Giovanni Battista Amici

Description of a new micrometer

(1814)

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[...] In my opinion the objective micrometer has just two main imperfections. The first is the fact that is very difficult, if not impossible, to construct lenses that can be mounted on large catadioptric telescopes; the second is the aberration produced by the lenses themselves, which makes the edges of the images indistinct, thus affecting the precision of the measurement of angles. But by simply placing the Dollond Micrometer between the objective and the eyepiece of a telescope in the manner I have envisaged, the first imperfection is entirely eliminated and the second is diminished to such an extent as to be rendered insignificant. At the same time, the benefit of a wider scale and other advantages are obtained as well as rapidity of observation.

Let MN be an objective lens of a telescope of focal length OF, and let B'A' be the image of an object AB that is to be measured. If at the point M'N' located between the objective and its focal point we place another convex lens, this will again refract the rays so as to form a new image of the same object AB at the point F'. The new image will be perfectly similar to B'A', differing only in its size. Let us now suppose that the lens M'N' is divided into two parts in the fashion of objective micrometers. The two segments can certainly be moved apart in such a way that the ends of the two images AB originating from them coincide at F'. Having said this, we should observe that point A sends to lens MN a cone of light rays which being refracted by the lens are all directed towards A' to form there the image of point A. But as these are collected first by the semi-lenses, they are bent in such a way as to produce two images of the same point A, one of which (the one originating from the semi-lens M'C) is assumed to be at F'. Of all these rays meeting the semi-lens M'C, only the one passing through the centre undergoes refraction. That same ray would therefore proceed to A', to where it is directed by virtue of the objective. Considering therefore that before reaching A', this ray must meet the others refracted by the semi-lens M'C at point F', thus forming the image of A at that point, it is evident that a straight line passing through A'F' will when extended pass through the centre C of the semi-lens. So if we extend the line B'F', this will indicate the direction of the centre C' of the other semi-lens. From this it follows that it will be half the distance of the centres of the semi-lenses to the tangent of half the angle subtended by the object at the centre of the objective, as O'F' to F'F, the radius being equal to the focal length of the objective MN. So the value of the angle that is to be measured will be determined by the separation of the semi-lenses, which for a given angle can be increased at will as it depends on the focal lengths of the objective and of the lens that serves as Micrometer and also on the distance of the latter from the objective.
However the extension of the scale must not be too large to avoid reducing the measurement of the angles to excessively narrow confines. It is sufficient to limit the scale to such a width that the errors deriving from it are smaller than the smallest distances that can be observed with the power of the Telescope.

The movement of the micrometer towards the focal point of the telescope must also be limited. Because of the excessive narrowing of the cone of light relative to each point of the object, the metal slip that separates the semi-lenses would intercept most of the rays that form the images.
When the Micrometer is placed in this position, the errors originating from the aberration of the lenses and from the difficulty of correcting them are reduced enormously due to the narrowness of the cone of light that the Micrometer receives and its proximity to the focal point of the objective.

Another significant advantage is that equally luminous images are obtained when measuring the various angles, which is not the case with the other Micrometer unless the separation of the semi-lenses is much greater than the telescope objective.

Lastly the Micrometer can be applied without any difficulty to any type of catadioptric or dioptric Telescope. I mounted one of these instruments on a Newtonian Reflector I had built myself with a focal length of eight feet and aperture of eleven inches.

The Micrometer is attached to the external part of the slider that holds the small flat mirror, to which is fixed a graduated circle to determine the position of said Micrometer in its rotary movement. The eyepiece always maintains an equal distance from the semi-lenses, which is about seven inches, and distinct vision in the Telescope is achieved by means of the usual movement of the slider on which the entire mechanism is mounted.

At the focal point of the eyepiece there are two very thin wires that intersect at right angles, one remaining parallel to the division of the Micrometer lens. These serve to measure the differences in right ascension and declination between two objects in the sky, provided these distances do not exceed the total extension of the scale, which is two minutes and 25", each minute corresponding to a separation of fourteen lines between the centres of the semi-lenses, so the separation of $\frac{14}{60}$ of a line is equivalent to a second.

While I have determined this scale by calculation from a knowledge of the focal lengths of the objective mirror and of the divided lens and likewise from a knowledge of the distance of the latter from the focal point of the mirror, I have also verified it experimentally by the usual method of transporting an object of known size to a suitable distance for it to subtend a given angle at the centre of the mirror.

Both semi-lenses can move both right and left and the divisions are on both sides of the zero, which is a big advantage as it enables the moment of contact and perfect coincidence of the two images to be determined with the greatest precision.

The reduction in distinctness of the Telescope caused by the addition of the Micrometer is insignificant, and even at a distance of 890 Paris feet with a magnification of 1152 it is possible to read characters and numbers with a height of nine points of a Paris foot.

The division of Saturn's ring, the dark band that divides its disc, and the five outermost satellites remain visible, even when the semi-lenses are separated by the greatest distance, better than in a good Newtonian Telescope of eight feet length and 6 ½ inches aperture without a micrometer.

[...] My instrument can conveniently be used for measuring the distances of terrestrial objects when their absolute size is known. To do this, it is sufficient to fit a Vernier onto the slider mounted on the machine to indicate the variations in focal length of the Telescope and to construct a Table that shows the consequent variations in the scale.

As I have said, the eyepiece of my instrument has at its focus two wires that intersect at right angles and are situated in such a way that one of them is parallel to the cut in the Micrometer lens, serving to determine the difference in right ascension and declination between two celestial objects.

The procedure for doing this with the Dollond Micrometer is well known. However, the method that must be adopted with my Micrometer is quite different because of the eyepiece wires, which always maintain the same position relative to the semi-lenses and therefore have the circular movement in common with them. I therefore believe it will be useful for me to explain this simple method for determining whether small stars move around other very close larger stars, a highly delicate area of study in which the celebrated Herschel has worked a great deal.

So let A, B (Fig. 4) be two stars between which we wish to determine the differences in right ascensions and declinations. Let the circle MXNY represent the field of the telescope and XY, MN be the two wires that intersect at right angles, while MN is constantly parallel to the line joining the centres of the semi-lenses. Let us rotate the Micrometer until a star, for example B, travels due to its diurnal movement along the wire MN, and then separate the semi-lenses to the point where the second image *a* of star A crosses the wire XY at the same instant that B crosses it. In this case the distance between the centres of the semi-lenses will indicate the difference in right ascension between the stars. The reason for this is evident. Now let us turn the Micrometer circularly until the two images B, *b* of star B, which were travelling along MN, cross it at the same instant due to their diurnal movement. In this situation the Micrometer will have turned by 90°. Therefore the separation of the semi-lenses, which was previously in the direction of the equator, is now in the direction of the hour circle which will be represented by MN. We will therefore obtain the difference in declination if we separate the semi-lenses so that the northernmost image of the southernmost star touches, and runs along, the wire parallel to the equator in the same time that is taken by the southernmost image of the northernmost star.

The wires that are used for the aforesaid purpose are also an excellent device for avoiding the errors that can arise with this instrument due to differences in sight. In the event of a change in sight, distinct images are no longer seen through the eyepiece in the same position as before, so if the eyepiece remains constantly at an equal distance from the micrometer, to obtain a distinct image it will be necessary to move the slider that carries the micrometer itself together with the small flat mirror. As a result of this movement, the image of the object will change in distance relative to the divided lens. So altering this distance, which is one of the elements that determines the width of the scale, will create errors in the measurement of the angle. This problem can be avoided by means of the aforementioned wires, which always remain equally distant from the semi-lenses; and because the eyepiece has a small partial movement along the tube, the wires can be seen distinctly through the eyepiece by moving it closer or further away according to the different sights. Having thus corrected the change in focal length of the eye by means of the partial movement of the eyepiece, the size of the angle can no longer be altered for this reason.

The use of the micrometer that I have described is limited to the measurement of very small angles. While this may be sufficient to recognise its utility, given that these measurements form the basis of many splendid and interesting studies, I have nonetheless sought a way of using it, with the same precision, for measuring larger angles such as the diameters of the Sun and the Moon.

For this purpose it is sufficient to use two identical achromatic prisms which when placed inside the Telescope near the lenses of the Micrometer have a refraction of approximately sixteen minutes and thirty seconds. By uniting these prisms by their triangular bases so that their refracting angles are opposite and located in proximity to the semi-lenses in such a way that the plane that joins them, when extended, passes through the cut in the lenses, the total refraction of both will be approximately 31 minutes, although with experience this value can be determined with a high degree of precision. Now the size of the semi-lenses can be chosen in such a way that refraction reaches three minutes or more without giving rise to any noticeable aberration; and since the semi-lenses must be mounted in such a way as to be separated on both sides of the zero of the scale, as mentioned above, the refractions of these semi-lenses will be either in the direction of those of the prisms or in the opposite direction, and it will therefore be possible to determine angles from 28' to 34', a range that includes the diameters of the Sun and the Moon.

Our description of the measurement of the angles subtended by the diameters of the Sun and the Moon also applies to other different angles of limited size by substituting other pairs of achromatic prisms of suitable refraction.

(English Translation by John Freeman)