

*Concerning the Apparent Magnitude of the Sun
and Moon, or the Apparent Distance of two
Stars, when nigh the Horizon, and when
Higher elevated.*

I DO not design so much to establish any thing of my own that may be satisfactory in solving this admirable Appearance, as to detect the Errors of those that have offered at a Solution thereof, and have come short (as I conceive) of being satisfactory; that thereby I may again set the Minds of Philosophers on Work, and rouse them up to enquire a new after this surprising *Phænomenon*. That I may do this the more effectually, I shall briefly declare the Matter of Fact, and then proceed to the Reason thereof, given by several, and to their Confutations.

First therefore it is well known that the mean apparent Magnitude of the Moon is $30^m. 30^s$. we will take it *Numero Rotundo* to be 30, that is, an Arch of a great Circle in the Heavens of 30 Minutes is covered by her Diameter, and this we'll suppose to be her apparent Diameter, at a full Moon in the midst of Winter, and when she's in the Meridian, and at her greatest Northern Latitude, and consequently the utmost that she can be elevated in our *Horizon*; 'tis as well known also, that when she is in this Posture, being looked upon by the naked Eye, she appears (that we may accomodate all to sensible Measures) to be *Magnitudinis Pedalis*, about a Foot broad. But the same Moon being looked upon just as she rises, she appears to be three or four Foot broad, and yet if with

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an Instrument we take her Diameter, both in one Posture and t'other, we shall find that still she shall be but 30 Minutes; the several ways of trying this I will not mention, they being as various as are the Methods of taking the Moon's apparent Diameter, common enough amongst the *Astronomers*; neither will I insist upon the Truth of the Matter of Fact, for that I think cannot reasonably be questioned, after so many Tryals and so many Experiments thereof, faithfully recorded by undoubted Witnesses; and it would be very unreasonable to imagine that so many Authors should rack their Brains for solving an Appearance, wherein they were not certain of the Matter of Fact. But because of *Nullius in Verba*, I can assert that I have accurately tryed it myself, and I have so found it: One of the Ways I proceeded was thus, I took a very good *Telescope* of about 6 Foot long, in the inward *Focus* of whose Eye-Glafs I apply'd a very fine Lattice made of the single Hairs of a Man's Head; then looking with this at the Moon when she was just risen and look'd extraordinarily big, I observed what Number of the Squares of the Lattice were occupy'd by her Body; then observing her again, when more elevated and free from all extravagant Greatness, I still found the same Squares of the Lattice possess'd by her. This way is equivalent to that now more used, of taking her Diameter by Mr. *Townly's Micrometers*: But I have also tryed and found the same thing by an accurate Sextant, taking the Distance of the Moon's opposite Limbs.

Now this *Phenomenon* affords two Things to be considered, first why the Moon (I still name the Moon as being an Object more adapted for our Sight, for the same thing holds in the Sun) should seem bigger about the *Horizon*, than when more elevated; and secondly, she appearing bigger, how it comes to pass, that her Diameter being taken, it is no greater than when she appears less. But the Disquisition concerning this latter being likely to

Comprehend the former, I shall not divide my Discourse into two Branches, but proceed in the Method propos'd. Only I desire it may be noted, that I suppose the *Horizontal* and *Meridional* Moon to be found both of the same Angle, whereas in Truth the Meridional Moon (tho' appearing less) shall be found of the greater Angle: Which increaseth the Wonder. But this proceeding from the different distances that one and t'other is looked at, (the Meridional Moon being nigher us by almost a Semidiameter of the Earth) and consequently easily solv'd that way; I have therefore chos'n to put between them a plain equality, for avoiding Confusion and Intricacy in Discourse.

Wherefore let us hear what the Ingenious of these latter Days can say to this Appearance. And first we find the celebrated *Des-Cartes* attributing this Appearance rather to a deceived Judgment, than to any natural Affection of the Organ or Medium of Sense; for the Moon (says he) being nigh the *Horizon*, we have a better Opportunity and Advantage of making an Estimate of her, by comparing her with the various Objects that incur the Sight, in its way towards her; so that tho' we imagine she looks bigger, yet 'tis a meer Deceit: For we only think so, because she seems nigher the Tops of Trees, or Chimneys, or Houses, or a space of Ground, to which we can compare her, and Estimate her thereby; but when we bring her to the Test of an Instrument that cannot be deluded or impos'd upon by these Appearances, then we find our Estimate wrong, and our Senses deceived. These Thoughts, my-thinks, are much below the accustomed Accuracy of the Noble *Des-Cartes*; for certainly if it be so, I may at any time increase the apparent bigness of the Moon, tho' in the Meridian; for it would be only by getting behind a Cluster of Chimnies, a ridge of a Hill, or the top of Houses, and comparing her to them in that posture, as well as in the *Horizon*: besides if the Moon be look'd at just as she is rising from an *Horizon* determin'd by a smooth Sea, and which has no more
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Variety of Objects to compare her to, than the pure Air; yet she will seem big, as if look'd at over the rugged Top of an uneven Town, or rocky Country. Moreover, all Variety of adjoining Objects may be taken off, by looking through an empty Tube, and yet the deluded Imagination is not at all helped thereby. I come next to the Solution hereof given by the Famous *Thomas Hobbs*: And for this we shall stand in need of the first *Fig.* wherein says he, let the Point *G* be the Center of the Earth, and *F* the Eye on the Surface of the Earth; on the same Center *G*, let there be struck the two Arches, *E H* determining the Atmosphere, and *A D* to represent that blue Surface in which we imagine the fixed Stars; and let *FD* be the *Horizon*. Divide the Arch *AD* into three equal Parts by the Lines *BF*, *CF*; it is manifest that the Angle *AFB* is greater than the Angle *BFC*, and this again greater than the Angle *CFD*. Wherefore, says he, to make the Angle *CFD* equal to the Angle *CFB*, the Arch *CD* must be greater than the Arch *CB*; and consequently, that the Moon may in the *Horizon* appear under the same Angle as when Elevated, she must cover a greater Arch, and therefore seem greater; that is, the Moon in the Meridian appearing under the Angle *BFC*, that she may appear under an equal Angle in the *Horizon*, as suppose *CFD*, 'tis necessary that Arch *CD* should be greater than *CB*; and consequently tho' she appear to subtend a greater Arch when in the *Horizon* than when Elevated, yet she appears under the same Angle. And all this without Refraction. The Geometry of this Figure is most certainly true and Demonstrable. At this I quarrel not; but it makes no more in our present Difficulty than if nothing had been said: For the Philosopher has here made a Figure of his own, and from thence he argues as confidently, as if Nature would accommodate herself to his Scheme, and he not obliged to accommodate his Scheme to Nature; for here he has made the Circle *GF* representing the Earth very large

in Proportion to the Circle AD ; and then indeed taking the Point F in the Earth's Surface, and by Lines from thence dividing the Angle AFD into whatever equal Parts, the intercepted Arches AB, BC, CD , shall be unequal. But if he had considered, that the Earth is as it were a Point in respect of the Sphere of the fix'd Stars, nay the very Annual Orbit of the Earth is almost, if not altogether imperceptible (saying the Truth of Mr. *Hook's* Attempt) he would have found that the Lines FB, FC, FD , must be all conceived as drawn from the point G , and then equal Angles will intercept equal Arches, and equal Arches equal Angles: And so it happens (at least beyond the Possibility of Discovery of Sense) to the Eye on the Surface of the Earth. And besides he should have consider'd, that all Observations Astronomical are performed as from the Center of the Earth, and therefore it is that they keep such a stir about Parallax; so that his drawing his Lines so far from G as F is, and to another concentrick Circle so nigh as AD , deceived him in this Point.

The Famous *Gassendus* has written 4 large Epistles on this Subject, the Substance of all which is, that the Moon being nigh the *Horizon* and look'd at thro' a more foggy Air, casts a weaker Light, and consequently forces not the Eye so much as when brighter; and therefore the *Pupil* does more enlarge itself, thereby transmitting a larger Projection on the *Retina*. In this Opinion I do find he is not alone, for in the Journals *des Scavans*, this Disquisition being again revived by a *French Abbe*, He therein follows this Sentiment of *Gassendus*; it was first published in the 3^d Conference presented to the *Dauphin* in August 1672, but by Reason of an Objection moved by Father *Pardye*, it was fain to be republished with some Additions and Amendments in *Octob.* 1672. The Addition was, that this Contracting and enlarging of the *Pupil* causeth a different Shape in the Eye; an open *Pupil* making the *Crystalline* flatter and the Eye longer, and the narrower *Pupil* shortening

ning the Eye, and making the *Crystalline* more convex, the first attends our looking at Objects which are remote, or which we think so; the latter accompanies the viewing Objects nigh at Hand. Likewise an open *Pupil* and flat *Crystalline* attends Objects of a more sedate Light, whilst Objects of more forcible Rays require a greater Convexity, and narrow *Pupil*. From these Positions the *Abbe* endeavoured to give an Account of our *Phenomenon*, as follows. When the Moon is nigh the *Horizon*, by Comparison with interposed Objects, we are apt to imagine her much farther from us than when more elevated, and therefore (says he) we order our Eyes as for viewing an Object farther from us, that is, we something enlarge the *Pupil*, and thereby make the *Crystalline* more flat: Moreover the Duskiſhneſs of the Moon in that Poſture does not ſo much ſtrain the Sight; and conſequently the *Pupil* will be more large, and the *Crystalline* more flat: Hence a larger Image ſhall be projected on the Fund of the Eye, and therefore the Moon ſhall appear larger. And this Diſpoſition of the Eye that magnifies her, magnifies alſo the Diviſions of our forementioned Lattice, and conſequently ſhe by her Body ſhall poſſeſs no more of the Diviſions, than when ſhe ſeems leſs. Theſe two forementioned Accidents, *viz.* the Moon's imaginary Diſtance and Duskiſhneſs, gradually vaniſhing as ſhe riſes, a different *Species* is hereby introduced in the Eye, and conſequently ſhe ſeems gradually leſs and leſs, till again ſhe approaches nigh the *Horizon*. Theſe two Opinions of *Gaſſendus* and the *Abbe* being ſo nigh a Kin, I ſhall conſider them both together, and firſt I aſſert that a wider or narrower Aperture increaſes not, neither dimin-iſhes the Projection on the *Retina*. I know *Honoratus Faber* in his *Synopſis Optica* endeavours to prove the clear contrary to this my Aſſertion, and that after this Manner. *Fig II.* *AB* is an Object, *EF* the greater Aperture of the *Pupil*, admitting the Projection *KI* on the *Retina*, whereas the leſſer Aperture

Aperture CD admits only the Projection GH ; but GH is less than KI , wherefore a lesser Aperture diminishes the Projection. I admire that any Man that undertook (as *Honoratus Faber*) to write of Opticks more accurately than all that went before him, should be guilty of so very gross an Error; and I do more admire that the celebrated *Gassendus*, and with him the Noble *Hervelius*, should be of the same Opinion: For tho' the foresaid Figure and Demonstration hold most certainly true in direct Projections, as in a dark Room with a plain Hole; yet it will not hold in Projections made by Refraction, as it is in those on the *Retina* in the Eye, by means of the *Crystalline* and other Coats and Humours of the Eye. For a Demonstration of this observe the *third Fig.* wherein let AB be a Remote Object, and EF the *Crystalline* at its large Aperture, projecting the Image IM on the *Retina*. Let then CD be the lesser Aperture of the *Pupil* before the *Crystalline*: I say the Image IM shall be projected as large as before, for the Cone of Rays EAF consists partly of the Cone of Rays CAD , therefore where the former EAF is projected, the latter CAD , as being a part of the former, shall be projected also. So that no more is effected by this narrow Aperture, but that the Sides of the Radiating Cones are intercepted, and consequently the Point I shall be affected with less Light, but it shall still be in the same place: What is said of that Cone and that Point, may be said of all other Cones and other Points of the Object. From hence appears first, the Invalidity of the Account given of the Moon's Appearance by *Gassendus* from this Reason; 2^{ly}, The Reason appears why a Telescope's greater or lesser Aperture, makes no difference in the Angle it receives: For imagine EF to be an Object-Glass of a Telescope, and 'tis plain. 3^{ly}, 'Tis evident why a greater or lesser Aperture on a Telescope should make the Objects appear lighter or darker, for thereby more or less Rays are admitted to determine on the Projection of each Point. But all this
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by and by. And this is sufficient for a Confutation of *Gassendus* and *Faber*; but our forementioned *Abbe* super-adds to a greater or lesser Aperture of the *Pupil*, as a necessary Consequent, a greater and lesser Convexity of the *Crystalline*, as also a lengthening and shortening the *Tube* of the Eye. And this I must confess would do something if we find it true in our Case; and this let us try. First, says he, the Duskihnness of the Moon nigh the *Horizon* admits the *Pupil* to enlarge itself, the *Crystalline* to flatten, and the Eye to lengthen: But what if we change our Object, and instead of the Moon take the Distance between some of the fixt Stars; (as suppose those of *Orion's* Girdle,) we shall find the same *Phænomenon* in them, and yet I hope neither he nor *Gassendus* will assert, that they at one time strain the Eye more than at another, or that at any time their *Fulgur* strains the Eye at all; if he do, let him take Stars of the lesser Magnitudes, nay, even those that can but just be perceived, and then he will be convinced: Or let him consider whether this will hold in looking at the Sun through very dark Glasses, which render the Sight thereof as inoffensive to the Eye, as that of a green Field; but perhaps he will then say that this other Reason holds, which is, *viz.* that the greater imaginary Distance at which we think the Moon near the *Horizon*, than when more elevated, makes us contemplate her as if really she was so, *viz.* with ample *Pupils*, &c. but this I have sufficiently overthrown in my Remarks against *Des-Cartes*: Therefore I pass it over, only subjoyning that if there were any thing in this Surmise, my-thinks the *Horizontal* Moon should be fancy'd nigher to us, than farther from us; for if we are for trying Natural Thoughts, let us take Children to determine the Matter, who are apt to think, that could they go to the Edge of that Space that bounds their Sight, they should be able (as they call it) to touch the Sky; and consequently the Moon seems then rather nigher to us than farther from us.

After

After I had writ thus far I accidentally cast my Eye upon *Riccioli's* Treatise of Refraction, at the End of his 2d Volume of the *Almagest*, *Lib. 10. Sect. 6. cap. 1. Quest. 13.* wherein he speaks of our present Difficulty; but to my Wonder I find him assert, that he and Father *Grimaldi* had often taken the *Horizontal* Sun and Moon's Diameters by a Sextant, when to the naked Eye they appeared very large; (*Grimaldus* directing his Sight to the left Edge, and *Ricciolus* to the right,) and that even by the Instrument they always found the Diameters greater than when more elevated, the Sun often subtending an Angle of almost a Degree, and frequently 45 Minutes, the Moon also 38 or 40 Minutes. This is down-right contrary to the Matter of Fact, which I have before alledged, and directly repugnant to the Matter of Fact asserted by the *French Abbe* in the forecited Journal. Whether of us be in the right I leave to accurate Experiment to determine, and submit the Whole to the Decision of the *Illustrious Royal Society*. Only give me leave to add one Word against *Riccioli*, for had his Experiments been accurately prosecuted, he should have tryed them when the *Horizontal* Moon had look'd ten times more large in Diameter than ordinary; and then if it be true, that even by an Instrument she will be found proportionally broader than really, she should subtend an Angle of 300 Minutes, or 5 Degrees: For very often I have seen the Moon when she appeared 10 times broader than ordinary, which the small Addition of 8 or 10 Minutes to her usual Diameter will never Cause.

Lastly as an Apology for my reviving this Disquisition to that Noble Company of *English* Philosophers, I shall only intimate the Words of the forementioned *Abbe's* Letter. *Pour la Raison de cette Apparence, & de la tromperie de nos Sens, je la tiens plus Difficile a trouver, que les plus grands Equations d'Algebre, & quand vous y aurez bien pense, vous m'Obligerez de m'en dire vostre Sentiment, &c.*

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After which I have only to subscribe myself an unworthy Member, and an humble Servant and Admirer of that Illustrious Company.

Dublin,
March 10th. 87.

William Molyneux.

*The Sentiments of the Reverend and Learned
Dr. John Wallis, R. S. Soc. upon the afore-
said Appearance, communicated in a Letter
to the Publisher.*

AS to the last Inquiry (concerning which, you say, the Royal Society would be glad to know my Opinion;) about the apparent Magnitude of the Sun near the *Horizon*, greater than when considerably high :

The Inquiry is ancient : And I remember, I discoursed it near forty Years ago with Mr. *Foster*, then Professor of Astronomy in *Gresham College* : Who did then assure me (from his own Observation, I suppose ; for I have never examined it myself,) that the apparent Magnitude taken by Instrument (however the Fancy may apprehend it) is not greater at the *Horizon*, than when higher. And Mr. *Caswell* (when your Letter was communicated to our Company here) affirmed the same.

And (though I have not myself made the Observation) I do not doubt but the Thing is so. For it is agreed ; That Refraction near the *Horizon*, though (as to appearance) it alters the Altitude of the Thing seen ; yet it alters not the *Azimuth* at all.

And it must needs be so. For, since this equally respects all Points of the *Horizon* ; let the Refraction be

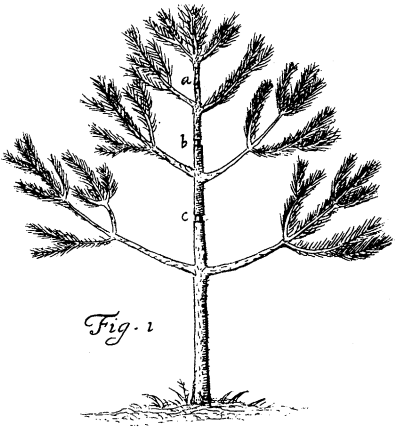


Fig. 1

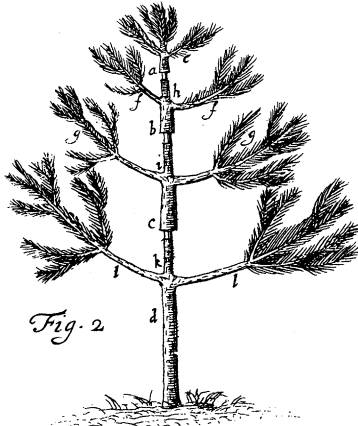


Fig. 2

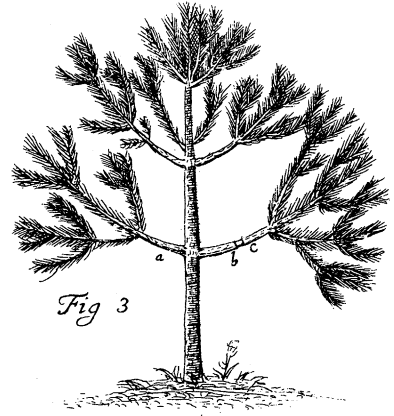


Fig. 3

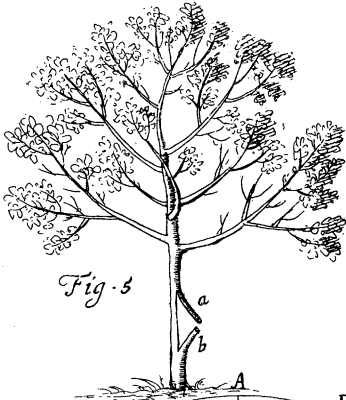


Fig. 4

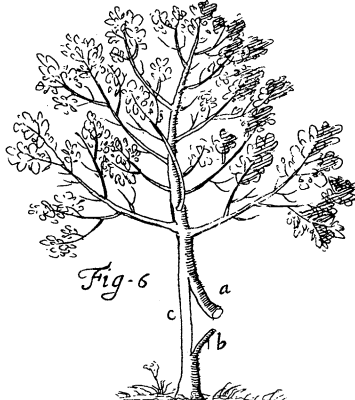


Fig. 5

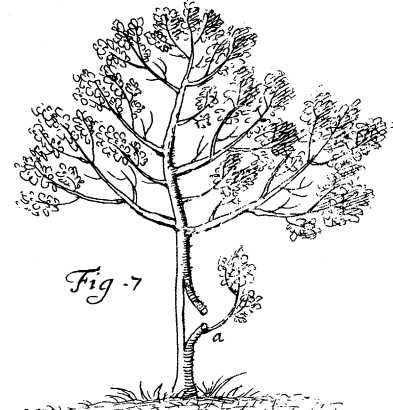


Fig. 6

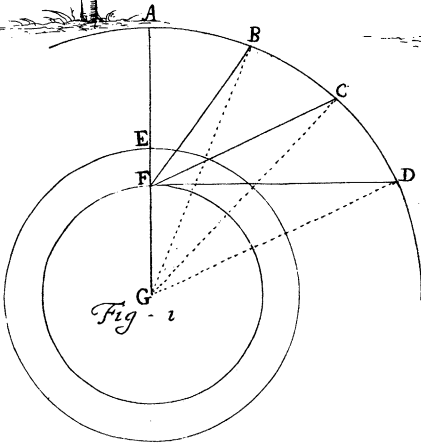


Fig. 7

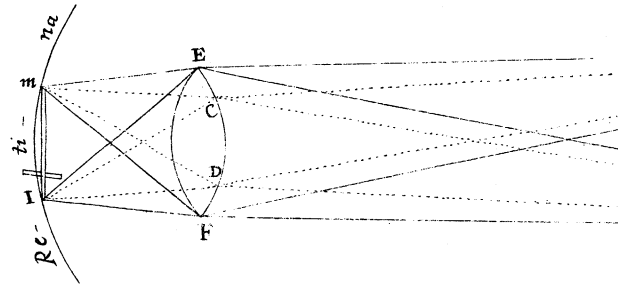


Fig. 8



Fig. 1



Fig. 2



Fig. 3



Fig. 4

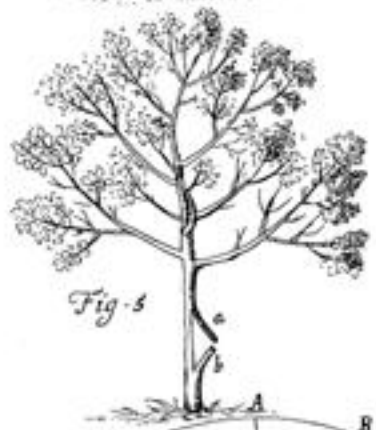


Fig. 5



Fig. 6



Fig. 7

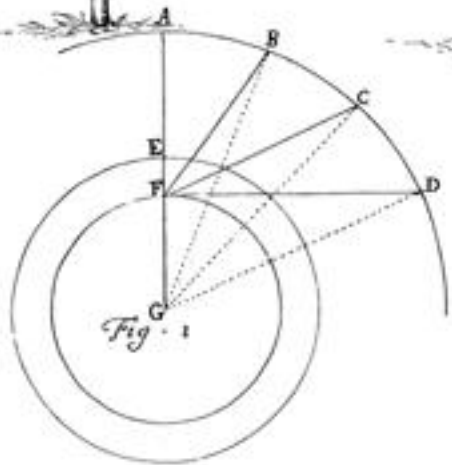


Fig. 1

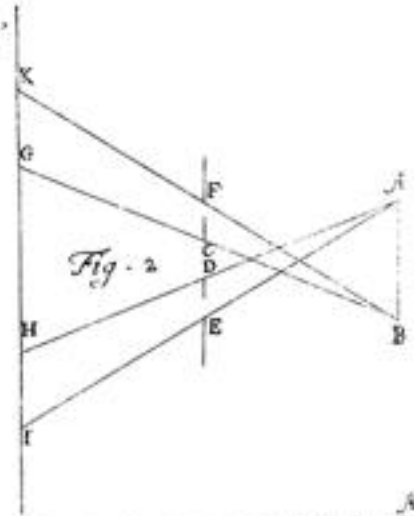


Fig. 2

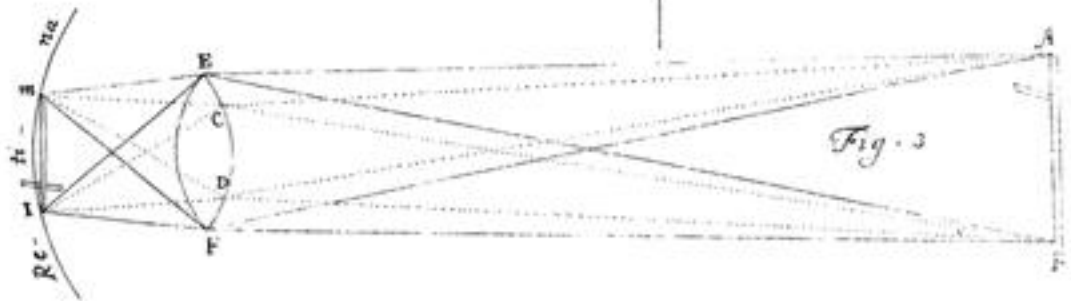


Fig. 3