A NEW DARK-FIELD MICROMETER FOR DOUBLE-STAR MEASUREMENT.

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Figs. 1, 2, 3, 4.

I often think it must be very pleasant for the ardent votary of science to have unlimited means at his command for obtaining such apparatus as he requires in the pursuit of his favourite study; apparatus elaborately finished, and perfectly adapted for the work for which it is designed. Yet it too often happens that such apparatus becomes a mere toy in the hands of its possessor, he merely contenting himself with its possession, and the enjoyment of its beauties. On the other hand, it remains a fact that some of the grandest achievements of science are due to workers who have had to be content with very simple and perhaps roughly constructed apparatus, the outcome of their own ingenuity, called forth by the necessities of the case. The writer claims the applicability of the foregoing remarks to his own case only so far as they relate to the necessity of trusting mainly to his own resources in his very limited field of scientific work. The instrument of which the following is a description, has been in this way the outcome of his necessity. Its special function is the measurement of very minute angular distances, such as those of double stars, giving at the same time the angle of position with reference to the meridian.

A few preliminary remarks on some of the existing forms of Micrometer may help to elucidate the special adaptability of the instrument to be described for the work for which it was designed. The *Reticle* Micrometer is specially useful for mapping star fields, but a driving clock for the telescope is almost essential. My first Micrometer was of this form, and consisted of a photograph (on thin micro. coverglass) of a scale, ruled on a sheet of glass coated with black paint, and having lines cut through the paint with the point of a penknife. The figure was a square subdivided into 400 by parallel lines each way (20 × 20). Each interlinear space was divided by a line running from the centre to the outside of the square each way. The one for use with my highest power is only $\frac{1}{10}$ in. square, the spaces between the lines being only $\frac{1}{200}$ in. It is, however, quite inadequate for double-star work.

The *Ring* Micrometer is adapted for distances occupying a considerable portion of the field, by timing the passages across the ring. But unless the passage describes chords at some distance from the diameter the measures are unreliable. It involves somewhat tedious calculation for differences of declination.

A very useful dark-field Micrometer, embracing the greater portion of the field, is the *Bar* Micrometer. My own form of it is a modification of that used by Lacaille in the preparation of his valuable Catalogue of Southern Stars. His was a rhomboid cut out of a piece of thin brass and placed in the focus of the eye-piece; mine is an equilateral triangle, formed of watch hair-spring. The differences of right ascension and declination are obtained by timing the passages in and out of the triangle. It is a very useful instrument for faint objects which will not bear illumination of the field, and especially for comet work.

The Micrometer, *par excellence*, for general work is doubtless the *Filar Position Micrometer*. A description of this is of course superfluous to those at all acquainted with telescopic work. The measurement is effected by parallel spider lines, moved to and fro by fine screws, the measures being read off by the number of turns, and by graduations on the screw heads. The scale is revolved by a pinion and wheel, so as to make a cross spider line intersect the objects to be measured, and the position angle is read from a graduated circle. This instrument is specially convenient for differences of declination; but for direct *oblique* distances, is difficult to use without a steady driving clock for the telescope. It is a delicate and expensive aparatus.

Many other forms and methods of Micrometer measurement are adopted, which it will be unnecessary to further refer to. I will now go on to describe my own, first giving the general principle.

If a strip of glass (A), coated with black paint, and having two fine converging lines cut through the paint, at an angle of 10 or 15 deg., be placed face to face with another piece of glass (B), similarly coated, and having a single line ruled across it—this line being placed so as to cross the lines of A—the intersection of the lines will show as luminous points by transmitted light. On sliding the slip A along, these points will recede or approach until they coalesce at the point of the angle. Now, if an image of these points can be projected into the field of the telescope, and brought into juxtaposition with the pair of objects whose angular distance is to be measured, we obviously have the means, by a proper adjustment of the points as to distance and parallelism, of determining the measurement required. The position of the slide A is read upon a graduated scale, the value of which is determined by well-known astronomical methods.

The projection of the image into the telescope is effected by means of an adjustable camera-lucida, constructed from a selected micro. cover-glass and attached to the eye-piece. The whole carrying arrangement of the glass plates is made to revolve in a suitable frame, so that the luminous points may be brought into parallelism with the pair of stars to be measured, and the angle read off from a graduated circle on the rim, the zero point being first ascertained by revolving the scale until a star shall run along the single line of plate B. The difference of readings will give the position angle with reference to the meridian, it being supposed that the telescope is mounted equatorially.

The foregoing will, I think, make the principle clear. Dimensions will depend very much on the size of the telescope. In my case, the glass slides are 7in. x 4in., the opening of the circle or ring 4in. The telescope is a Newtonian reflector —speculum $8\frac{1}{2}$in. The apparatus is fixed perpendicularly on the telescope tube at a distance (towards the speculum end) of $19\frac{1}{2}$in. from the eye-tube, this distance being adopted for convenience, as giving a value of $\frac{1}{2}$ sec. of arc with the power I generally use for double stars. The sliding glass slip fits into a brass sliding frame, or carrier, which moves by a rack and pinion. A scale of 100 divisions is engraved on the side of the frame, answering to the length of the glass slide. (See A and F, Fig. 1.)

For the glass slides I prepare a coated slip three lengths in one, ruling the diverging lines the whole length of the slip, from the angle at one end to an opening of about $3\frac{1}{2}$in. at the other. This slip is then cut into 3 lengths (commencing from the point of the angle), each length being exactly equal to the 100 divisions on the frame. This gives scale readings to 100, 200, 300, the glasses being interchangeable in the frame. The whole arrangement, with its graduated circle, revolves in the frame which supports it, by a pinion in the support, working in a toothed wheel on the circle. My apparatus is fitted with a small electric lamp ($2\frac{1}{2}$ candle), with a contact conveniently near the eye-piece. At the back of the lamp is a concave reflector, to throw a parallel beam of light upon the scale. It is of advantage to *frost* the back surface of the glass (next to the lamp). The coated surfaces should be next each other without rubbing.

The measurement is effected, not by *direct coincidence*, but by *comparison*. Supposing we are working without a driving-clock, the "ghost," as I will call it (*i.e.*, the image of the points), is brought to about the middle of the field, and the star brought into position with it. The circle is then revolved until the "ghost" is sensibly parallel with the line joining the components of the star, and the slide moved to correspond with the distance. When these adjustments are perfect, as the star approaches and recedes from the "ghost," the four points will form a perfect parallelogram. (Fig. 2.)

Practically it will be found that the eye is very sensitive to any irregularity in the figure; I think more so than with respect to coincidence with spider lines, as in the use of the filar micrometer, especially when, without a driving-clock, the object is moving obliquely across the field, and only a momentary contact can be obtained in passing. The similarity of the images in the former case favours the comparison. Fig. 3 shows the general arrangement of the apparatus as applied to a Newtonian reflector.

My first experimental arrangement was fitted to my 3in. refractor, and was a very primitive affair, the carrier being of tin, revolving in a paper tube. For a refractor, a different arrangement from that described above has to be adopted. With the Newtonian reflector, the position of the scale being at right angles with the direction of vision, a single reflection at 45deg. throws the image into the eye-piece. With the refractor, on the other hand, the only practicable position for the apparatus is on the body of the tube towards the object-glass; that is in the direction of vision. This necessitates an intermediate reflection at an angle of 45, to throw down the image of the scale upon the camera-lucida. (Fig. 4.)

The apparatus admits of very considerable elaboration and development; as, for instance, star photometry. Further; the whole apparatus may be made to travel to or from the eye on a suitable slide, having a graduated scale; a single plate with parallel lines being placed in the plate-holder. By this arrangement planetary discs and differences of declination may be read off, as with the filar micrometer. I will not, however, add to the tediousness of this paper by further reference to this matter.

I must, in closing, express my obligation to Mr. Alex. Wallace, of this city, a clever amateur mechanic, for his kindness and generosity in the successful construction of my present apparatus.