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Description of a Lamp-Micrometer, and the Method of Using It. By Mr. William Herschel, F. R. S.

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XIII. *Description of a Lamp-Micrometer, and the Method of using it.* By *Mr.* William Herſchel, *F. R. S.*

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THE great difficulty of meaſuring very ſmall angles, ſuch as hardly amount to a few ſeconds, is well known to aſtronomers. Since I have been engaged in obſervations on double ſtars, I have had ſo much occaſion for micrometers that would meaſure exceeding ſmall diſtances exactly, that I have continually been endeavouring to improve theſe inſtruments.

The natural imperfections of the parallel wire micrometer in taking the diſtance of very cloſe double ſtars are the following. When two ſtars are taken between the parallels, the diameters muſt be included. I have in vain attempted to find lines ſufficiently thin to extend them acroſs the centers of the ſtars ſo that their thickneſs might be neglected. The ſingle threads of the ſilk-worm, with ſuch lenſes as I uſe, are ſo much magnified that their diameter is more than that of many of the ſtars. Beſides, if they were much leſs than they are, the power of deflection of light would make the attempt to meaſure the diſtance of the centers this way fruitleſs: for I have always found the light of the ſtars to play upon thoſe lines and ſeparate their apparent diameters into two parts. Now ſince the ſpurious diameters of the ſtars thus included, to my certain knowledge, are continually changing according to the ſtate of the air, and the length of time we look at them, we are, in

ſome reſpect, left at an uncertainty, and our meaſures taken at different times, and with different degrees of attention, will vary on that account. Nor can we come at the true diſtance of the centers of any two ſtars, one from another, unleſs we could tell what to allow for the ſemi-diameters of the ſtars themſelves; for different ſtars have different apparent diameters, which, with a power of 227, may differ from each other (as I have experienced) as far as two ſeconds.

The next imperfection is that which ariſes from a deflection of light upon the wires when they approach very near to each other; for if this be owing to a power of repulſion lodged at the ſurface, it is eaſy to underſtand, that ſuch powers muſt interfere with each other, and give the meaſures larger in proportion than they would have been if the repulſive power of one wire had not been oppoſed by a contrary power of the other wire.

Another very conſiderable imperfection of theſe micrometers is a continual uncertainty of the real zero. I have found, that the leaſt alteration in the ſituation and quantity of light will affect the zero, and that a change in the poſition of the wires, when the light and other circumſtances remain unaltered, will alſo produce a difference. To obviate this difficulty, whenever I took a meaſure that required the utmoſt accuracy, my zero was always taken immediately after, while the apparatus remained in the ſame ſituation it was in when the meaſure was taken; but this enhances the difficulty becauſe it introduces an additional obſervation.

The next imperfection, which is none of the ſmalleſt, is that every micrometer that has hitherto been in uſe requires either a ſcrew or a divided bar and pinion to meaſure the diſtance of the wires or divided image. Thoſe who are acquainted

quainted with works of this kind are but too ſenſible how difficult it is to have ſcrews that ſhall be perfectly equal in every thread or revolution of each thread; or pinions and bars that ſhall be ſo evenly divided as perfectly to be depended upon in every leaf and tooth to perhaps the two, three, or four thouſandth part of an inch; and yet, on account of the ſmall ſcale of thoſe micrometers, theſe quantities are of the greateſt conſequence; an error of a ſingle thouſandth part inducing in moſt inſtruments a miſtake of ſeveral ſeconds.

The laſt and greateſt imperfection of all is, that theſe wire micrometers require a pretty ſtrong light in the field of view: and when I had double ſtars to meaſure, one of which was very obſcure, I was obliged to be content with leſs light than is neceſſary to make the wires perfectly diſtinct; and ſeveral ſtars on this account could not be meaſured at all, though otherwiſe not too cloſe for the micrometer.

The inſtrument I am going to deſcribe, which I call a Lamp-Micrometer, is free from all theſe defects, and has, moreover, to recommend it, the advantage of a very enlarged ſcale. The conſtruction of it is as follows.

ABGCFE (fig. 1) is a ſtand nine feet high, upon which a ſemi-circular board *qbogp* is moveable upwards or downwards, in the manner of ſome fire-ſcreens, as occaſion may require, and is held in its ſituation by a peg *p* put into any one of the holes of the upright piece AB. This board is a ſegment of a circle of fourteen inches radius, and is about three inches broader than a ſemi-circle, to give room for the handles *r*D, *e*P, to work. The uſe of this board is to carry an arm L, thirty inches long, which is made to move upon a pivot at the center of the circle, by means of a ſtring, which paſſes in a groove upon the edge of the ſemi-circle *pgobq*; the ſtring is faſtened

to

to a hook at *o* (not expreſſed in the figure being at the back of the arm L), and paſſing along the groove from *ob* to *q* is turned over a pulley at *q*, and goes down to a ſmall barrel *e*, within the plane of the circular board, where a double-jointed handle *e*P commands its motion. By this contrivance we ſee the arm L may be lifted up to any altitude from the horizontal poſition to the perpendicular, or be ſuffered to deſcend by its own weight below the horizontal to the reverſe perpendicular ſituation. The weight of the handle P is ſufficient to keep the arm in any given poſition; but if the motion ſhould be too eaſy, a friction ſpring applied to the barrel will moderate it at pleaſure.

In front of the arm L a ſmall ſlider, about three inches long, is moveable in a rabbet from the end L towards the center backwards and forwards. A ſtring is faſtened to the left ſide of the little ſlider, and goes towards L, where it paſſes round a pulley at *m*, and returns under the arm from *m*, *n*, towards the center, where it is led in a groove on the edge of the arm, which is of a circular form, upwards to a barrel (raiſed above the plane of the circular board) at *r*, to which the handle *r*D is faſtened. A ſecond ſtring is faſtened to the ſlider, at the right ſide, and goes towards the center, where it paſſes over a pulley *n*, and the weight *w*, which is ſuſpended by the end of this ſtring, returns the ſlider towards the center when a contrary turn of the handle permits it to act.

a and *b* are two ſmall lamps, two inches high, 1 ½ in breadth by 1 ¼ in depth. The ſides, back, and top, are made ſo as to permit no light to be ſeen, and the front conſiſts of a thin braſs ſliding door. The flame in the lamp *a* is placed three-tenths of an inch from the left ſide, three-tenths from the front, and half an inch from the bottom. In the lamp *b* it is placed at the

the ſame height and diſtance meaſuring from the right ſide. The wick of the flame conſiſts only of a ſingle very thin lamp-cotton thread; for the ſmalleſt flame being ſufficient it is eaſier to keep it burning in ſo confined a place. In the top of each lamp muſt be a little ſlit, lengthways, and alſo a ſmall opening in one ſide near the upper part, to permit air enough to circulate to feed the flame. To prevent every reflection of light, the ſide opening of the lamp *a* ſhould be to the right, and that of the lamp *b* to the left. In the ſliding door of each lamp is made a ſmall hole with the point of a very fine needle juſt oppoſite the place where the wicks are burning, ſo that when the ſliders are ſhut down, and every thing dark, nothing ſhall be ſeen but two fine lucid points of the ſize of two ſtars of the third or fourth magnitude. The lamp *a* is placed ſo that its lucid point may be in the center of the circular board where it remains fixed. The lamp *b* is hung to the little ſlider which moves in the rabbet of the arm, ſo that its lucid point, in a horizontal poſition of the arm, may be on a level with the lucid point in the center. The moveable lamp is ſuſpended upon a piece of braſs faſtened to the ſlider by a pin exactly behind the flame upon which it moves as a pivot. The lamp is balanced at the bottom by a leaden weight, ſo as always to remain upright, when the arm is either lifted above, or depreſſed below, the horizontal poſition. The double-jointed handles *r*D, *e*P, conſiſt of light deal rods, ten feet long, and the loweſt of them may have diviſions, marked upon it near the end P, expreſſing exactly the diſtance from the central lucid point in feet, inches, and tenths.

From this conſtruction we ſee, that a perſon at a diſtance of ten feet may govern the two lucid points, ſo as to bring them into any required poſition ſouth or north preceding or following,

from 0 to 90° by uſing the handle P, and alſo to any diſtance from ſix-tenths of an inch to five or ſix and twenty inches by means of the handle D. If any reflection or appearance of light ſhould be left from the top or ſides of the lamps, a temporary ſcreen, conſiſting of a long piece of paſte-board, or a wire frame covered with black cloth, of the length of the whole arm and of any required breadth, with a ſlit of half an inch broad in the middle, may be affixed to the arm by four bent wires projecting an inch or two before the lamps, ſituated ſo that the moveable lucid point may paſs along the opening left for that purpoſe.

Fig. 2. repreſents part of the arm L, half the real ſize; S the ſlider; *m* the pulley, over which the cord *xtyz* is returned towards the center; *v* the other cord going to the pulley *n* of fig. 1. R the braſs piece moveable upon the pin *c*, to keep the lamp upright. At R is a wire rivetted to the braſs piece, upon which is held the lamp by a nut and ſcrew. Fig. 3. 4. repreſent the lamps *a*, *b*, with the ſliding doors open, to ſhew the ſituation of the wicks. W is the leaden weight with a hole *d* in it, through which the wire R of fig. 2. is to be paſſed when the lamp is to be faſtened to the ſlider S. Fig. 5. repreſents the lamp *a* with the ſliding door ſhut; *l* the lucid point; and *ik* the openings at the top, and *s* at the ſides for the admiſſion of air.

Every ingenious artiſt will ſoon perceive that the motions of this micrometer are capable of great improvement by the application of wheels and pinions, and other well known mechanical reſources; but, as the principal object is only to be able to adjuſt the two lucid points to the required poſition and diſtance, and to keep them there for a few minutes, while the obſerver

obſerver goes to meaſure their diſtance, it will not be neceſſary to ſay more upon the ſubject.

I am now to ſhew the application of this inſtrument. It is well known to opticians and others, who have been in the habit of uſing optical inſtruments, that we can with one eye look into a microſcope or teleſcope, and ſee an object much magnified, while the naked eye may ſee a ſcale upon which the magnified picture is thrown. In this manner I have generally determined the power of my teleſcopes; and any one who has acquired a facility of taking ſuch obſervations will very ſeldom miſtake ſo much as one in fifty in determining the power of an inſtrument, and that degree of exactneſs is fully ſufficient for the purpoſe.

The Newtonian form is admirably adapted to the uſe of this micrometer; for the obſerver ſtands always erect, and looks in a horizontal direction, notwithſtanding the teleſcope ſhould be elevated to the zenith. Beſides, his face being turned away from the object to which his teleſcope is directed, this micrometer may be placed very conveniently without cauſing the leaſt obſtruction to the view: therefore, when I uſe this inſtrument I put it at ten feet diſtance from the left eye, in a line perpendicular to the tube of the teleſcope, and raiſe the moveable board to ſuch a height that the lucid point of the central lamp may be upon a level with the eye. The handles, lifted up, are paſſed through two loops faſtened to the tube, juſt by the obſerver, ſo as to be ready for his uſe. I ſhould obſerve, that the end of the tube is cut away ſo as to leave the left eye intirely free to ſee the whole micrometer.

Having now directed the teleſcope to a double ſtar, I view it with the right eye, and at the ſame time with the left ſee it pro-

jected upon the micrometer: then, by the handle P, which commands the poſition of the arm, I raiſe or depreſs it ſo as to bring the two lucid points to a ſimilar ſituation with the two ſtars; and, by the handle D, I approach or remove the moveable lucid point to the ſame diſtance of the two ſtars, ſo that the two lucid points may be exactly covered by, or coincide with the ſtars. A little practice in this buſineſs ſoon makes it eaſy, eſpecially to one who has already been uſed to look with both eyes open.

What remains to be done is very ſimple. With a proper rule, divided into inches and fortieth parts, I take the diſtance of the lucid points, which may be done to the greateſt nicety, becauſe, as I obſerved before, the little holes are made with the point of a very fine needle. The meaſure thus obtained is the tangent of the magnified angle under which the ſtars are ſeen to a radius of ten feet; therefore, the angle being found and divided by the power of the teleſcope gives the real angular diſtance of the centers of a double ſtar.

For inſtance, September 25, 1781, I meaſured α Herculis with this inſtrument. Having cauſed the two lucid points to coincide exactly with the ſtars center upon center, I found the radius or diſtance of the central lamp from the eye 10 feet 4,15 inches; the tangent or diſtance of the two lucid points 50,6 fortieth parts of an inch; this gives the magnified angle $35'$, and dividing by the power 460, which I uſed, we obtain $4'' 34''$ for the diſtance of the centers of the two ſtars. The ſcale of the micrometer at this very convenient diſtance, with the power of 460 (which my teleſcope bears ſo well upon the fixed ſtars that for near a twelve-month paſt I have hardly uſed any other) is above a quarter of an inch to a ſecond; and by putting on my power of 932, which in very fine evenings is

extremely distinct, I obtain a scale of more than half an inch to a second, without increasing the distance of the micrometer; whereas the most perfect of my former micrometers, with the same instrument, had a scale of less than the two thousandth part of an inch to a second.

The measures of this micrometer are not confined to double stars only, but may be applied to any other objects that require the utmost accuracy, such as the diameters of the planets or their satellites, the mountains of the moon, the diameters of the fixed stars, &c.

For instance, October 22, 1781, I measured the apparent diameter of α Lyræ; and judging it of the greatest importance to increase my scale as much as convenient, I placed the micrometer at the greatest convenient distance, and (with some trouble, for want of longer handles, which might easily be added) took the diameter of this star by removing the two lucid points to such a distance as just to inclose the apparent diameter. When I measured my radius it was found to be twenty-two feet six inches. The distance of the two lucid points was *about* three inches; for I will not pretend to *extreme* nicety in this observation, on account of the very great power I used, which was 6450. From these measures we have the magnified angle $38' 10''$: this divided by the power gives $0'',355$ for the apparent diameter of α Lyræ. The scale of the micrometer, on this occasion, was no less than 8,443 inches to a second, as will be found by multiplying the natural tangent of a second with the power and radius in inches.

November 28, 1781, I measured the diameter of the new star; but the air was not very favourable, for this singular star was not so distinct with 227 that evening as it generally is

with 460: therefore, without laying much ſtreſs upon the exactneſs of the obſervation, I ſhall only report it to exemplify the uſe of the micrometer. My radius was 35 feet 11 inches. The diameter of the ſtar, by the diſtance of the lucid points, was 2,4 inches, and the power I uſed 227: hence the magnified angle is found 19′, and the real diameter of the ſtar 5″,022. The ſcale of this meaſure ,474 milleſimals of an inch, or almoſt half an inch to a ſecond.