish us with a proper standard, with which the solar phaenomena may be compared. This leads me to remark, that, although I have, in my first Paper, sufficiently noticed the want of a proper criterion for ascertaining the temperature of the early periods where the sun has been recorded to have been without spots, and have also referred to future observations for shewing *whether a due distribution of dry and wet weather, with other circumstances which are known to favour the vegetation of corn, do or do not require a certain regular emission of the solar beams, yet, I might still have added, that the actual object we have in view, is perfectly independent of the result of any observations that may hereafter be made, on the favourable or defective vegetation of grain in this or in any other climate. For, if the thermometer, which will be our future criterion should establish the symptoms we have assigned, of a defective or copious emission of the solar rays, or even help us to fix on different ones, as more likely to point out the end we have in view, we may leave it entirely to others, to determine the use to which a fore-knowledge of the probable temperature of an approaching summer, or winter, or perhaps of both, may be applied ; but still it may be hoped that some advantage may be derived, even in agricultural economy, from an improved knowledge of the nature of the sun, and of the causes, or symptoms, of its emitting light and heat more or less copiously. Before I proceed, I must hint to those who may be willing to attend to this subject, that I have a strong suspicion that one half of our sun is less favourable to a copious emission of rays than the other ; and that its variable lustre may possibly appear to other solar systems, as irregular periodical stars are seen by us ; but, whether this arises from some permanent construction of the solar surface, or is merely an accidental circumstance, must be left to future investigation : it should, however, be carefully attended to.*

Observations of the Sun

March 4, 1801. *I viewed the sun with a skeleton eyepiece, into the vacancy of which may be placed a moveable trough, shut up at the ends with well-polished plain glasses, so that the sun's rays may be made to pass through any liquid contained in the trough before they come to the eyeglass (see fig. I and 2). Through spirit of wine, I saw the sun very distinctly. There are 10 openings without shallows: and a pretty considerable one with a shallow. The opening is nearly round; and the shallow is concentric with it, and also round. The want of shallows about the small openings, and the roundness of that about the largest, indicate that the elastic empyreal gas which passes through them, is without side bias in its motion.*

March 8. *I viewed the sun through water. It keeps the heat off so well, that we may look for any length of time, without the least inconvenience. There are a few openings, many ridges, and nodules.*

March 9. *The ridges near the preceding limb are more extensive than I have ever seen them; there is a broad zone of them.*

March 12. *There is a cluster of 20 small openings; none of them have any shallows.*

March 13. *There are 31 openings in the cluster of yesterday: they are contained in a double row, nearly parallel to the sun's equatorial motion; the largest of them has now a shallow of a considerable size, on its north-following side. The number of small openings near each other, indicates a perpendicular ascent of the empyreal gas that breaks through the atmospheric clouds; and their want of shallows shews the same thing.*

March 15. *The set of openings which began to enter on the 8th, consists now of 29. There are 3 other small openings in different parts of the sun.*

March 16. *There is an opening lately entered. The cluster of yesterday has undergone considerable changes.*

March 18. *The opening of the i6th consists now of 8 different ones; none of them have any shallows. The whole space about the cluster of the 8th, is surrounded with luminous ridges in many directions. The corrugations all over the sun are beautiful, and coarse; resembling small nodules joined together like irregular honeycomb. In a multitude of places, the corrugations are quite detached, like luminous wisps, or slender tufts, standing upright.*

March 19. *Another set of ridges has entered the disk; it contains one opening. The corrugations are rich, and may be called luminous wisps, being much disjoined, except at their bottom; they are so rich, that they partake of the yellowish colour of the ridges. The northern ridges extend a good way into the disk, like a zone.*

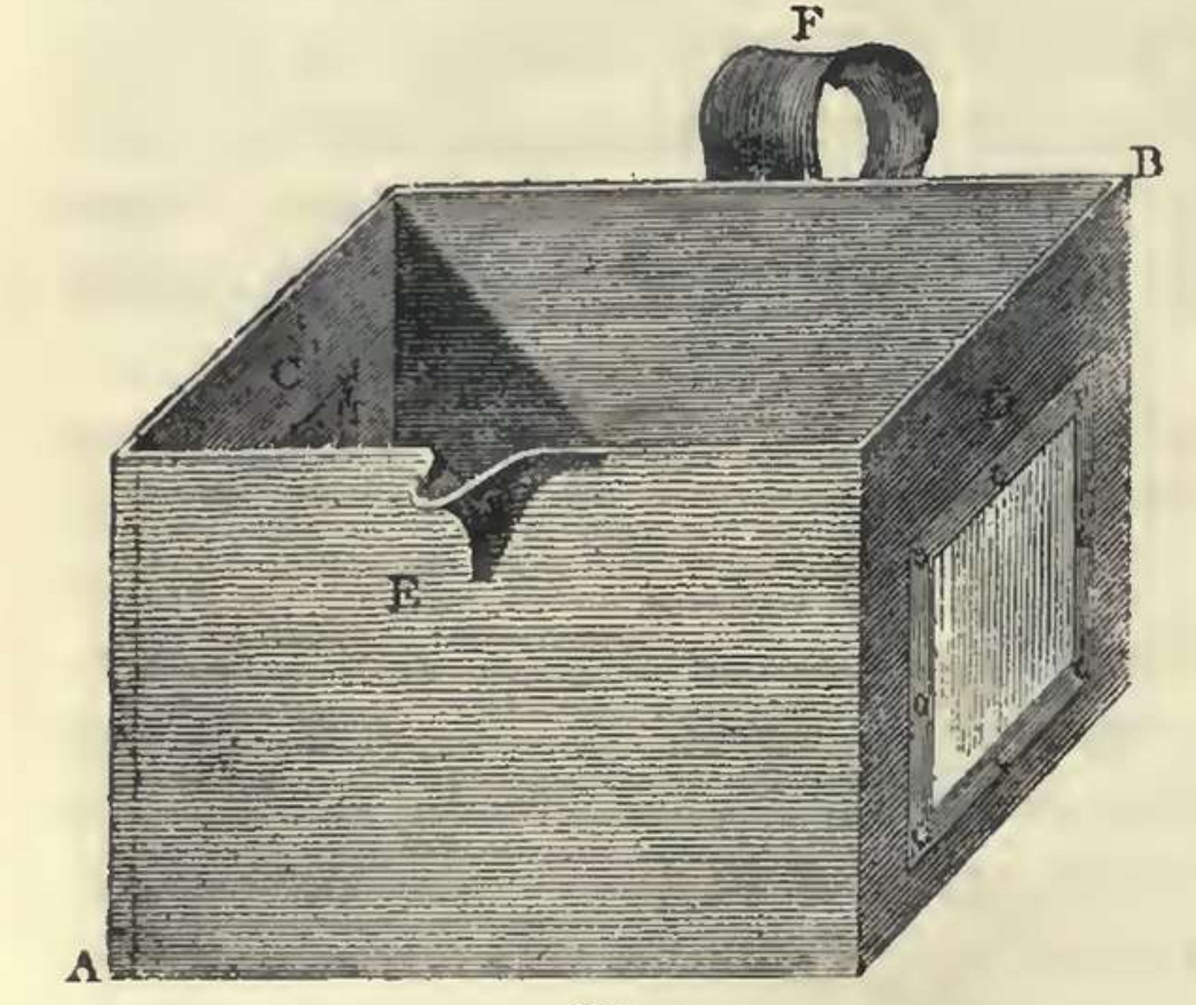

FIG. 1.

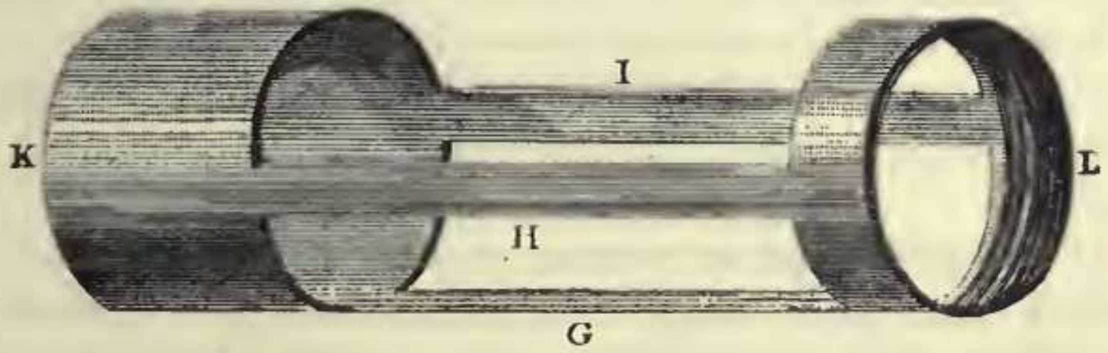

FIG. 2.

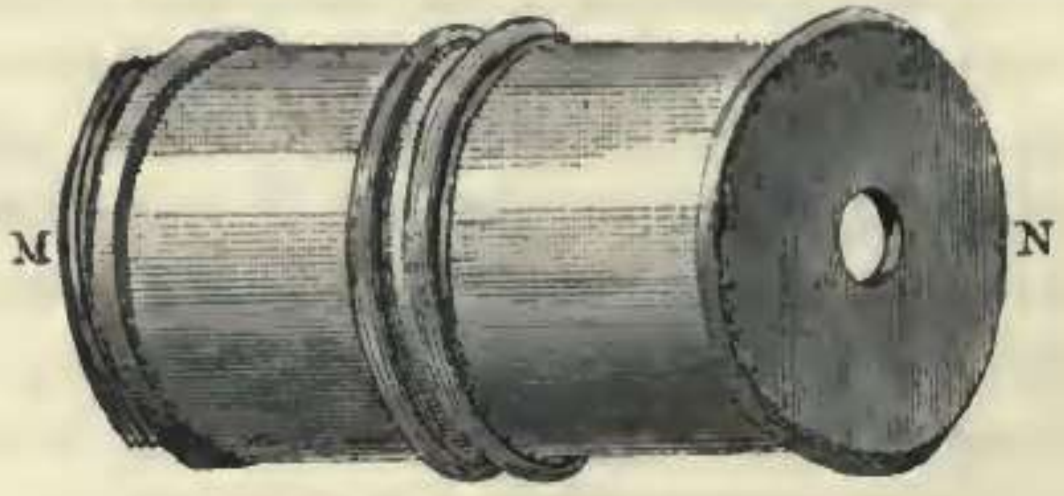

FIG. 3.

EXPLANATION OF THE FIGURES.

A B, ***Fig. 1****, is a square trough, closed at the two opposite ends C D, by well-polished plain glasses. It will hold any liquid through which the sun's rays are to be transmitted. E is a small spout, and F a handle, so that any portion of the liquid may conveniently be poured out, when the rest is to be diluted. The trough is made to fit into the open part of the skeleton eye-tube,* ***Fig. 2****, resting on the bottom G, and being held in its proper situation by the sides H and I. The end K, at the time of observation, is put into a short tube fixed to the Newtonian telescope, and may be turned about, so as always to have the open part H I horizontal. When the eyepiece Fig. 3, is screwed, by its end M, into the skeleton tube at L,* ***Fig. 2****, and the trough Fig. i, with any liquid to be tried, is placed in the open part G H I, the sun's rays will come from the small mirror of the telescope to K, and, passing through the plain glasses C D, inclosing the liquid, will enter the eye-piece M, and, after the necessary refractions, come to the eye at N. Any other, single or double, eyepieces, of different magnifying powers, may be screwed into L, instead of the piece* ***Fig. 3****; and the liquid may easily be tempered so as to intercept a proper quantity of light to suit every eyeglass which is in use, and thus to render the inspection of the sun perfectly convenient.*

March 21. *There are five sets, containing 29 openings, none of which have any shallows. At equal distances from the limb, the corrugations are equally coarse all over the disk of the sun.*
March 22. *An additional opening, with surrounding ridges, has lately entered the north-following limb. I counted 21 openings.*
March 31*. An opening very near the preceding limb is surrounded by a shallow, which is bordered by a luminous ridge all round it. The opening itself is also bordered by an elevated edge, which is nearly as high as the general surface of the corrugations; but not so high as that which borders the shallow and stands above the general surface. April I, ii" 30'. I saw the opening of yesterday go out of the limb: it was the only one left. 2" o'. The sun is now without any openings; but the corrugations are very luminous and rich.*
April 2. *A considerable opening has entered the disk, accompanied with ridges. From its present situation, I conclude it must have entered not long after my last observation yesterday. The sun is very rich in luminous corrugations, interspersed with bright nodules towards the south pole.*
April 4. *There are 4 considerable openings, and many ridges, as well as nodules, on the south and north preceding and following limbs. The north-preceding ridges extend into the sun, till I can no longer distinguish them; and begin again at the north-following side, as far as they generally can be seen from the limb; so that there is probably a whole zone across the disk. Where I lose them, they are generally converted into tufted, rich, coarse corrugations, such as the sun is now everywhere covered with.*

April 6. *There are many ridges and rich corrugations; but I can perceive no opening. The air is not clear enough to discover very small ones.*
April 8. *A cluster of 7 small openings is visible: and many ridges.*
April 10. *Five sets contain 32 openings. The sun is full of rich tufted corrugations.*
April 17. *Two sets of openings contain 20 of them.*
April 19. *I count 45 openings. The corrugations are extremely rich. The whole solar surface seems to be studded with nodules. There are probably two belts of ridges across the sun's disk; for, on the preceding side, as well as on the following, I see two ends of belts of ridges very plainly, extending over all the space where these phaenomena can be seen. April 20. The whole surface of the sun is rich: the corrugations are tufted. I count more than 50 openings; many of them have considerable shallows about them.*
April 23, *6hThere are above 60 openings in the sun. The last set is much towards the sun's north pole, very rich in ridges, and disturbed neighbouring surface. April 24. I count above 50 openings. The corrugations seem to be closer than they were yesterday.*
April 26. *I viewed the sun through Port wine, and without smoke on the darkening glasses; but distinctness was much injured.*
April 27. *I count 39 openings. Many ridges and rich corrugations.*
April 29. *Six different sets contain 24 openings. There are many sets of ridges and rich corrugations. 4". I viewed the sun through a mixture of ink diluted with water and filtered through paper. It gave an image of the sun as white as snow; and I saw objects very distinctly, without darkening glasses. As one of the largest openings had a considerable shallow, I found, in viewing it through this mixture, that the difference between what I suppose to be the light reflected from opaque, and the direct light of empyreal clouds, is now more striking than I ever had observed it before. The ridges, through this composition, appear whiter than the rest of the sun. The tops of the corrugations are whiter than their indentations, instead of approaching to a yellowish cast, as they do in my former way of seeing through green smoked glasses. The corrugations are very small and contracted to-day. Suspecting that this new way of seeing might represent objects less than they appear, when I view them through an eyepiece that gives them in the manner, I have been used to see them, I put on again the former composition; but found the corrugations as small and close then as they appeared before. I count 36 openings. When the ink mixture is more diluted, the sun's image will become tinged with purple. solution of green vitriol, with a sufficient number of drops of the tincture of galls to stop as much light as is required, gives a dark blue colour to the sun; and, by dilution with water, a light blue. It is considerably distinct. With this composition, the corrugations look whiter at the top than in their indentations. The tincture of galls, with as many drops of the solution of green vitriol as will turn it sufficiently black to stop light, makes the sun look of a deep red colour; and, by dilution, the red will be paler. This composition is not so distinct as the former.*
May 2. *5h 20'. There are 36 openings, contained in six sets. As I have remarked, March 19th, April 4th, and April 19th, that ridges are generally placed in equatorial zones, so I now may add, that the different sets of openings have also been generally arranged in the same directions.*
May 3. *11h 56'. Ink mixture. There are 37 openings, arranged in two zones. Four sets in the southern zone contain 27, and three sets in the northern have 10 openings. Through this mixture, I can observe the sun in the meridian, for any length of time, without danger to the eye or to the glasses, with a mirror of nine inches in diameter, and with the eye-pieces open, as they are used for night observations.*