Sidereus Nuncius

A page by page translation

Based on the version by Edward Stafford Carlos
Rivingtons
London
1880

Newly edited and corrected by Peter Barker
Byzantium Press
Oklahoma City
2004

Notes on the translation. My aim has been to restore page breaks, paragraphs, and emphatic capitals, so that the interested reader may easily locate the corresponding Latin in Galileo's original text. Given the differences in grammar between Latin and English it has seldom been possible to locate page breaks at corresponding words; I have generally chosen a clear phrase which the reader may use to connect the translation and the Latin text. I have also corrected several mistranslations and anachronisms, and restored a lost figure at the foot of folio 21, but I have not corrected errors in Galileo's original figures.

On the last line of folio 5 Galileo mistakenly gives the Earth's distance from the Moon as 60 diameters; this is an error in units. The accepted distance in Galileo's day was sixty times the radius of the earth, or 60 semi-diameters. This error has been corrected by hand in the copy reproduced here and duly noted on the equivalent page of the translation. A corresponding change required on the reverse of folio 6 was not made in the original but has been noted in the translation.

Galileo provides a number of informative page headings. These have also been reproduced here, using capital letters.

In the figures showing Jupiter's satellites, 'Ori.' stands for 'Oriens' meaning 'East', and 'Occ.' stands for 'Occidens' meaning 'West.'

THE HERALD
OF THE STARS

unfolding

GREAT, and HIGHLY ADMIRABLE

Sights, and presenting to the gaze
of everyone, but especially

PHILOSOPHERS, and ASTRONOMERS,

those things observed by

GALILEO GALILEI
PATRICIAN OF FLORENCE

Public Mathematician of the University of Padua
with the aid of a

TELESCOPE

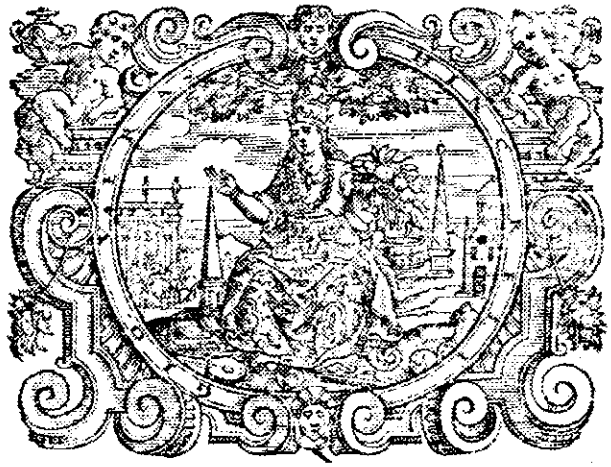
which he has recently devised on THE FACE OF THE MOON, INNUMERABLE FIXED STARS, THE MILKY WAY, CLOUDLIKE STARS, and especially concerning

FOUR PLANETS

revolving around the star of JUPITER with unequal intervals and periods, with wonderful swiftness, which, known to no-one up to this day, the Author most recently discovered for the first time; and

DETERMINED TO NAME

THE MEDICEAN STARS



VENICE, At the place of Thomas Baglioni, 1610.

With the Higher Authorities' Permission, & Authorization.

TO THE MOST SERENE COSIMO DE' MEDICI THE SECOND, FOURTH GRAND-DUKE OF TUSCANY

There is certainly something very noble and large minded in the intention of those who have endeavored to protect from envy the noble achievements of distinguished men, and to rescue their names, worthy of immortality, from oblivion and decay. This desire has given us the lineaments of famous men, sculptured in marble, or fashioned in bronze, as a memorial of them to future ages; to the same feeling we owe the erection of statues, both ordinary and equestrian; hence, as the poet says, has originated expenditure, mounting to the stars, upon columns and pyramids; with this desire, lastly, cities have been built, and distinguished by the names of those men, whom the gratitude of posterity thought worthy of being handed down to all ages. For the state of the human mind is such that, unless it be continually stirred by the counterparts of matters obtruding themselves upon it from without, all recollection of the matters easily passes away from it.

But others, having regard for more stable and more lasting monuments, secured the eternity of the fame of great men by placing it under the protection, not of marble or bronze,

but of the Muses' guardianship and the imperishable monuments of literature. But why do I mention these things, as if human wit, content with these regions, did not dare to advance further; whereas, since she well understood that all human monuments do perish at last by violence, by weather, or by age, she took a wider view, and invented more imperishable signs, over which destroying Time and envious Age could claim no rights; so, betaking herself to the sky, she inscribed on the well-known orbs of the brightest stars – those everlasting orbs – the names of those who, for eminent and god-like deeds, were accounted worthy to enjoy an eternity in company with the stars. Wherefore the fame of Jupiter, Mars, Mercury, Hercules, and the rest of the heroes by whose names the stars are called, will not fade until the extinction of the splendor of the constellations themselves. But this invention of human shrewdness, so particularly noble and admirable, has gone out of date ages ago, inasmuch as primeval heroes are in possession of those bright abodes, and keep them by a sort of right; into whose company the affection of Augustus in vain attempted to introduce Julius Caesar; for when he wished that the name of the Julian constellation should be given to a star, which appeared in his time, one of those which the Greeks and the Latins alike name, from their hair-like tails, comets, it vanished in a short time and mocked his too eager hope. But we are able to read the heavens for your highness, most Serene Prince, far more truly and more happily, for scarcely have the immortal graces of your mind begun to shine on earth, when bright stars present themselves in the heavens, like tongues

to tell and celebrate your most surpassing virtues to all time. Behold therefore, four stars reserved for your famous name, and those not belonging to the common and less conspicuous multitude of fixed stars, but in the bright ranks of the planets, four stars which, with different motions among themselves, together hold their paths and orbs with marvelous speed around the planet Jupiter, the most glorious of all the planets, as if they were his own children, while all the while with one accord they complete all together mighty revolutions every twelve years round the center of the universe, that is, round the Sun. But the Maker of the Stars himself seemed to direct me by clear reasons to assign these new planets to the famous name of your Highness in preference to all others. For just as these stars, like children worthy of their sire, never leave the side of Jupiter by any appreciable distance, so who does not know that clemency, kindness of heart, gentleness of manners, splendor of royal blood, nobleness in public functions, wide extent of influence and power over others, all of which have fixed their common abode and seat in your Highness, who, I say, does not know that all these qualities, according to the providence of God, from whom all good things do come, emanate from the benign star of Jupiter? Jupiter, Jupiter, I maintain, at the instant of the birth of your Highness having at length emerged from the turbid mists of the horizon, and being in possession of the middle quarter of the heavens, and illuminating the eastern angle, from his own royal house, from that exalted throne, looked out upon your most happy birth, and poured forth into a most pure atmosphere

all the brightness of his majesty, in order that your tender body and your mind, though that was already adorned by God with still more splendid graces, might imbibe with your first breath the whole of that influence and power. But why should I use only plausible arguments when I can almost absolutely demonstrate my conclusion? It was the will of Almighty God that I should be judged by your most serene parents not unworthy to be employed in teaching your highness mathematics, which duty I discharged, during the four years just passed, at that time of the year when it is customary to take a relaxation from severer studies. Wherefore, since it evidently fell to my lot by God's will, to serve your highness, and so to receive the rays of your surpassing clemency and beneficence in a position near your person, what wonder is it if you have so warmed my heart that it thinks about scarcely anything else day and night, but how I, who am indeed your subject not only by inclination, but also by my very birth and lineage, may be known to be most anxious for your glory, and most grateful to you? And so, inasmuch as under your patronage, most serene C O S I M O, I have discovered these stars, which were unknown to all astronomers before me, I have, with very good right, determined to designate them with the most august name of your family. And as I was the first to investigate them, who can rightly blame me if I give them a name, and call them the M E D I C E A N S T A R S, hoping that as much consideration may accrue to these stars from this title, as other stars have brought to other heroes? For not to speak of your most serene ancestors, to whose everlasting glory

the monuments of all history bear witness, your virtue alone, most Mighty Sire, can confer on those stars an immortal name. For who can doubt that you will not only maintain and preserve the expectations about yourself which you have aroused by the very happy beginning of your government, high though they be, but also that you will far surpass them, so that when you have conquered others like yourself, you may still vie with yourself, and become day by day greater than yourself and your greatness?

Accept, then, most clement Prince, this addition to the glory of your family, reserved by the stars for you, and may you enjoy for many years those good blessings, which are sent to you not so much from the stars as from God, the Maker and Governor of the stars.
Padua, March 12, 1610

Your Highness'

Most Devoted Servant,

Galileo Galilei.

The most excellent gentlemen, the Heads of the Ecclesiastical Council of Ten, designated below, having received the assurance of the Governing Council of the University of Padua, based on a report of the two persons deputized to investigate, that is from the reverend Father Inquisitor, and from the Secretary of the Senate, Giorgio Maraviglia, with an oath, that the book entitled SYDEREUS NUNCIUS, etc., by Lord Galileo Galilei contains nothing contrary to the Holy Catholic Faith, principles, and good customs, and that it is fit for printing, grant a license, so that it may be printed in this city.

Given on the first day of March 1610.

Lord Marco Antonio Valaresso
Lord Nicolo Bon
Lord Lunardo Marcello
} Heads of the Ecclesiastical Council of Ten

Secretary to the most illustrious Council of Ten
Bartolomeo Comino

1610, 8 March, Registered in the records, on page 39.

Office of Ioannes Baptista Breatto
Coadjutor of the Council on Blasphemy

THE ASTRONOMICAL HERALD

Observations recently made
with the aid of a newly invented Telescope respecting the Moon's surface, the Milky Way, cloudlike stars, innumerable fixed stars, and also respecting
four Planets
THE ~~COSMIC~~ MEDICEAN STARS
never before seen, are here contained and set forth.

In the present small treatise I set forth some matters of great interest for all observers of natural phenomena to look at and consider. They are of great interest, I think, both from their intrinsic excellence, and from their absolute novelty, and also on account of the instrument by the aid of which they have been presented to my apprehension.

The number of the Fixed Stars which observers have been able to see without artificial powers of sight up to this day can be counted. It is therefore decidedly a great feat to add to their number, and to set distinctly before the eyes other stars in myriads, which have never been seen before, and which surpass the old, previously known, stars in number more than ten times.

Again, it is a most beautiful and delightful sight to behold the body of the Moon, which is distant from us nearly sixty [semi-]diameters of the Earth, as near as if

it was at a distance of only two of the same measures; so that the diameter of this same Moon appears about thirty times larger, its surface about nine hundred times, and its solid mass nearly 27,000 times larger than when it is viewed only with the naked eye; and consequently any one may know, with the certainty that is due to the use of our senses, that the Moon certainly does not possess a smooth and polished surface, but one rough and uneven, and, just like the face of the Earth itself, is everywhere full of vast protuberances, deep chasms, and sinuosities.

Then to have got rid of disputes about the Galaxy or Milky Way, and to have made its nature clear to the very senses, not to say to the understanding, seems by no means a matter which ought to be considered of slight importance. In addition to this, to point out, as with one's finger, the nature of those stars which every one of the astronomers up to this time has called cloud-like, and to demonstrate that it is very different from what has hitherto been believed, will be pleasant, and very fine.

But that which will excite the greatest astonishment by far, and which indeed especially moved me to call the attention of all astronomers and philosophers, is this, namely, that I have discovered Four Erratic Stars, neither known nor observed by any one of the astronomers before my time, which have their revolutions round a certain bright star, one of those previously known, like Venus and Mercury round the Sun, and are sometimes in front of it, sometimes behind it, though they never depart from it beyond certain limits. All which facts were discovered and observed a few days ago by the help of a telescope devised by me, through God's grace first enlightening my mind.

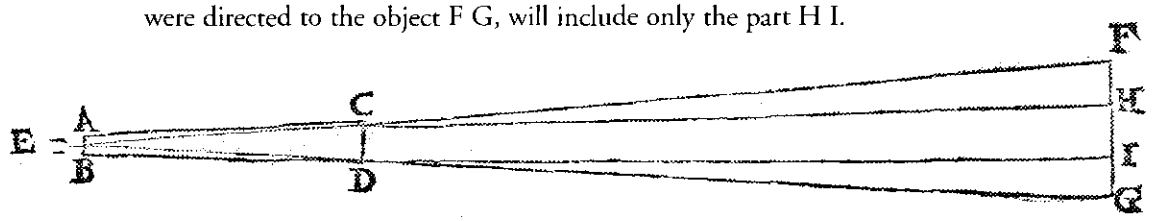
Perchance other discoveries still more excellent will be made from time to time by me or by other observers, with the assistance of a similar instrument, so I will first briefly record its shape and preparation, as well as the occasion of its being devised,

and then I will give an account of the observations made by me.

About ten months ago a report reached my ears that a Dutchman had constructed a telescope, by the aid of which visible objects, although at a great distance from the eye of the observer, were seen distinctly as if near; and some proofs of its most wonderful performances were reported, which some gave credence to, but others contradicted. A few days after, I received confirmation of the report in a letter written from Paris by a noble Frenchman, Jacques Badovere, which finally determined me to give myself up first to inquire into the principle of the telecope, and then to consider the means by which I might compass the invention of a similar instrument, which a little while after I succeeded in doing, through deep study of the theory of Refraction; and I prepared a tube, at first of lead, in the ends of which I fitted two glass lenses, both plane on one side but on the other side one spherically convex, and other concave. Then bringing my eye to the concave lens I saw objects satisfactorily large and near, for they appeared one-third of the distance off and nine times larger than when they are seen with the natural eye alone. I shortly afterwards constructed another telescope with more nicety, which magnified objects more than sixty times. At length, by sparing neither labor nor expense, I succeeded in constructing for myself an instrument so superior that objects seen through it appear magnified nearly a thousand times, and more than thirty times nearer than if viewed by the natural powers of sight alone. It would be altogether a waste of time to enumerate the number and importance of the benefits which this instrument may be expected to confer, when used by land or sea. But without paying attention to its use for terrestrial objects, I betook myself to observations of the heavenly bodies; and first of all, I viewed the Moon

as near as if it was scarcely two [semi-]diameters of the Earth distant. After the Moon, I frequently observed other heavenly bodies, both fixed stars and planets, with incredible delight; and, when I saw their very great number, I began to consider about a method by which I might be able to measure their distances apart, and at length I found one. And here it is fitting that all who intend to turn their attention to observations of this kind should receive certain cautions. For, in the first place, it is absolutely necessary for them to prepare a most perfect telescope, one which will show very bright objects distinct and free from any mistiness, and will magnify them at least 400 times, for then it will show them as if only one-twentieth of their distance off. For unless the instrument be of such power, it will be in vain to attempt to view all the things which have been seen by me in the heavens, or which will be enumerated hereafter. But in order that anyone may be a little more certain about the magnifying power of his instrument, he shall fashion two circles, or two square pieces of paper, one of which is 400 times greater than the other, which will be the case when the diameter of the greater is twenty times the length of the diameter of the other. Then he shall view both surfaces, fixed on the same wall, simultaneously from a distance, the smaller with one eye applied to the telescope, and the larger with the other eye unassisted; for that may be done without inconvenience at one and the same instant with both eyes open. Then both figures will appear of the same size, if the instrument magnifies objects in the desired proportion. After such an instrument has been prepared, the method of measuring distances remains for inquiry, and this we shall accomplish by the following contrivance. For the sake of being more easily understood, I will suppose a tube A B C D. Let E be the eye of the observer; then, when there are no lenses in the tube, rays from the eye to the object F G would be drawn in the straight lines E C F, E D G, but when the lenses have been inserted,

let the rays go in the bent lines E C H, E D I, for they are contracted, and those which originally, when unaffected by the lenses, were directed to the object F G, will include only the part H I.



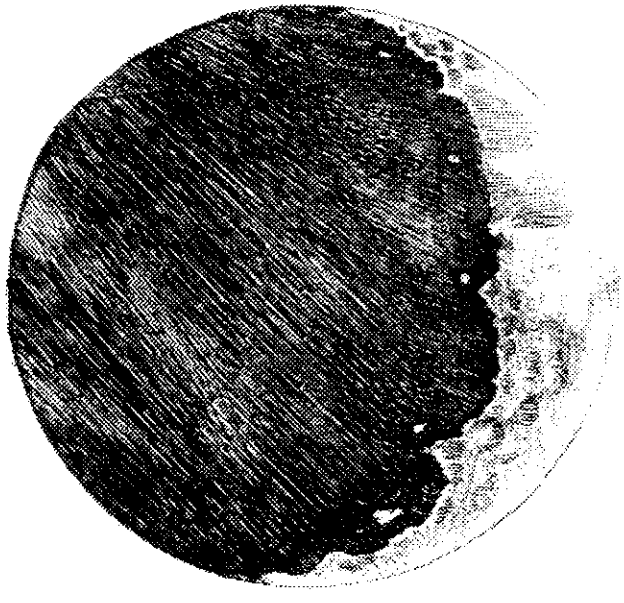
Hence the ratio of the distance E H to the line H I being known, we shall be able to find, by means of a table of sines, the magnitude of the angle subtended at the eye by the object H I, which we shall find to contain only some minutes. But if we fit on the lens C D thin plates of metal, pierced, some with larger, others with smaller apertures, by putting on over the lens sometimes one plate, sometimes another, as may be necessary, we shall construct at our pleasure different subtending angles of more or fewer minutes, by the help of which we shall be able to measure conveniently the intervals between stars separated by an angular distance of some minutes, within an error of one or two minutes. But let it suffice for the present to have thus slightly touched, and as it were just put our lips to these matters, for on some other opportunity I will publish the theory of this instrument in completeness. Now let me review the observations made by me during the two months just past, again inviting the attention of all who are eager for true philosophy to the beginnings which led to the sight of most important phenomena.

Let me speak first of the surface of the Moon, which is turned towards us.

For the sake of being understood more easily, I distinguish two parts in it, which I call respectively the brighter and the darker. The brighter part seems to surround and pervade the whole hemisphere; but the darker part, like a sort of cloud, discolors the Moon's surface and makes it appear covered with spots. Now these spots, as they are somewhat dark and of considerable size, are plain to everyone, and every age has seen them, wherefore I shall call them great or ancient spots, to distinguish them from other spots, smaller in size, but so thickly scattered that they sprinkle the whole surface of the Moon, but especially the brighter portion of it. These spots have never been observed by anyone before me; and from my observations of them, often repeated, I have been led to that opinion which I have expressed, namely, that I feel sure that the surface of the Moon is not perfectly smooth, free from inequalities and exactly spherical, as a large school of philosophers considers with regard to the Moon and the other heavenly bodies, but that, on the contrary, it is full of inequalities, uneven, full of hollows and protuberances, just like the surface of the Earth itself, which is varied everywhere by lofty mountains and deep valleys. The appearances from which we may gather these conclusions are the following.

On the fourth or fifth day after new moon, when the Moon presents itself to us with bright horns, the boundary which divides the part in shadow from the shining part does not extend continuously in an ellipse, as would happen in the case of a perfectly spherical body, but it is marked out by an irregular, uneven, and very wavy line, as represented in the figure given, for several bright excrescences, as they may be called, extend beyond the boundary of light and shadow into the dark part, and on the other hand pieces of shadow encroach upon the light. Indeed a great quantity of small blackish spots,

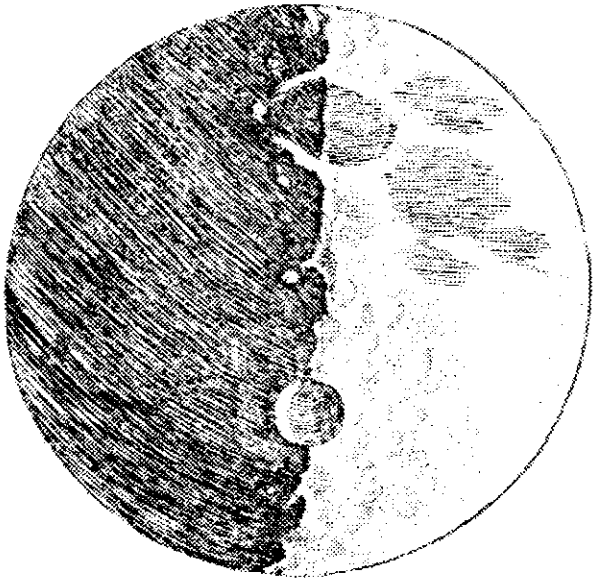
altogether separated from the dark part, sprinkle everywhere almost the whole space which is at the time flooded with the Sun's light, with the exception of that part alone which is occupied by the great and ancient spots. I have noticed that the small spots just mentioned have this common characteristic always and in every case, that they have the dark part towards the Sun's portion, and on the side away from the Sun they have brighter boundaries, as if they were crowned with shining summits. Now we have an appearance quite similar on the Earth about sunrise, when we behold the valleys, not yet flooded with light, but the mountains surrounding them on the side opposite to the Sun already ablaze with the splendor of his beams; and just as the shadows in the hollows of the Earth diminish in size as the Sun rises higher, so also these spots on the Moon lose their shadows as the illuminated part grows larger and larger.

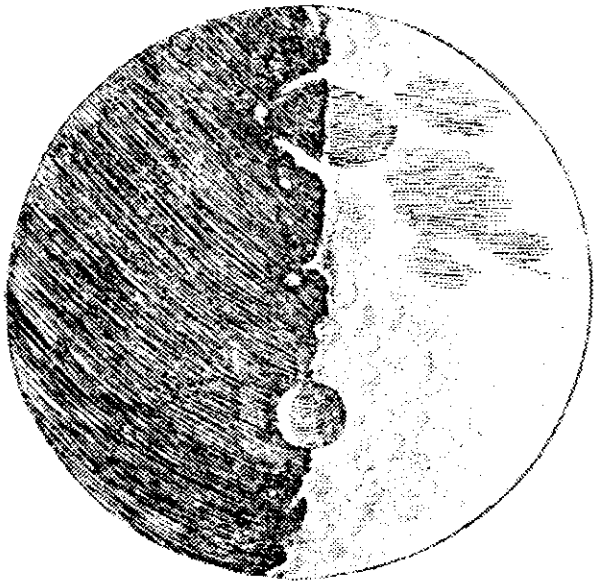


Again, not only are the boundaries of light and shadow in the Moon seen to be uneven and sinuous, but—and this produces still greater astonishment—there appear very many bright points within the darkened portion of the Moon, altogether divided and broken off from the illuminated tract, and separated from it by no inconsiderable interval, which, after a little while, gradually increase in size and brightness, and after an hour or two become joined on to the rest of the bright portion, now become somewhat larger; but in the meantime others, one here and another there, shooting up as if growing, are lighted up within the shaded portion, increase in size and at last are linked on to the same luminous surface, now even more extended. An example of this is given in the same figure. Now, is it not the case on the Earth before sunrise, that while the level plain is still in shadow the peaks of most lofty mountains are illuminated by the Sun's rays? After a little while does not the light spread further, while the middle and larger parts of those mountains are becoming illuminated; and at length, when the Sun has risen, do not the illuminated parts of the plains and hills join together? The grandeur, however, of such prominences and depressions in the Moon seems to surpass both in magnitude and extent the ruggedness of the Earth's surface, as I shall hereafter show. And here I cannot refrain from mentioning what a remarkable spectacle I observed while the Moon was rapidly approaching her first quarter, a representation of which is given in the same illustration, placed above. A protuberance of the shadow, of great size, indented the illuminated part in the neighborhood of the lower cusp; and when I had observed this indentation longer, and had seen that it was dark throughout, at length, after about two hours, a bright peak began to arise a little below the middle of the depression; this by degrees increased, and presented a triangular shape, but was as yet quite detached and separated from the illuminated surface. Soon around it three other small points

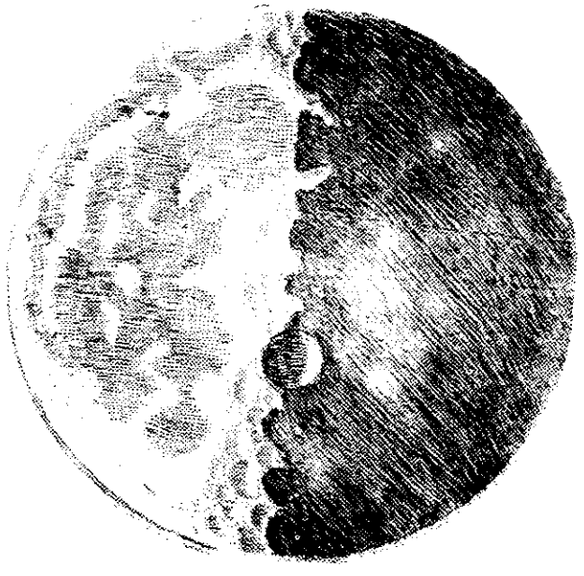
began to shine, until, when the Moon was about to set, that triangular figure, having now extended and widened, began to be connected with the rest of the illuminated part, and, still marked with the three bright peaks already mentioned, suddenly burst into the indentation of shadow like a vast promontory of light. At the ends of the upper and lower cusps also certain bright points, quite away from the rest of the bright part, began to rise out of the shadow, as is seen depicted in the same illustration. In both horns also, but especially in the lower one, there was a great quantity of dark spots, of which those which are nearer the boundary of light and shadow appear larger and darker, but those which are more remote less dark and more indistinct. In all cases, however, just as I have mentioned before, the dark portion of the spot faces the position of the Sun's illumination, and a brighter edge surrounds the darkened spot on the side away from the Sun, and towards the region of the Moon in shadow. This part of the surface of the Moon, where it is marked with spots like a peacock's tail with its azure eyes, is rendered like those glass vases which, through being plunged while still hot from the kiln into cold water, acquire a crackled and wavy surface, from which circumstance they are commonly called frosted glasses *(Glaciales Ciati)*. Now the great spots of the Moon observed at the same time are not seen to be at all similarly broken, or full of depressions and prominences, but rather to be even and uniform; for only here and there some spaces, rather brighter than the rest, crop up; so that if any one wishes to revive the old opinion of the Pythagoreans, that the Moon is another Earth, so to say, the brighter portion may very fitly represent the surface of the land, and the darker the expanse of water. Indeed, I have never doubted that if the sphere of the Earth were seen from a distance, when flooded with the Sun's rays, that part of the surface which is land would present itself to view as brighter, and that which is water as darker in comparison.

The great spots in the Moon are seen to be more depressed than the brighter tracts; for in the Moon, both when crescent and when waning, on the boundary between the light and shadow, which projects in some places round the great spots, the adjacent regions are always brighter, as I have noticed in drawing my illustrations, and the edges of the spots referred to are not only more depressed than the brighter parts, but are more even, and are not broken by edges or ruggednesses. But the brighter part stands out most near the spots, so that both before the first quarter and about the third quarter also, around a certain spot in the upper part of the figure, that is, occupying the northern region of the Moon, some vast prominences on the upper and lower sides of it rise to an enormous elevation, as the illustrations show.





This same spot before the second quarter is seen to be walled round with boundaries of a deeper shade, which just like very lofty mountain summits appear darker on the side away from the Sun, and brighter on the side where they face the Sun; but in the case of the cavities the opposite happens, for the part of them away from the Sun appears brilliant, and that part which lies nearer to the Sun dark and in shadow. After a time, when the enlightened portion of the Moon's surface has diminished in size, as soon as the whole or nearly so of the spot already mentioned is covered with shadow, the brighter ridges of the mountains mount high above the shade. These two appearances are shown in the illustrations which are given.



There is one other point which I must on no account forget, which I have noticed and rather wondered at: the middle of the Moon seems to be occupied by a certain cavity larger than all the rest, and in shape perfectly round. I have looked at this depression near both the first and third quarters, and I have represented it as well as I can in the second illustration already given. It produces the same appearance as to effects of light and shade as a tract like Bohemia would produce on the Earth, if it were shut in on all sides by very lofty mountains arranged on the circumference of a perfect circle. For the tract in the Moon is walled in with peaks of such enormous height that the furthest side adjacent to the dark portion of the Moon is seen bathed in sunlight before the boundary between light and shade reaches half-way across the circular space. But according to the characteristic property of the rest of the spots, the shaded portion of this too faces the Sun, and the bright part is towards the dark side of the Moon, which for the third time I advise to be carefully noticed as a most solid proof of the ruggedneses and unevennesses spread over the whole of the bright region of the Moon. Of these spots, moreover, the darkest are always those which are near to the boundary line between the light and the shadow, but those further off appear both smaller in size and less decidedly dark; so that at length, when the Moon at opposition becomes full, the darkness of the cavities differs from the brightness of the prominences with a subdued and very slight difference.

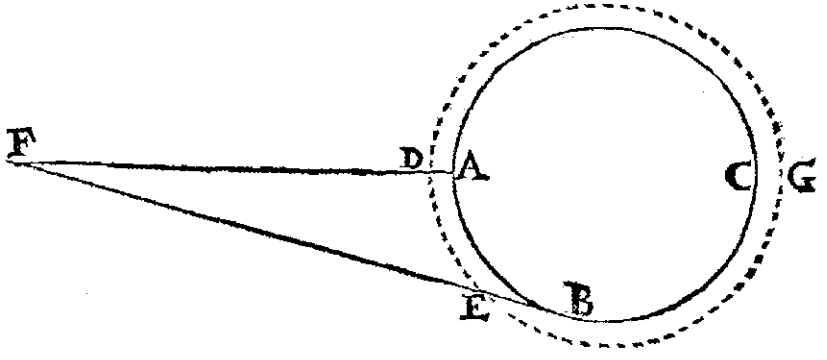
These phenomena which we have reviewed are observed in the bright tracts of the Moon. In the great spots we do not see such differences of depressions and prominences as we are compelled to recognize in the brighter parts, owing to the change of their shapes under different degrees of illumination by the Sun's rays according to the manifold variety of the Sun's position with regard to the Moon. Still, in the great spots there do exist some spaces

rather less dark than the rest, as I have noted in the illustrations, but these spaces always have the same appearance, and the depth of their shadow is neither intensified nor diminished; they do appear indeed sometimes a little more shaded, sometimes a little less, but the change of colour is very slight, according as the Sun's rays fall upon them more or less obliquely; and besides, they are joined to the adjacent parts of the spots with a very gradual connection, so that their boundaries mingle and melt into the surrounding region. But it is quite different with the spots which occupy the brighter parts of the Moon's surface, for, just as if they were precipitous crags with numerous rugged and jagged peaks, they have well-defined boundaries through the sharp contrast of light and shade. Moreover, inside those great spots certain other tracts are seen brighter than the surrounding region, and some of them very bright indeed, but the appearance of these, as well as of the darker parts, is always the same; there is no change of shape or brightness or depth of shadow, so that it becomes a matter of certainty and beyond doubt that their appearance is owing to real dissimilarity of parts, and not to unevennesses only in their configuration, changing in different ways the shadows of the same parts according to the variations of their illumination by the Moon, which really happens in the case of the other smaller spots occupying the brighter portion of the Moon, for day by day they change, increase, decrease, or disappear, inasmuch as they derive their origin from the shadows of prominences.

But here I feel that some people may be troubled with grave doubt, and perhaps seized with a difficulty so serious as to compel them to feel uncertain about the conclusion just explained and supported by so many phenomena. For if that part of the Moon's surface which reflects the Sun's rays most brightly is full of sinuosities, protuberances, and cavities innumerable, why, when the Moon is increasing, does the outer edge which looks toward the west, or when the Moon is waning, the other half-circumference towards the east,

and at full-moon the whole circle, appear not uneven, rugged and irregular, but perfectly round and circular, as sharply defined as if marked out with a pair of compasses, and without the indentations of any protruberances or cavities? And most remarkably so, because the whole unbroken edge belongs to that part of the Moon's surface which possesses the property of appearing brighter than the rest, which I have said to be throughout full of protuberances and cavities. For not one of the great spots extends quite to the circumference, but all of them are seen to be together away from the edge. Of this phenomenon, which affords a handle for such serious doubt, I produce two causes, and so two solutions of the difficulty. The first solution which I offer is this: If the protuberances and cavities in the body of the Moon existed only on the edge of the circle that bounds the hemisphere which we see, then the Moon might, or rather must, show itself to us with the appearance of a toothed wheel, being bounded with an irregular and uneven circumference; but if, instead of a single set of prominences arranged along the actual circumference only, very many ranges of mountains with their cavities and ruggednesses are set one behind the other along the extreme edge of the Moon, and that too not only in the hemisphere which we see, but also in that which is turned away from us, but still near the boundary of the hemisphere, then the eye, viewing them afar off, will not at all be able to detect the differences of prominences and cavities, for the intervals between the mountains situated in the same circle, or in the same chain, are hidden by the jutting forward of other prominences situated in other ranges, and especially if the eye of the observer is placed in the same line with the tops of the prominences mentioned. So on the Earth, the summits of a number of mountains close together appear situated in one plane, if the spectator is a long way off and standing at the same elevation. So when the sea is rough, the tops of the waves

seem to form one plane, although between the billows there is many a gulf and chasm, so deep that not only the hulls, but even the bulwarks, masts, and sails of stately ships are hidden amongst them. Therefore, as within the Moon, as well as round her circumference, there is a manifold arrangement of prominences and cavities, and the eye, regarding them from a great distance, is placed in nearly the same plane with their summits, no one need think it strange that they present themselves to the visual ray which just grazes them as an unbroken line quite free from unevennesses. To this explanation may be added another, namely, that there is round the body of the Moon, just as round the Earth, an envelope of some substance denser than the rest of the ether, which is sufficient to receive and reflect the Sun's rays, although it does not possess so much opaqueness as to be able to prevent our seeing through it—especially when it is not illuminated. That envelope, when illuminated by the Sun's rays, renders the body of the Moon apparently larger than it really is, and would be able to stop our sight from penetrating to the solid body of the Moon, if its thickness were greater; now, it is of greater thickness about the circumference of the Moon, greater, I mean, not in actual thickness, but with reference to our sight-rays, which cut it obliquely; and so it may stop our vision, especially when it is in a state of brightness, and may conceal the true circumference of the Moon on the side towards the Sun. This may be understood more clearly from the adjoining figure, in which the body of the Moon, A B C,

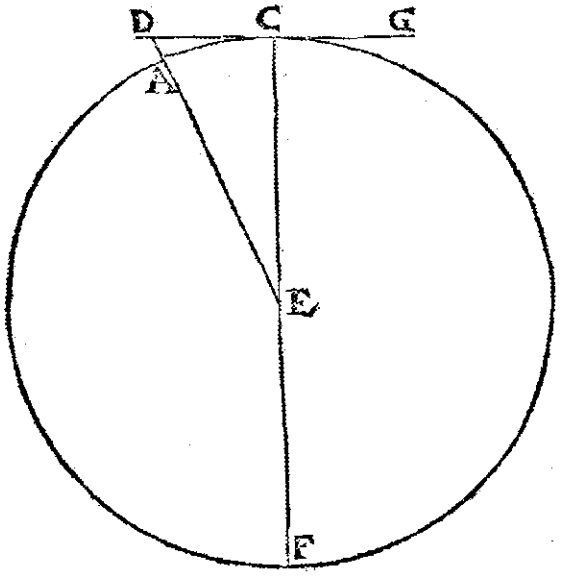


is surrounded by an enveloping atmosphere, D E G. An eye at F penetrates to the middle parts of the Moon, as at A, through a thickness, D A, of the atmosphere; but towards the extreme parts a mass of atmosphere of greater depth, E B, shuts out its boundary from our sight. An argument in favor of this is that the illuminated portion of the Moon appears of larger circumference than the rest of the orb which is in shadow. Perhaps also some will think that this same cause affords a very reasonable explanation why the greater spots on the Moon are not seen to reach to the edge of the circumference on any side, although it might be expected that some would be found about the edge as well as elsewhere; and it seems credible that there are spots there, but that they cannot be seen because they are hidden by a mass of atmosphere too thick and bright for the sight to penetrate.

It is therefore clear that the brighter part of the Moon's surface is dotted everywhere with protuberances and cavities, from the appearances already explained; it only remains for me to speak about their size and to show that the ruggednesses of the Earth's surface are far smaller than those of the Moon's; smaller, I mean absolutely, so to say, and not only smaller in proportion to the size of the orbs on which they are. And this is plainly shown.

As I often observed in various positions of the Moon with reference to the Sun, that some summits within the portion of the Moon in shadow appeared illumined, although at some distance from the boundary of the light (the terminator), by comparing their distance with the complete diameter of the Moon, I learnt that it sometimes exceeded the one-twentieth (1/20th) part of the diameter. Suppose the distance to be exactly 1/20th part of the diameter, and let the diagram represent the Moon's orb, of which C A F is a great circle, E its center, and C F a diameter, which consequently bears to the diameter of the Earth the ratio 2:7; and since the diameter of the Earth, according to the most exact observations, contains 7000 Italian miles, C F will be 2000, and C E

1000, and the 1/20thpart of the whole, C F, 100 miles. Also let C F be a diameter of the great circle



which divides the bright part of the Moon from the dark part (for, owing to the very great distance of the Sun from the Moon this circle does not differ sensibly from a great one), and let the distance of A from the point C be1/20th part of that diameter; let the radius EA be drawn, and let it be produced to cut the tangent line G C D which represents the ray that illumines the summit, in the point D. Then the arc C A or the straight line C D will be 100 of such units, as C E contains 1000. The sum of the squares of D C, C E is therefore 1,010,000, and the square of DE is equal to this; therefore the whole E D will be more than 1004; and A D will be more than 4 of such units, as C E contained 1000. Therefore the height of A D in the Moon, which represents a summit reaching up to the Sun's rays G C D, and separated from the extremity C by the distance C D, is more than

Italian miles; but in the Earth there are no mountains which reach to the perpendicular height of even one mile. We are therefore left to conclude that it is clear that the prominences of the Moon are loftier than those of the Earth.

I wish in this place to assign the cause of another lunar phenomenon well worthy of notice, and although this phenomenon was observed by me not lately, but many years ago, and has been pointed out to some of my intimate friends and pupils, explained, and assigned to its true cause, yet as the observation of it is rendered easier and more vivid by the help of a telescope, I have considered that it would not be unsuitably introduced in this place, but I wish to introduce it chiefly in order that the connection and resemblance between the Moon and the Earth may appear more plainly.

When the Moon, both before and after conjunction, is found not far from the Sun, not only does its orb show itself to our sight on the side where it is furnished with shining horns, but a slight and faint circumference is also seen to mark out the circle of the dark part, that part, namely, which is turned away from the Sun, and to separate it from the darker background of the sky. But if we examine the matter more closely, we shall see that not only is the extreme edge of the part in shadow shining with a faint brightness, but that the entire face of the Moon, that side, that is, which does not feel the Sun's glare, is illuminated with a pale light of considerable brightness. At the first glance only a fine circumference appears shining, on account of the darker part of the sky adjacent to it; whereas, on the contrary, the rest of the surface appears dark, on account of the contiguity of the shining horns, which destroys the clearness of our sight. But if any one chooses such a position for himself, that by the interposition of a roof, or a chimney, or some other object between his sight and the Moon (but at a considerable distance from his eye) the shining horns are hidden, and the

rest of the Moon's orb is left exposed to his view, then he will find that this tract of the Moon also, although deprived of sunlight, gleams with considerable light, and particularly so if the gloom of the night has already deepened through the absence of the Sun; for with a darker background the same light appears brighter. Moreover, it is found that this secondary brightness of the Moon, as I may call it, is greater in proportion as the Moon is less distant from the Sun; for it abates more and more in proportion to the Moon's distance from that body, so much so that after the first quarter, and before the end of the second, it is found to be weak and very faint, although it be observed in a darker sky; while, at an angular distance of 60° or less, even during twilight, it is wonderfully bright, so bright indeed that, with the help of a good telescope, the great spots can be distinguished in it. This strange brightness has afforded no small perplexity to philosophical minds; and some have published one thing, some another, as the cause to be alleged for it. Some have said that it is the inherent and natural brightness of the Moon; some that it is imparted to that body by the planet Venus; or, as others maintain, by all the stars; while some have said that it comes from the Sun, whose rays, they say, find a way through the solid mass of the Moon. But statements of this kind are disproved without much difficulty, and convincingly demonstrated to be false. For if this kind of light were the Moon's own, or were contributed by the stars, the Moon would retain it, particularly in eclipses, and would show it then, when left in an unusually dark sky, but this is contrary to experience. For the brightness which is seen on the Moon in eclipses is far less intense, being somewhat reddish, and almost copper-colored, whereas this is brighter and whiter; besides, the brightness seen during an eclipse is changeable and shifting, for it wanders over the face of the Moon, so that that part which is near the circumference of the circle of shadow thrown by the Earth is bright, but the rest of the Moon is always seen to be dark. From which circumstance we understand without hesitation that this brightness is due to the proximity of the Sun's rays

coming into contact with some denser region which surrounds the Moon as an envelope, owing to which contact a sort of dawn light is diffused over the neighboring regions of the Moon, just as the twilight spreads in the morning and evening on the Earth; but I will treat more fully of this matter in my book on the system of the world. Again, to assert that this sort of light is imparted to the Moon by the planet Venus is so childish as to be undeserving of an answer; for who is so ignorant as not to understand that at conjunction and within an angular distance of 60° it is quite impossible for the part of the Moon turned away from the Sun to be seen by the planet Venus? But that this light is derived from the Sun penetrating with its light the solid mass of the Moon, and rendering it luminous, is equally untenable. For then this light would never lessen, since the hemisphere of the Moon is always illuminated by the Sun, except at the moment of a lunar eclipse, yet really it quickly decreases while the Moon is drawing near to the end of her first quarter, and when she has passed her first quarter it becomes quite dull. Since, therefore, this kind of secondary brightness is not inherent and the Moon's own, nor borrowed from any of the stars, nor from the Sun, and since there now remains in the whole universe no other body whatever except the Earth, what, pray, must we conclude? What must we assert? Shall we assert that the body of the Moon, or some other dark and sunless orb, receives light from the Earth? Why should it not be the Moon? And most certainly it is. The Earth, with fair and grateful exchange, pays back to the Moon an illumination like that which it receives from the Moon nearly the whole time during the darkest gloom of night. Let me explain the matter more clearly. At conjunction, when the Moon occupies a position between the Sun and the Earth, the Moon is illuminated by the Sun's rays on her half towards the Sun which is turned away from the Earth, and the other half with which she regards the Earth is covered with darkness, and so in no degree illuminates the Earth's surface. When the Moon has slightly separated from the Sun, straightway she is partly illuminated on the half directed towards us; she turns towards us a slender silvery crescent, and slightly illuminates the Earth; there is an increase as the Moon

approaches her first quarter in the illumination of the Sun, and the reflection of that light increases on the Earth; the brightness in the Moon next extends beyond the semicircle, and our nights grow brighter; at length the entire face of the Moon looking towards the Earth is irradiated with the most intense brightness by the Sun, which happens when the Sun and Moon are on opposite sides of the Earth; then far and wide the surface of the Earth shines with the flood of moonlight; after this the Moon, now waning, sends out less powerful beams, and the Earth is illumined less powerfully; at length the Moon draws near her first position of conjunction with the Sun, and forthwith black night invades the Earth. In such a cycle the moonlight gives us each month alternations of brighter and fainter illumination. But the benefit of her light to the Earth is balanced and repaid by the benefit of the light of the Earth to her; for while the Moon is found near the Sun about the time of conjunction, she has in front of her the entire surface of that hemisphere of the Earth which is exposed to the Sun, and vividly illumined with his beams, and so receives light reflected from the Earth. Owing to such reflexion, the hemisphere of the Moon nearer to us, though deprived of sunlight, appears of considerable brightness. Again, when removed from the Sun through a quadrant, the Moon sees only one-half of the Earth's hemisphere illuminated, namely the western half, for the other, the eastern, is covered with the shades of night; the Moon is, therefore, less brightly enlightened by the Earth, and accordingly that secondary light appears fainter to us. But if you imagine the Moon to be set on the opposite side of the Earth to the Sun, she will see the hemisphere of the Earth, now between the Moon and the Sun, quite dark, and steeped in the gloom of night; if, therefore, an eclipse should accompany such a position of the Moon, she will receive no light at all, being deprived of the illumination of the Sun and Earth together. In any other position, with regard to the Earth and the Sun, the Moon receives more or less light by reflection from the Earth, according as she sees a greater or smaller portion of the hemisphere of the Earth illuminated by the Sun; for such a law is observed between these two orbs, that at whatever times the Earth is most brightly enlightened by the Moon, at those

times, on the contrary, the Moon is least enlightened by the Earth; and contrariwise. Let these few words on this subject suffice in this place; for I will consider it more fully in my *System of the World*, where, by very many arguments and experimental proofs, there is shown to be a very strong reflection of the Sun's light from the Earth, for the benefit of those who urge that the Earth must be separated from the starry host, chiefly for the reason that it has neither motion nor light, for I will prove that the Earth has motion, and surpasses the Moon in brightness, and is not the place where the dull refuse of the universe has settled down; I will demonstrate this, and I will confirm it with six hundred arguments taken from natural phenomena.

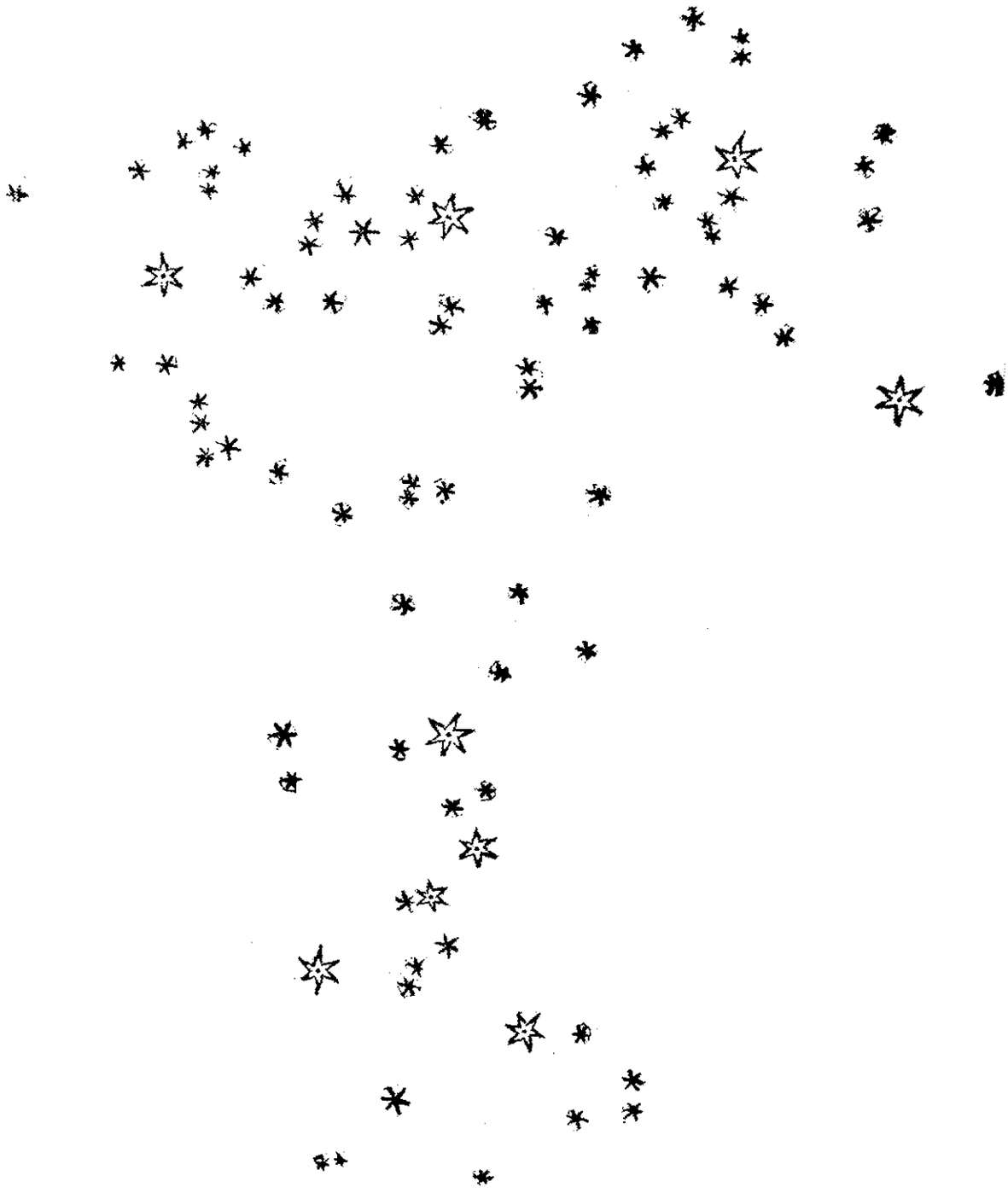
So far I have spoken of the observations which I have made concerning the Moon's body; now I will briefly announce the phenomena which have been, as yet, seen by me with reference to the Fixed Stars. And first of all the following fact is worthy of consideration. The stars, fixed as well as erratic, when seen with a telescope, by no means appear to be increased in magnitude in the same proportion as other objects and the Moon herself increase in size; but in the case of the stars such increase appears much less, so that you may consider that a telescope, which, for example, is powerful enough to magnify other objects a hundred times, will scarcely render the stars magnified four or five times. But the reason of this is as follows. When stars are viewed with our natural eyesight they do not present themselves to us of their bare, real size, but beaming with a certain vividness, and fringed with sparkling rays, especially when the night is far advanced; and from this circumstance they appear much larger than they would if they were stripped of those adventitious fringes, for the angle which they subtend at the eye is determined not by the primary disc of the star, but by the brightness which so widely surrounds it. Perhaps you will understand this most clearly

from the well-known circumstance that when stars rise just at sunset, in the beginning of twilight, they appear very small, although they may be stars of the first magnitude; and even the planet Venus itself, on any occasion when it may present itself to view in broad daylight, is so small to see that it scarcely seems to equal a star of the last magnitude. It is different in the case of other objects, and even of the Moon, which, whether viewed in the light of midday or in the depth of night, always appears of the same size. We conclude therefore that the stars are seen at midnight in uncurtailed glory, but their fringes are of such a nature that the daylight can cut them off, and not only daylight, but any slight cloud which may be interposed between a star and the eye of the observer. A dark veil or colored glass has the same effect, for upon placing them before the eye, between it and the stars, all the blaze that surrounds them leaves them at once. A telescope also accomplishes the same result, for it removes from the stars their adventitious and accidental splendors before it enlarges their true discs (if indeed they are of that shape), and so they seem less magnified than other objects, for a star of the fifth or sixth magnitude seen through a telescope is shown as of the first magnitude only.

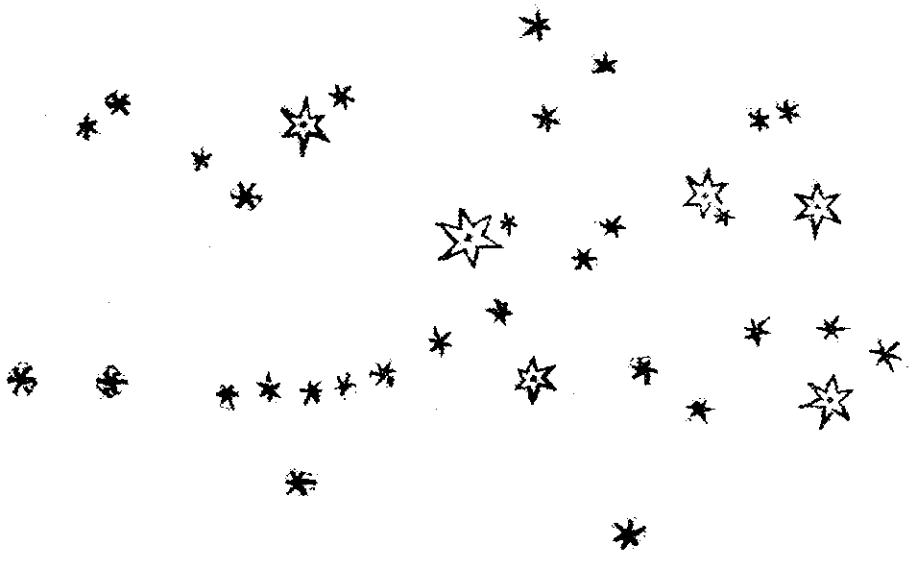
The difference between the appearance of the planets and the fixed stars seems also deserving of notice. The planets present their discs perfectly round, just as if described with a pair of compasses, and appear as so many little Moons, completely illuminated and of a globular shape; but the fixed stars do not look to the naked eye bounded by a circular circumference, but rather like blazes of light, shooting out beams on all sides and very sparkling, and with a telescope they appear of the same shape as when they are viewed by simply looking at them, but so much larger that a star of the fifth or sixth magnitude seems to equal Sirius, the largest of all the fixed stars.

But beyond the stars of the sixth magnitude you will behold through the telescope a host of other stars, which escape the unassisted sight, so numerous as to be almost beyond belief, for you may see more than six other differences of magnitude, and the largest of these, which I may call stars of the seventh magnitude, or of the first magnitude of invisible stars, appear with the aid of the telescope larger and brighter than stars of the second magnitude seen with the unassisted sight. But in order that you may see one or two proofs of the inconceivable manner in which they are crowded together, I have determined to make out a case using two star clusters, that from them as a specimen you may decide about the rest. As my first example I had determined to depict the entire constellation of Orion, but I was overwhelmed by the vast quantity of stars and by want of time, and so I have deferred attempting this to another occasion, for there are adjacent to, or scattered among, the old stars more than five hundred new stars within the limits of one or two degrees. For this reason I have selected the three stars in Orion's Belt and the six in his Sword, which have been long well known groups, and I have added eighty other stars recently discovered in their vicinity, and I have preserved as exactly as possible the intervals between them. The well known or old stars, for the sake of distinction, I have depicted of larger size, and I have outlined them with a double line; the others, invisible to the naked eye, I have marked smaller and with one line only. I have also preserved the differences of magnitude as much as I could. As a second example I have depicted the six stars of the constellation Taurus, called the PLEIADES (I say six intentionally, since the seventh is scarcely ever visible), a group of stars which is enclosed in the heavens within very narrow precincts. Near these there lie more than forty others invisible to the naked eye, no one of which is much more than half a degree off any of the aforesaid six; of these I have noticed only thirty-six in my diagram. I have preserved their intervals, magnitudes, and the distinction between the old and the new stars, just as in the case of the constellation Orion.

Belt and Sword of the ORION Constellation



THE PLEIADES CONSTELLATION [16b]



In third place, I have observed the essence or substance of the MILKY WAY circle. By the aid of a telescope anyone may behold this in a manner which so distinctly appeals to the senses that all the disputes which have tormented philosophers through so many ages are exploded at once by the unquestionable evidence of our eyes, and we are freed from wordy disputes upon this subject, for the GALAXY is nothing else but a mass of innumerable stars planted together in clusters. Upon whatever part of it you direct the telescope straightway a vast crowd of stars presents itself to view; many of them are tolerably large and extremely bright, but the number of small ones is quite beyond determination.

And whereas that milky brightness, like the brightness of a white cloud, is not only to be seen in the GALAXY, but several spots of a similar color shine faintly here and there in the heavens, if you turn the telescope upon any of them you will find a cluster of stars packed close together.

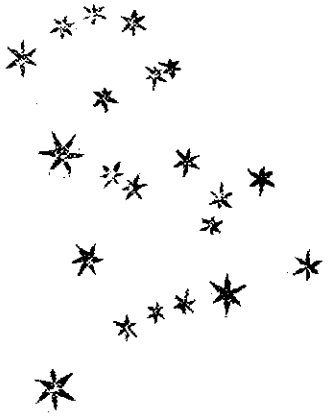
OBSERVATIONS OF THE STARS

Further—and you will be more surprised at this—the stars which have been called by every one of the astronomers up to this day cloud-like objects (nebulae), are groups of small stars set thick together in a wonderful way, and although each one of them on account of its smallness, or its immense distance from us, escapes our sight, from the commingling of their rays there arises that brightness which has hitherto been believed to be the denser part of the heavens, able to reflect the rays of the stars or the Sun. I have observed some of these, and I indicate below the star clusters of two of these nebulae.

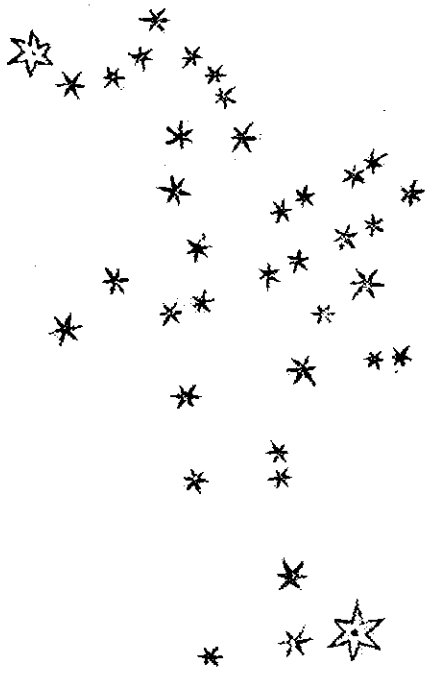
First, you have a diagram of the NEBULA called that of Orion's Head, in which I have counted twenty-one stars.

The second cluster contains the PRAESEPE NEBULA, which is not one star only, but a mass of more than forty small stars. I have noticed thirty-six stars, besides the Aselli [the known stars of the nebula], arranged in the order of the accompanying diagram.

ORION NEBULA

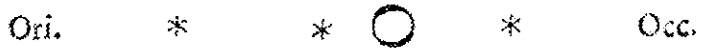


PRAESEPE NEBULA

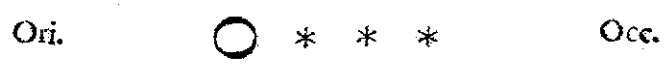


I have now finished my brief account of the observations which I have thus far made with regard to the Moon, the Fixed Stars, and the Galaxy. There remains the matter, which seems to me to deserve to be considered the most important in this work, namely, that I should disclose and publish to the world the occasion of discovering and observing four PLANETS, never seen from the very beginning of the world up to our own times, their positions, and the observations made during the last two months about their movements and their changes of magnitude; and I summon all astronomers to apply themselves to examine and determine their periodic times, which it has not been permitted me to achieve up to this day, owing to the restriction of my time. I give them warning however again, so that they may not approach such an inquiry to no purpose, that they will want a very accurate telescope, and such as I have described in the beginning of this account.

On the 7th day of January in the present year, 1610, in the first hour of the following night, when I was viewing the constellations of the heavens through a telescope, the planet Jupiter presented itself to my view, and as I had prepared for myself a very excellent instrument, I noticed a circumstance which I had never been able to notice before, owing to want of power in my other telescope, namely, that three little stars, small but very bright, were near the planet; and although I believed them to belong to the number of the fixed stars, yet they made me somewhat wonder, because they seemed to be arranged exactly in a straight line, parallel to the ecliptic and to be brighter than the rest of the stars equal to them in magnitude. The position of them with reference to one another and to Jupiter was as follows.

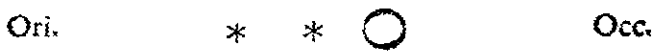


On the east side there were two stars, and a single one towards the west. The star which was furthest towards the east, and the western star, appeared rather larger than the third. I scarcely troubled at all about the distance between them and Jupiter, for, as I have already said, at first I believed them to be fixed stars; but when on January 8th, led by some fate, I turned again to look at the same part of the heavens, I found a very different state of things, for there were three little stars all west of Jupiter, and nearer together than on the previous night, and they were separated from one another by equal intervals, as the accompanying illustration shows. At this point, although I had not turned my thoughts at all upon the proximity of the stars to one another,



yet my surprise began to be excited, how Jupiter could one day be found to the east of all the aforesaid fixed stars when the day before it had been west of two of them; and forthwith I became afraid lest the planet might have moved differently from the calculation of astronomers, and so had passed those stars by its own proper motion. I therefore waited for the next night with the most intense longing, but I was disappointed of my hope, for the sky was covered with clouds in every direction.

But on January 10th the stars appeared in the following position with regard to Jupiter; there were two only, and both on the east side



of Jupiter, the third, as I thought, being hidden by the planet. They were situated just as before, exactly in the same straight line with Jupiter, and along the Zodiac. When I had seen these phenomena, as I knew that corresponding changes

of position could not by any means belong to Jupiter, and as, moreover, I perceived that the stars which I saw had been always the same, for there were no others either in front or behind, within a great distance, along the Zodiac. At length, changing from doubt into surprise, I discovered that the interchange of position which I saw belonged not to Jupiter, but to the stars to which my attention had been drawn, and I thought therefore that they ought to be observed henceforward with more attention and precision.

Accordingly, on January 11th I saw an arrangement

of the following kind, namely, only two stars to the east of Jupiter, the nearer of which was distant from Jupiter three times as far as from the star further to the east; and the star furthest to the east was nearly twice as large as the other one; whereas on the previous night they had appeared nearly of equal magnitude. I therefore concluded, and decided unhesitatingly, that there are three stars in the heavens moving about Jupiter, as Venus and Mercury round the Sun; which at length was established as clear as daylight by numerous other subsequent observations. These observations also established that there are not only three, but four, erratic sidereal bodies performing their revolutions round Jupiter, observations of whose changes of position made with more exactness on succeeding nights the following account will supply. I have measured also the intervals between them with the telescope in the manner already explained. Besides this, I have given the times of observation, especially when several were made in the same night, for the revolutions of these planets are so swift that an observer may generally get differences of position every hour.

Jan. 12. At the first hour of the next night I saw these heavenly bodies arranged in this manner. The star furthest to the east

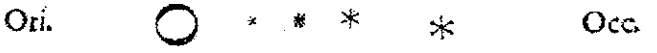
was greater than the star furthest to the west; but both were very conspicuous and bright; the distance of each one from Jupiter was two minutes. A third star, certainly not in view before, began to appear at the third hour; it nearly touched Jupiter on the east side, and was exceedingly small. They were all arranged in the same straight line, along the ecliptic.

Jan. 13. For the first time four stars were in view in the following position with regard to Jupiter. There were three to the west, and one to the east; they made a nearly straight line,

but the middle star of those to the west deviated a little from the straight line towards the north. The star furthest to the east was at a distance of 2' from Jupiter; there were intervals of 1' only between Jupiter and the nearest star, and between the stars themselves, west of Jupiter. All the stars appeared of the same size, and though small they were very brilliant, and far outshone the fixed stars of the same magnitude.

Jan. 14. The weather was cloudy.

Jan. 15. At the third hour of the night the four stars were in the state depicted in the next diagram with reference to Jupiter.



All were to the west, and arranged nearly in the same straight line; but the star which counted third from Jupiter

was raised a little to the north. The nearest to Jupiter was the smallest of all; the rest appeared larger and in order of magnitude; the intervals between Jupiter and the three nearest stars were all equal, and were of the magnitude of 2' each; but the star furthest to the west was distant 4' from the star nearest to it. They were very brilliant, and not at all twinkling, as they have always appeared both before and since. But at the seventh hour there were only three stars,

presenting with Jupiter an appearance of the following kind. They were, that is to say, in the same straight line to a hair; the nearest to Jupiter was very small, and distant from the planet 3'; the distance of the second from this one was 1'; and of the third from the second 4' 30". But after another hour the two middle stars were still nearer, for they were only 30", or less, apart.

Jan. 16. At the first hour of the night I saw three stars arranged in this order. Jupiter

was between two of them, which were at a distance of 0' 40" from the planet on either side, and the third was west of Jupiter at a distance of 8'. The stars near to Jupiter appeared brighter than the star further off, but not larger.

Jan. 17. After sunset 0 hours 30 minutes, the configuration was of this kind. There was only one star to the east,

at a distance of 3' from Jupiter; to the west likewise there was only one star, distant 11' from Jupiter. The star on the east appeared twice as large as the star to the west; and there were no more than these two. But four hours after, that is, nearly at the fifth hour, a third star began to emerge on the east side, which, before its appearance, as I think, had been joined with the former of the two other stars, and the position was of this kind.

The middle star was very near indeed to the star on the east, and was only 20" from it; and was a little towards the south of the straight line drawn through the two extreme stars and Jupiter.

Jan. 18. At 0 h. 20 m. after sunset, the appearance was such as this. The star to the east was larger

than the western one, and was at a distance from Jupiter of 8', the western one being at a distance of 10'.

Jan. 19. At the second hour of the night the relative position of the stars was as follows:

there were three stars exactly in a straight line with Jupiter, one to the east, at a distance of 6' from Jupiter; between Jupiter and the first star to the west in order, there was an interval of 5'; this star was 4' off the other one more to the west. At that time I was doubtful whether or not there was a star between the star to the east and Jupiter, but so very close to Jupiter as almost to touch the planet; but at the fifth hour I saw this star distinctly,

by that time occupying exactly the middle position between Jupiter and the eastern star, so that the configuration was thus.

Moreover, the star which had just come into view was very small; yet at the sixth hour it was nearly as large as the rest.

Jan. 20 : 1 h. 15 m. A similar arrangement was seen. There were three stars,

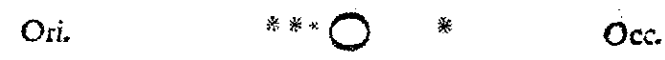
so small as scarcely to be distinguishable; their distances from Jupiter, and from one another, were not more than 1'. I was doubtful whether on the western side there were two stars or three. About the sixth hour they were grouped in this way. The eastern star was twice

as far away from Jupiter as before, that is 2'; on the western side, the star in the middle was distant from Jupiter 0' 40", and from the star still further to the west 0' 20"; at length, at the seventh hour, three stars were seen on the western side. The star nearest to Jupiter

was distant from the planet 0' 20"; between this one and the star furthest to the west there was an interval of 40". Between these I saw another slightly to the south,

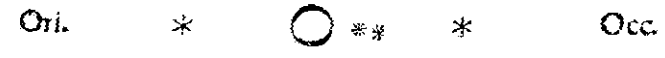
and no more than 10" distant from the most westerly star.

Jan. 21. 0 h. 30 m. There were three stars on the east side; the stars and Jupiter were at equal distances apart.



The intervals were by estimation 50" each. There was also one star on the west, distant 4' from Jupiter. The star on the east side nearest to Jupiter was the least of all.

Jan. 22 . 2 h. The grouping of the stars was similar.

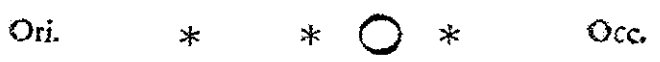


There was an interval of 5' from the star on the east to Jupiter; from Jupiter to the star farthest to the west 7'. The two interior stars on the western side were 0' 40" apart, and the star nearer to Jupiter was 1' from the planet. The inner stars were smaller than the outer ones, but they were situated all in the same straight line, along the ecliptic, except that the middle of the three western stars was slightly to the south of it, but at the sixth hour of the night they appeared in this position.

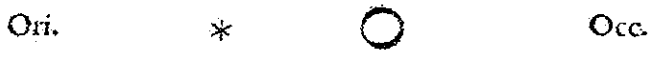
The star on the east was very small, at a distance from Jupiter of 5' as before; but the three stars on the west were separated by equal distances from Jupiter and from each other; and the intervals were nearly 1' 20" each.

The star nearest Jupiter appeared smaller than the other two on the same side, but they all appeared arranged exactly in the same straight line.

Jan. 23. At 0 h. 40 m. after sunset, the grouping of the stars was nearly after this fashion.

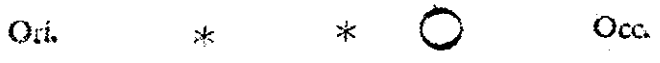


There were three stars with Jupiter in a straight line along the ecliptic, as they always have been; two were on the east of the planet, one on the west; the star furthest to the east was 7' from the next one, and this star 2' 40" from Jupiter; Jupiter was 3' 20" from the star on the west; and they were all of nearly the same size. But at the fifth hour the two stars which had been previously near Jupiter were no longer visible, being, as I suppose, hidden behind Jupiter, and the appearance presented was such as this.



Jan. 24. Three stars, all on the east side, were visible, and nearly, but not quite, in the same straight line

with Jupiter, for the star in the middle was slightly to the south of it. The star nearest to Jupiter was 2' distant from the planet; the next in order 0' 30" from this star, and the third was 9' further off still; they were all very bright. But at the sixth hour two



stars only presented themselves to view in this position, namely in the same straight line with Jupiter exactly, and the distance of the nearest to the planet was lengthened to 3'; the next was 2' further off, and unless I am mistaken, the two stars previously observed in the middle had come together, and appeared as one.

Jan. 25. At 1 h. 40 m., the stars were grouped thus.

There were only two stars on the east side, and these were rather large. The star farthest to the east was 5' from the star in the middle, and it was 6' from Jupiter.

Jan. 26. At 0 h. 40 m., the relative positions of the stars were thus.

Three stars were in view, of which two were east and the third west of Jupiter; this one was distant 3' from the planet. On the east side the star in the middle was at a distance of 5' 20"; the further star was 6' beyond; they were arranged in a straight line. and were of the same size. At the fifth hour the arrangement was nearly the same, with this difference only,

that the fourth star was emerging on the east side near Jupiter. It was smaller than the rest, and was then at a distance of 0' 30" from Jupiter; but was raised a little above the straight line towards the north, as the accompanying figure shows.

Jan. 27. 1 h. after sunset, a single

star only was in view, and that on the east

side in this position. It was very small, and at a distance of 7' from Jupiter.

Jan. 28 and 29. Owing to the intervention of clouds, I could make no observation.

Jan. 30. At the first hour of the night the stars were in view, arranged in the following way.

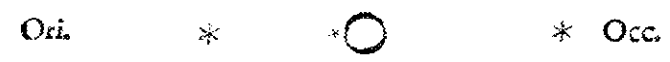
There was one star on the east side, at a distance of 2' 30" from Jupiter; and there were two stars on the west, of which the one nearer to Jupiter was 3' off the planet, and the other star 1' further. The places of the outer stars and Jupiter were in the same straight line; but the star in the middle was a little above it to the north. The star farthest to the west was smaller than the rest.

On the last day of the month, at the second hour, two stars on the east side were visible, and one on the west. Of the stars east of the planet, the one in the middle was

distant from Jupiter; and the star further to the east was 0' 30" from the middle star; the star on the west was at a distance of 10' from Jupiter. They were in the same straight line nearly, and would have been exactly so, only the star on the east nearest to Jupiter was raised a little towards the north. At the fourth hour, the two stars on the east

were still nearer together, for they were only 20' apart. The western star appeared rather small in these two observations.

Feb. 1. At the second hour of the night the arrangement was similar. The star farthest to the east from Jupiter



was at a distance of 6', and the western star 8'. On the east side there was a very small star, at a distance of 20' from Jupiter. They made a perfectly straight line.

Feb. 2. The stars were seen arranged thus. There was one only on the east, at a distance of 6'

from Jupiter. Jupiter was 4' from the nearest star on the west; between this star and the star further to the west there was an interval of 8'; they were in the same straight line exactly, and were nearly of the same magnitude. But at the seventh hour four stars were there

two on each side of Jupiter. Of these stars, the most easterly was at a distance of 4' from the next; this star was 1' 40" from Jupiter; Jupiter was 6' from the nearest star on the west, and this one from the star farther to the west, 8'; and they were all alike in the same straight line, drawn in the direction of the Zodiac.

Feb. 3. 7 h. The stars were arranged in the following way. The star on the east was at a distance of 1' 30" from Jupiter.

The nearest star on the west, 2', and there was a long distance,

10', from this star to the star further to the west. They were exactly in the same straight line, and of equal magnitude.

Feb. 4. 2 h. Four stars attended Jupiter, two on the east and two on the west,

arranged in one perfectly straight line, as in the adjoining figure. The star farthest to the east was at a distance of 3' from the next star. This one was 0' 40" from Jupiter; Jupiter 4' from the nearest star on the west; and this one from the star further to the west 6'. In magnitude they were nearly equal; the star nearest to Jupiter was rather smaller in appearance than the rest. But at the seventh hour the eastern stars were at a distance of only 0' 30" apart. Jupiter

was 2' from the nearest star on the east; and from the star on the west, next in order, 4'; this one was distant 3' from the star farther to the west. They were all equal in magnitude, and in a straight line, drawn in the direction of the ecliptic.

Feb. 5. The sky was cloudy.

Feb. 6. Two stars only appeared,

with Jupiter between them, as is seen in the accompanying figure. The star on the east was 2' from Jupiter, and that on the west 3'. They were in the same straight line with Jupiter, and were equal in magnitude.

Feb. 7. There were two stars side by side to the east of Jupiter,

arranged in this manner. The intervals between the stars and Jupiter were equal, and of 1' each; and a straight line would go through them and the center of Jupiter.

Feb. 8. 1 h. Three stars were there,

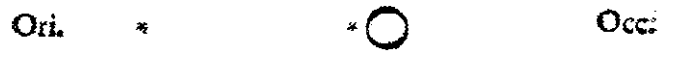
all on the east side of Jupiter, as in the diagram. The nearest to Jupiter, a rather small one, was distant from the planet 1' 20"; the middle one was 4' from this star, and was rather large; the star farthest to the east, a very small one, was at a distance of 0' 20" from this star. It was doubtful whether there was one star near to Jupiter or two, for sometimes it seemed that there was another star by its side towards the east, wonderfully small, and only 10" from it. They were all situated at points in a straight line drawn in the direction of the Zodiac. At the third hour the star nearest to Jupiter was almost touching the planet, for it was only distant 10" from it; but the others had become further off, for the middle one was 6' from Jupiter. At length, at the fourth hour, the star which was previously the nearest to Jupiter joined with the planet and disappeared.

Feb. 9. 0 h. 30 m. There were two stars next to Jupiter

on the east side, and one on the west, in an arrangement such as this.

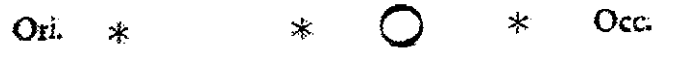
The star furthest to the east, which was a rather small one, was distant 4' from the next star; the star in the middle was larger, and at a distance of 7' from Jupiter. Jupiter was distant 4' from the western star, which was a small one.

Feb. 10. 1 h. 30 m. A pair of stars, very small, and both on the east of the planet, were visible, in the following position.

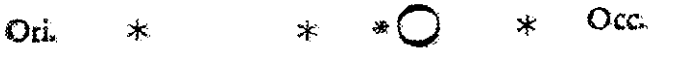


The farther star was distant from Jupiter 10', the nearer 0' 20", and they were in the same straight line; but at the fourth hour the star nearest to Jupiter no longer appeared, and the other seemed so diminished that it could scarcely be kept in sight, although the atmosphere was quite clear, and the star was farther from Jupiter than before, since its distance was now 12'.

Feb. 11. 1 h. There were two stars on the east, and one on the west. The western star was at a distance of

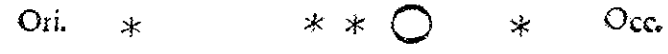


4' from Jupiter. The star on the east, nearest to the planet, was likewise 4' from Jupiter; but the star farther to the east was at a distance from this one of 8'; they were fairly clear to view, and in the same straight line; but at the third hour



the fourth star was visible near to Jupiter on the east,

less in magnitude than the rest, separated from Jupiter by a distance of 0' 30", and slightly to the north out of the straight line drawn through the rest. They were all very bright and extremely distinct, but at 5 h. 30 m. the star on the east nearest to Jupiter had moved farther away from the planet, and was occupying a position midway between the planet and the neighboring star farther to the east. They were all in the same straight line exactly, and of the same magnitude, as may be seen in the accompanying diagram.



Feb. 12. 0 h. 40 m. A pair of stars on the east, a pair likewise on the west, were near the planet. The star on the east furthest removed

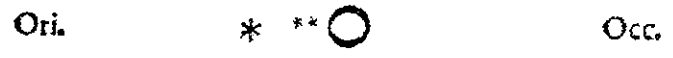
from Jupiter was at a distance of 10', and the farther of the stars on the west was 8' off. They were both fairly distinct. The other two were very near to Jupiter, and very small, especially the star to the east, which was at a distance of 0' 40" from Jupiter. The distance of the western star was 1'. But at the fourth hour the star which was nearest to Jupiter on the east was visible no longer.

Feb. 13: 0 h. 30 m. Two stars were visible in the east, two also in the west. The star on the east near Jupiter

was fairly distinct; its distance from the planet was 2'. The star further to the east was less noticeable; it was distant 4' from the other. Of the stars on

the west, the one furthest from Jupiter, which was very distinct, was parted from the planet 4'. Between this star and Jupiter intervened a small star close to the most westerly star, being not more than 0' 3" off. They were all in the same straight line, corresponding exactly to the direction of the ecliptic.

Feb. 15 (for on the 14th the sky was covered with clouds), at the first hour, the position of the stars was thus; that is, there were three stars on the east, but none



were visible on the west. The star on the east nearest to Jupiter was at a distance of 0' 50" from the planet; the next in order was 0' 20" from this star, and the furthest to the east was 2' from the second star, and it was larger than the others, for those nearer to Jupiter were very small. But about the fifth hour

only one of the stars which had been near to Jupiter was to be seen; its distance from Jupiter was 0' 30". The distance of the star furthest to the east from Jupiter had increased, for it was then 4'. But at the sixth hour, besides the two situated as just described on the east,

one star was visible towards the west, very small, at a distance of 2' from Jupiter.

Feb. 16. 6 h. Their places were arranged as follows; that is, the star on the east was 7' from Jupiter,

Jupiter 5' from the next star on the west, and this 3' from the remaining star still further to the west. They were all

of the same magnitude nearly, rather bright, and in the same straight line, corresponding accurately to the direction of the Zodiac.

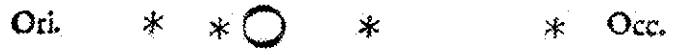
Feb. 17. 1 h. Two stars were in view, one on the east, distant 3' from Jupiter; the other on the west, distant 10'.

The latter was somewhat less than the star on the east; but at the sixth hour the eastern star was nearer to Jupiter, being at a distance of 0' 50", and the western star was further off, namely 12'. At both observations they were in the same straight line with Jupiter, and were both rather small, especially the eastern star in the second observation.

Feb. 18. 1 h. Three stars were in view, of which two were on the west and one on the east; the distance of the eastern star from Jupiter

was 3', and of the nearest star on the west 2'; the remaining star, still farther to the west, was 8' from the middle star. They were all in the same straight line exactly, and of about the same magnitude. But at the second hour the stars nearest to the planet were at equal distances from Jupiter, for the western star was now also 3' from the planet But at the sixth hour the fourth star was visible between the star on the east and Jupiter, in the following configuration. The star furthest to the east was at a distance of 3' from the next

in order; this one was at a distance of 1' 50" from Jupiter; Jupiter was at a distance of 3'



from the next star on the west, and this 7' from the star still further to the west. These were nearly equal in magnitude, only the star on the east nearest to Jupiter was a little smaller than the rest, and they were all in the same straight line parallel to the ecliptic.

Feb. 19. 0 h. 40 m. Two stars only were in view, west of Jupiter, rather large, and arranged exactly in the same straight line

with Jupiter, in the direction of the ecliptic. The nearer star was at a distance of 7' from Jupiter and of 6' from the star further to the west.

Feb. 20. The sky was cloudy.

Feb. 21. 1 h. 30 m. Three stars, rather small, were in view, placed thus. The star to the east was

2' from Jupiter; Jupiter was 3' from the next, which was on the west; and this one was 7' from the star farther to the west. They were exactly in the same straight line parallel to the ecliptic.

Feb. 25. 1 h. 30 m. (for on the three previous nights the sky was obscured by clouds). Three stars appeared,

two on the east, at an equal distance from each other and from Jupiter,

4' apart, the same as the distance of the nearer star from Jupiter; on the west there was one star at a distance of 2' from Jupiter. They were exactly in the same straight line in the direction of the ecliptic.

Feb. 26. 0 h. 30 m. A pair of stars only were present, one on the east, distant 10' from Jupiter; the other was on the west,

at a distance of 6'. The eastern star was slightly smaller than the western. At the fifth hour three stars were visible; for, besides the two

already noticed, a third star was in view, on the west, near Jupiter, very small, which previously had been hidden behind Jupiter, and it was at a distance of 1' from the planet. But the star on the east was seen to be farther off than before, being at a distance of 11' from Jupiter. On this night, for the first time, I determined to observe the motion of Jupiter and the adjacent planets (his stars) along the zodiac, by reference to some fixed star; for there was a fixed star in view, eastwards of Jupiter, at a distance of 11' from the star on the east, and a little to the south, in the following manner.

Feb. 27. 1 h. 4 m.The stars appeared in the following configuration. The star farthest to the east was at a distance of 10' from Jupiter; the next in order was near Jupiter, being at a distance of 0' 30" from the planet. The next star was on the western side,

at a distance of 2' 30" from Jupiter; and the star further to the west was at a distance of 1' from this.

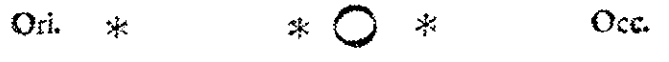
* fixa

The two stars near to Jupiter appeared small, especially the star on the east; but the stars farthest off were very bright, particularly that on the west, and they made a straight line in the direction of the ecliptic exactly. The motion of the planets towards the east was plainly seen by reference to the aforesaid fixed star, for Jupiter and his attendant stars were nearer to it, as may be seen in the accompanying figure. At the fifth hour the star on the east, near to Jupiter, was 1' from the planet.

Feb. 28. 1 h. Only two stars were visible, one on the east, at a distance of 9' from Jupiter, and another on the west, at a distance of 2'; they were

* fixa

both rather bright, and in the same straight line with Jupiter, and a straight line drawn from the fixed star perpendicular to this straight line fell upon the star on the east, as in the figure. At the fifth hour a third little star on the east



was seen at a distance of 2' from Jupiter in the position shown in the figure.

March 1. 0 h. 40 m. Four stars, all on the east

of the planet, were seen; the star nearest to Jupiter was 2' from the planet; the next 1' from this; the third was 0' 20" from the second, and was

* fixa

brighter than the others; and the star still further to the east was at a distance of 4' from it, and was smaller than the others. They made a straight line very nearly, only the star third from Jupiter was slightly above the line. The fixed star formed with Jupiter and the most easterly star an equilateral triangle, as in the figure.

March 2. 0 h. 40 m. Three planets were in attendance, two on the east and one on the west, in the configuration shown in the diagram.

* fixa

The star furthest to the east was 7' from Jupiter; from this star the next was distant 0' 30", and the star on the west was separated from Jupiter by an interval of 2'. The stars furthest off were brighter and larger than the remaining star, which appeared very small. The star furthest to the east seemed to be raised a little towards the north, out of the straight line drawn through the other stars and Jupiter. The fixed star already noticed was at a distance of 8' from the western star, that is, from the perpendicular drawn from that star to the straight line drawn through all the system, as shown in the figure given.

These determinations of the motion of Jupiter and the adjacent planets by reference to a fixed star,

I have thought well to present to the notice of astronomers, in order that anyone may be able to understand from them that the movements of these planets both in longitude and in latitude agree exactly with the motions [of Jupiter] which are extracted from tables.

These are my observations upon the four Medicean planets, recently discovered for the first time by me; and although it is not yet permitted to me to deduce by calculation from these observations the periods of these bodies, yet I may be allowed to make some statements, based upon them, well worthy of attention. In the first place, since they are sometimes behind, sometimes before Jupiter, at like distances, and withdraw from this planet towards the east and towards the west only within very narrow limits of divergence, and since they accompany this planet alike when its motion is retrograde and direct, it can be a matter of doubt to no one that they perform their revolutions about this planet, while at the same time they all move as one around the center of the world in twelve years. They revolve in unequal circles, which is evidently the conclusion to be drawn from the fact that I have never been permitted to see two planets in conjunction when their distance from Jupiter was great, whereas near Jupiter two, three, and sometimes all, have been found closely packed together. It follows from what is said above that the revolutions of the planets which describe the smallest circles round Jupiter are the most rapid, for the stars nearest to Jupiter are often to be seen in the east, when the day before they have appeared in the west, and contrariwise. Also the planet traversing the greatest orb seems to me, after carefully weighing the occasions of its returning to positions previously noticed, to have a periodic time of half a month. Besides, we have a notable and splendid argument to remove the scruples of those who can tolerate the revolution of the planets round the Sun in the Copernican system, yet are so disturbed by the motion of one Moon about the Earth, while both travel around the Sun in an orb over the course of a year, that they consider that this theory of the constitution of the universe must be upset as impossible; for now we have not one planet only revolving about another, while both traverse a vast orb about the Sun, but our sense of sight presents to us four stars circling about Jupiter, like the Moon about the Earth,

while all of them together with Jupiter traverse a great orb moving around the Sun in the space of twelve years. Lastly, I must not pass over the consideration of the reason why it happens that the Medicean stars, in performing very small revolutions about Jupiter, seem sometimes more than twice as large as at other times. We can by no means look for the explanation in the mists of the Earth's atmosphere, for they appear increased or diminished, while the discs of Jupiter and neighboring fixed stars are seen quite unaltered. That they approach and recede from the Earth at the points of their revolutions nearest to and furthest from the Earth to such an extent as to account for so great changes seems altogether untenable, for a strict circular motion can by no means show those phenomena; and an elliptical motion (which in this case would be nearly rectilinear) seems to be both untenable and by no means in harmony with the phenomena observed. But I gladly publish the explanation which has occurred to me upon this subject, and submit it to the judgment and criticism of all true philosophers. It is certain that when atmospheric mists intervene the Sun and Moon appear larger, but the fixed stars and planets less than they really are; hence the former luminaries, when near the horizon, are larger than at other times, but stars appear smaller, and are frequently scarcely visible; also they are still more diminished if those mists are bathed in light; so stars appear very small by day and in the twilight, but the Moon does not appear so, as I have previously remarked. Moreover, it is certain that not only the Earth, but also the Moon, has its own vaporous sphere enveloping it, for the reasons which I have previously mentioned, and especially for those which shall be stated more fully in my *System*, and we may consistently decide that the same is true with regard to the rest of the planets. So that it seems to be by no means an untenable opinion to place round Jupiter also an orb denser than the rest of the ether, about which the MEDICEAN planets revolve, like the Moon about the sphere of the elements. And that by the interposition of this orb they appear smaller when they are in apogee. But when in perigee, through the absence or attenuation of that orb, they appear larger. Lack of time prevents my going further into these matters; kind Reader, expect more on these subjects shortly.

F I N I S