

VIII. *An Account of a Catadioptrick Telescope, made by John Hadley, Esq; F. R. S. With the Description of a Machine contriv'd by him for the applying it to use.*

THE Instrument consists of a metalline *Speculum*, about six Inches in Diameter. The *Radius* of the Sphere, on which its concave Surface was ground, is ten Feet, five Inches and one quarter, and consequently its focal Length is $62 \frac{1}{4}$ Inches. The Back has a hollow Screw made at its Centre, to receive the End of a Handle, which is screw'd on, whenever the Metal is to be moved, in order to avoid fullying its polish'd Surface by handling.

This Object-Metal A, *Pl. II. Fig. 1.* is placed in one End of an octangular Tube, B B, about six Feet long, and something wider than what is sufficient to receive the Metal, dyed black on the Inside. About six or seven Inches in Length of the three uppermost Sides of the Tube C, (toward that End, at which the Metal is plac'd) are separated from the rest, and open with two Hinges, to make room for the Metal to be put in and taken out. The End of the Tube is closed by an octangular Piece of Board D, which has an opening *d*, about $\frac{1}{3}$ of an Inch broad, from the Top down to a little below the Centre, to give room for the beforemention'd Handle, when the Object-Metal is lifted into or out of the Tube; at other times it is closed with a sliding Shutter. The

B b b 2

Metal

Metal is placed so, as to have its *Axis* coincide with that of the Tube, by the means of three small Buttons fix'd to the Inside of the Tube, having their hinder Ends all in the same Plane, to which this *Axis* is perpendicular. Two of these appear at *aa*, the third being at the middle of the Bottom of the Tube, is not seen. The foreside of the Metal rests against these Buttons in three Points of its Circumference, nearly equidistant from each other, and is held to them by three Screws, (one of which appears at *b*) which run through the octangular Board at the End of the Tube, and bear against the Back of the Metal, (in three Points, which directly answer those three on the foreside) with just so much Force, as is requisite to keep it steady in its Place. They must not be screw'd harder against the Metal for Fear of bending it, which (tho' it is half an Inch in Thickness) a very little Force is sufficient to do. When the Instrument is not used, these Screws are loosen'd, and the Object-Metal is taken out and laid by, to prevent its tarnishing.

The oval Plane is compos'd of a Plate of the same Metal with the great *Speculum*, about $\frac{1}{4}$ or $\frac{1}{2}$ of an Inch in Thickness, folder'd on the Back to another of Brass. Its Breadth is something less than half an Inch, and is in Proportion to its Length as 1 to $\sqrt{2}$. At one End of the Oval, the Brass Plate projects a little beyond the other, and has a Screw cut through it in that Part, as likewise another directly against the Centre of the foreside. The other End is cypher'd away on the Backside, that it may intercept as few of the Rays, in their Passage towards the Object-Metal, as is possible. The two Screw-holes in the Back serve to fix this Oval A, *Fig. 2.* to a Brass Arm, B, which is fastened at the other End into a Slider E E. *Fig. 1. and 2.* This
Slider

Slider is of an equal Thickness with the Side of the Tube, and has a Groove, G G, *Fig. 1.* cut for it in that Side, parallel to the *Axis*, and long enough to give room for its Motion, to set the two *Specula* at the different Distances, which the several Eye-Glasses require. It rests on the Inside against two thin Ledges, fastened within the Tube along the Sides of the Groove. On the Outside it is kept in its Place by a sliding Shutter, not expressed in the Figure. In the Middle it has a Cylandrick Cavity, D, *Fig. 2.* whose *Axis* is exactly perpendicular to its inner and outer Surfaces. Each of the Boxes, in which the Eye-Glasses are contained, is fitted to this Cavity. The beformention'd Brass Arm is fix'd into the Inside of this Slider, towards the End farthest from the Object-Metal; it rises perpendicular for about two Inches, and is made flat, so as to turn one Edge to the Rays, which come from the Object. About *b*, it is bent forwards and flattened the other Way, so that when the Back of the oval Plane is held flat to it, by the two Screws *cc*, the *Axis* of the Cylandrick Cavity may fall on the Centre of its foreside, inclin'd to its Surface in an Angle of something less than fourty five Degrees. This Angle is brought to be exact by two very small Screws, *ii*, whose Threads take hold in the flattened End of the Brass Arm, and their Points bearing against the Back of the Oval, raise one End of it a little from the flat of the Arm. The *Specula* are set at their due Distance, by turning of a long Screw, C C, for which there is a Nut lodged in the Slider at *g*; the Screw is kept from moving backward or forward, when 'tis turned, by a Brass Plate, F, which is to be fix'd to the flat End of the Side of the Tube, and taken off at Pleasure. Each of the Eye-Glass Boxes, H, has a Screw on the outward End, to fasten to it a Bowl, or Dish

Dish, I, to receive the Ball of the Eye, and guard it from external Light.

On the Top of the Tube is fix'd, on two small Pedestals, a common Dioptrick Telescope, H, *Fig. 1.* about eighteen Inches long, its *Axis* parallel to that of the Tube; and having two Hairs plac'd in the common *Focus* of its Object and Eye-Glasses, crossing one another in its *Axis*.

There are three convex Eye-Glasses belonging to the Instrument. The first, or shallowest, has its focal Distance of about $\frac{1}{2}$ of an Inch; the second, of $\frac{1}{12}$; and the deepest, of $\frac{1}{16}$, or something less. When the first of these is used with the Instrument, it magnifies about 188, or 190 times, in Diameter; with the second, about 208; and with the third, 228 or 230. Each of these Glasses has placed, in that *Focus* nearest the Oval, a Circle to determine the Part of the Object seen at one View; and in the other *Focus* toward the Eye, a Brass Plate with a little Hole in the middle, to let no Light pass to the Eye from the Inside of the Tube, but what comes from the Oval. Besides these three convex, there are two concave Eye-Glasses, with which it magnifies about 200 and 220 times; and also a Set of three Convex, which turn it into a Day Telescope, magnifying about 125 times. The Aperture is limited by a Circle of Card, or Pastboard, placed before the Object-Metal in the Tube. To vary the Aperture there are three of these Circles, and the Apertures allowed by them are five Inches and an half, five Inches, and four and an half, tho' for some Objects the whole Metal may be left open.

The Engine made use of to direct the Tube to any Object, consists of a strong Plank, FF, *Fig. 1.* and 3. about fourteen Inches wide, and two Feet and an half, or three Feet long, which serves as a Foundation for the

the whole. Near one End of this Plank is placed an upright four-sided Box, III, *Fig. 1.* and *3.* about two Feet high, narrower at the Back next the End of the Plank than before: Its two Sides are mortised both into the Plank below, *aa*, *Fig. 3.* and into the Top of the Box above, *dd*; the back and fore Part are fasten'd to the Edges of the Sides with Wood-Screws. The Top has a circular Hole cut in it, something above three Inches in Diameter, whose Centre is about three Inches distant from the outside of the Back, and at an equal Distance from the two Sides. This Hole gives Passage to a turning Pillar B, in the Bottom of which there is fix'd an Iron Pivot *c*, to turn in a thick Brass Plate lodged in the Plank, *b*. The upper End of the Pillar rises about an Inch and an half above the Top of the Box, and is mortised into a strong Head, K, *Fig. 1.* and *3.* about eight Inches in Length, and four or five in Breadth and Thickness. This Head carries two Cheeks, LL, about thirteen or fourteen Inches in Height, their hinder Edges, towards the lower End, extending five Inches beyond the *Axis* of the Pillar backward. Along the Back of these Cheeks, at equal Distances above one another, there are Notches, tending obliquely downwards, and answering one another in each Cheek, to receive the Pivots of a crooked Iron *Axis*, C, *Fig. 3.* on which the Tube is plac'd. The Notches are made at different Heights, to keep the Eye-Glass at a proper Height for the Eye, in different Elevations of the Object above the Horizon. The Figure of the *Axis* answers that of the three under Sides of the Tube. The *Axis* of the Tube lies about two Inches and an half higher than the *Axis* of the Motion upon these Pivots, and the Centre of Gravity, when the Object-Metal is in, is about three Inches backwarder. To keep the Tube from slipping back, when its fore End is raised, it has

two

two Buttons fixed to it, which rest against the fore Part of the *Axis*.

To keep the Pillar from touching any of the Sides of the round Hole, in which it turns, a Cylandrick Sector, containing about 65° or 70° , and about an Inch in Height, is cut out on the back Part of the Pillar, near the upper End D. In the square Angle of this Cavity is fix'd a thin Steel Plate *oo*, bent cross the middle to the same Angle. The internal angular Edge, between the two Parts of this Plate, lies in the *Axis* of the Pillar, and turns upon the harden'd Edge of a Wedgelike Iron, *f*, whose Base, or Board Part, is fasten'd with two strong Screws on the Top of the Box, directly behind the round Hole beforemention'd.

The upper Parts of the Cheeks are strengthened by two Brackets, GG, leaving Room between them for the Bottom of the Tube to touch the upper Edge of the fore Part of the Head. The hinder Part of the Head is also hollow'd, in the Manner represented in the third Figure.

The Head on its fore Part carries a flat Arm, M, *Fig. 1.* about twenty seven Inches long, a little taper towards the farther End, where it is four Inches broad. This is strengthened by a narrow Slip, glew'd edge-wise along the middle underneath, O, and also by a Brace or Stay, N, reaching from the turning Pillar to within nine Inches of the End of the Arm. The Stay passes through a transverse opening cut in the fore Part of the Box, P, which is long enough to allow room for a sufficient Motion of the Pillar round its *Axis*.

On the other End of the Bottom Plank, transversely to its Length, is erected a Board about twelve Inches wide, and twenty six or twenty seven high, Q, the Top of it reaching within an Inch and an half of the under Side of the Arm. This Board is held firm in its
Position

Position by a Spur, R, part of its upper End on the outside is pared off toward the Edges, to form it into the Segment of a Cylinder, whose *Axis* coincides with that of the Pillar. Its Use is to support a Rest, SS, on which the End of the flat Arm moves backward and forward. This Rest being apply'd transversely to the outer Part of the upright Board, where it is made Cylindrick, is bent into the same Figure, by the means of four Screw-Pins, two of which passing through each End of this, and of another Piece of the same Length, T, (but something narrower) placed over against it on the inside of the Board, by their Nuts, draw them together, so as to grasp the End of the upright Board between them ; the upper Edge of the Rest being first shot with a Plane very strait and smooth. To render the Motion of the Arm along the Rest smooth and easy, it has two Rollers lodged in a Box fix'd near to the End, on its underside, V, to roll upon the Edge of the Rest, when the End of the Arm is moved along it. One of the Rollers is placed near each Edge of the Arm, and their *Axes* lye in Lines passing through the *Axis* of the turning Pillar. The Rest is kept up to them, with a proper Degree of Force, by two Screws, W W, which run in two Plugs, XX, fastened on the Sides of the upright Board, and bear against the under Sides of two Pieces fix'd on the Inside of the Rest.

The Motion of the Tube is governed by two Brass Pegs, Y and Z. The first of these, Y, is plac'd about 10 or 11 Inches from the End of the Arm, and has a Line wound round it, which passing under a small Pulley, f, fix'd in a vertical Position near the End of the Arm, is fastened to a Staple on the under side of the Tube g. This Line, by the turning of the Peg, brings the fore End of the Tube to its due Elevation, being acted against by the Excess of Weight in the hinder End

of the Tube, when the Metal is in it, which is equivalent to about two Pound at *g*, where the Line is fastened. In great Elevations of the Object above the Horizon, the Line is not carried so far as the Point *g*; but is fasten'd a little above the Pulley, to a light square Stick, *b*, having at one End a Hook, by which it takes hold of the Staple *g*. This is done, that the Springyness of the Line may not continue a vibrating Motion in the Tube, (when any thing happens to shake the Instrument) and make the Object appear to tremble. The lower Part of the Stick rests against the end of the Arm, and by its slight Friction contributes to the same Effect.

The other Peg, *z*, is so plac'd, that it may be conveniently reached by one Hand of the Observer, while the other is employed about the Peg *Y*: It regulates the Horizontal Motion of the Tube, by means of a Line, which being wound about the Peg at one End, passes by another small Pulley placed close by the Side of the aforementioned one in an Horizontal Posture (not to be seen in the Figure) and is hung on a Pin driven into the little Head *K*. It is acted against by two Springs, *m* and *n* *Fig. 3.* placed in the Box, *III*, one on each Side of the turning Pillar; that on the right Hand, *m*, draws the right Side of the Pillar forward, by a very strong Line, which being fastened to the Head of the Spring, passes round the back Part of the Pillar to a Pin, at *P*, by which it is strain'd to its due Strength. The Spring on the Left Hand *n*, draws the Left Side of the Pillar backwards in the same manner. These Pins are plac'd on the Pillar a little higher than the Tops of the Springs, that being drawn a little downwards, as well as turn'd round its *Axis*, the Pivot in its Bottom may not be raised out of the Hole in the Brass Plate, when the Rest bears hard against the Rollers at the End of the Arm. Each of these Springs draws with a Force equal to about

18 or 20 Pounds Weight, when the End of the Arm is carried close to the small Head *k*, Fig. 1. and consequently (the Semidiameter of the Pillar being an Inch and Half, and the Distance of that Head from the *Axis* about 28 or 29 Inches) the End of the Arm will be carried by the united Forces of both the Springs, towards the other End of the Rest, with a Force equivalent to the Weight of about two Pounds. Each of the Pegs, *Y* and *Z*, turns in a Hole made in a Piece of Wood *l*, fastned to the under Side of the Arm; and the Pieces being slit with a Saw from one End through the Hole, and about half an Inch beyond it, the separated Parts are drawn together by a Skrew *m*, till the End of the Peg is griped between them, with a due Degree of Force. By these Pegs, with the help of the Telescope *H*, the Tube is easily directed to any Object, and made to accompany a Celestial one in its Diurnal Motion, while the End of the Arm moves the whole Length of the rest.

If it be desired, that when the Object is found, the turning of one Peg should carry the Tube along with the Motion of the Heavens, so as to keep the Object always in sight; this may easily be effected in various Manners.

The concave Surface of the Object-Metal has many little Spots in it, which could not be brought to take a Polish. In one, or two Places, the Metal itself seems to have some small Parts, something harder or softer than the rest, occasioning an irregularity in the Figure of the Metal about them. But these Parts being small, in Proportion to the whole, do not seem considerably to affect the Distinctness of the Appearance.

The open Air has commonly an undulating Motion in its Parts, especially in the day time, which occasions the Rays of Light to deflect a little from the strait Lines, in which they ought to move, in order to render the

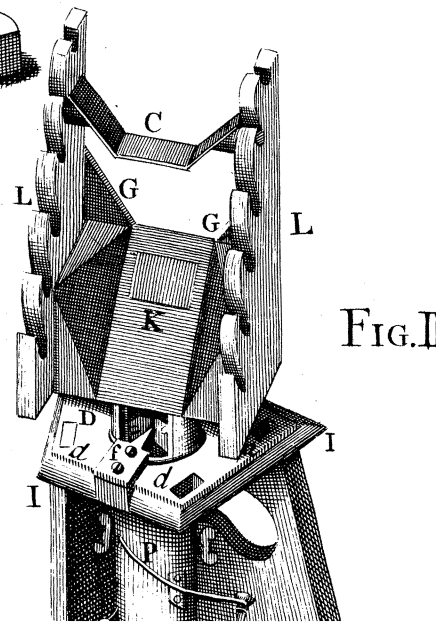
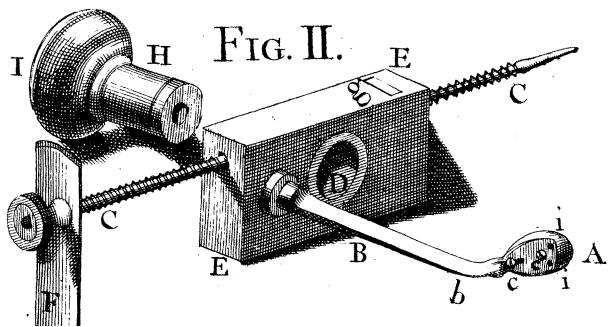
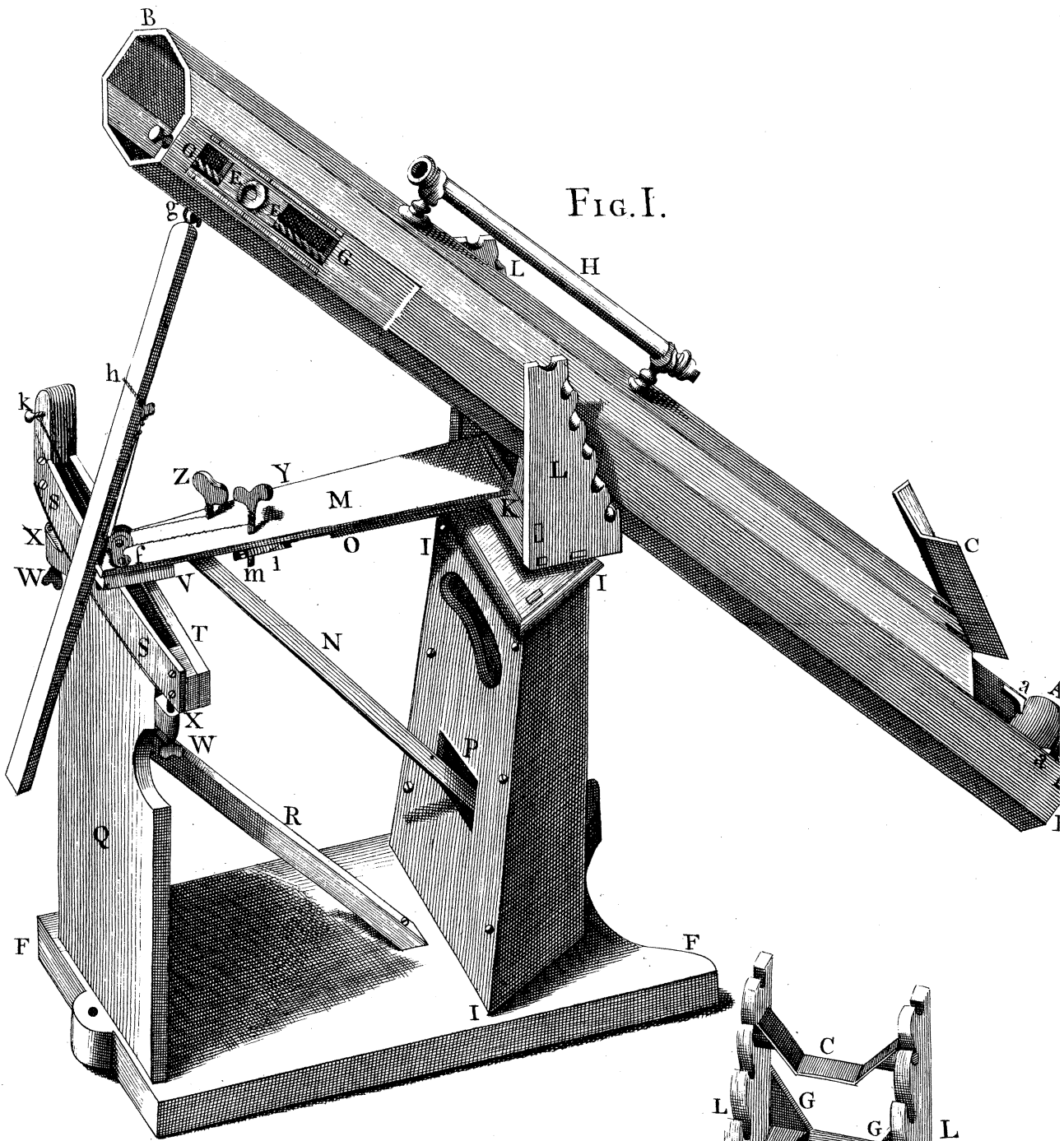
Species perfectly distinct. The Effect of this, though insensible to the naked Eye, or even through a small Telescope, becomes considerable, when the Object is very much magnified. The Instrument, when try'd at an Object enclosed, so as to secure it from this Inconvenience, seems to bear an Aperture of five Inches and an half, with the deepest of the forementioned Eye-Glasses, as well as the common Telescopes do the usual Charge and Aperture given to them, except that in these the Objects appear a little brighter.

Fig. 1. Represents the Instrument placed on the Machine, in order to be apply'd to Use.

Fig. 2. Represents the Inside of the Slider, with the rest of the *Apparatus* belonging to the oval Plane and Eye-Glass.

Fig. 3. Represents the hinder Part of the Machine, the Back, and one side of the Box, being taken away, to shew the turning Pillar and Springs on the Inside.

Fig. 4. Represents *Saturn*, as it appear'd in *June, 1720*, by this Telescope.



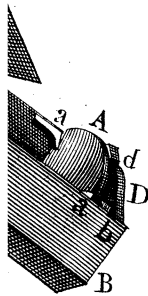


FIG. III.

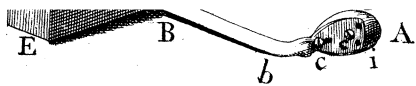
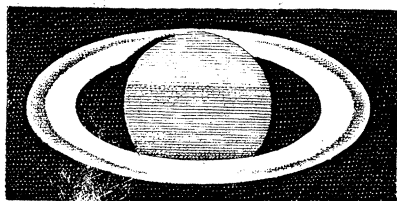
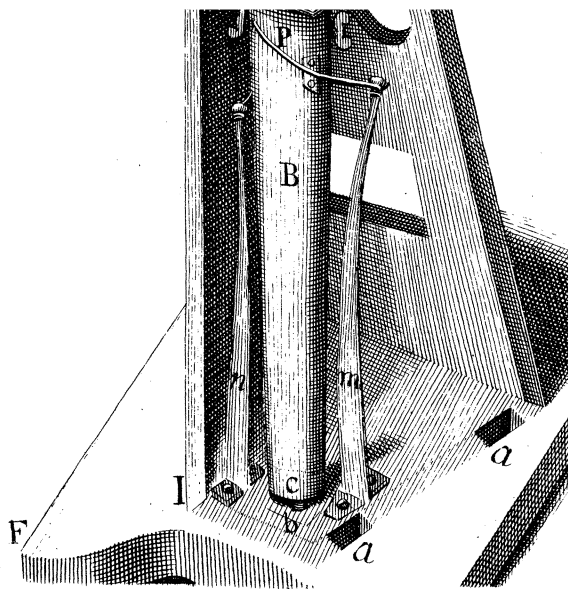
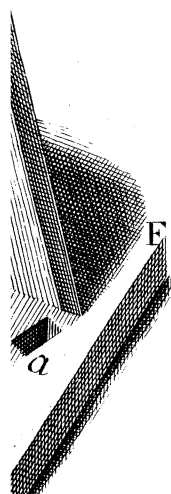


FIG. IV.



I. Stuart sculp.





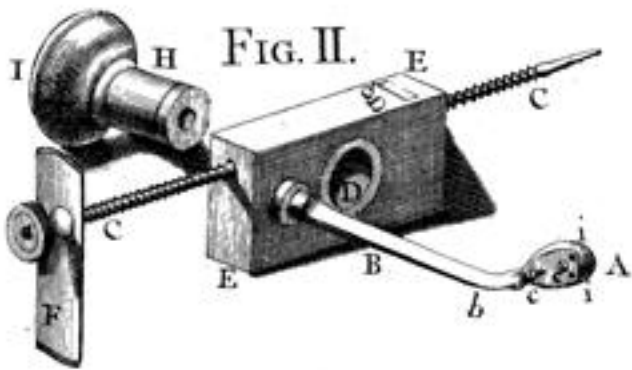
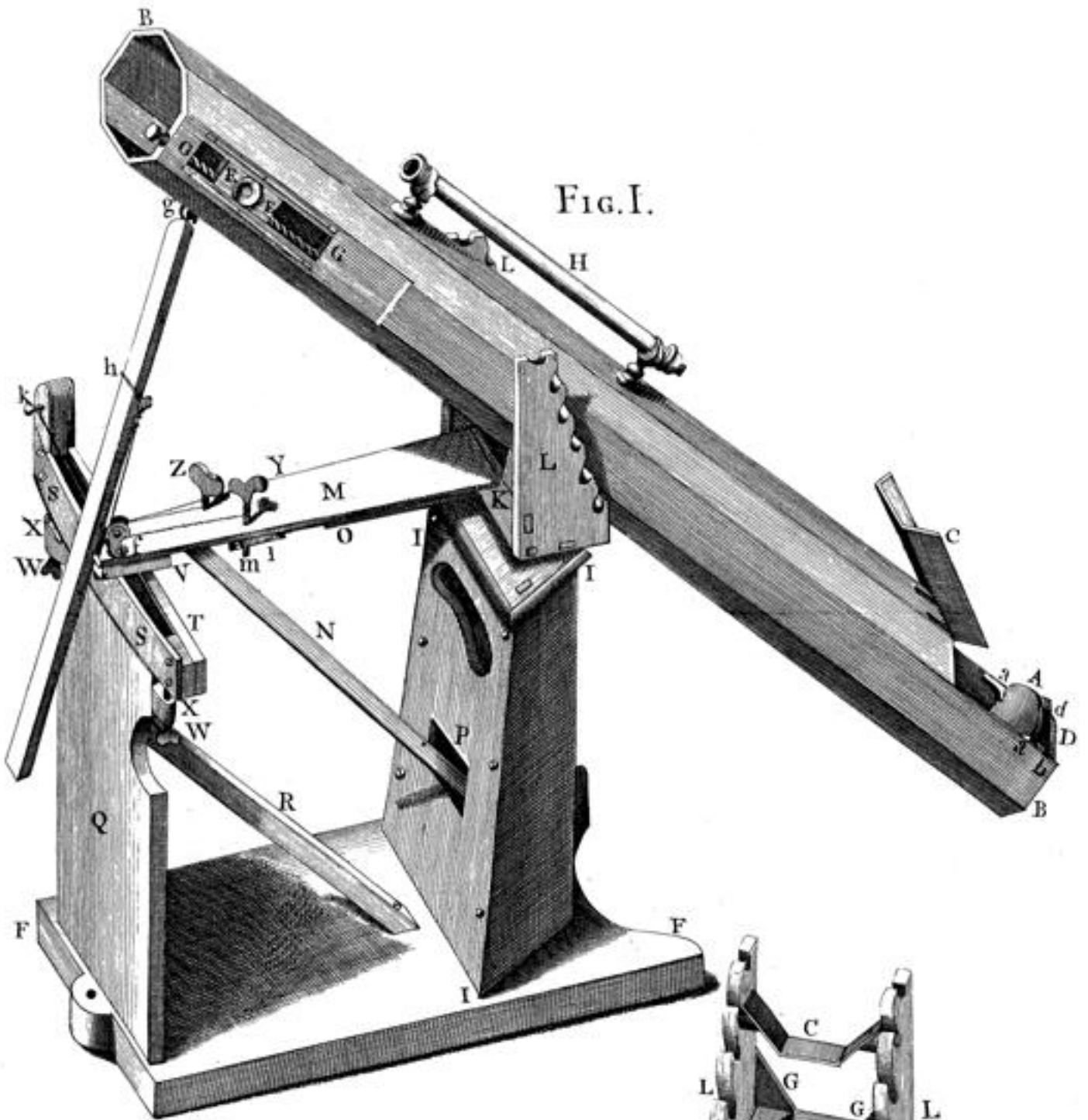


FIG. IV.

