ENGLISH TRANSLATION

Octavo®

Galileo Galilei

Sidereus Nuncius

Venice, 1610

➤ **English Translation**

This printable version of the translation of *Sidereus Nuncius* is arranged to match the 1610 edition page-for-page. The notes have been moved to the end of the document.

SIDEREAL MESSENGER
unfolding great and very wonderful sights
and displaying to the gaze of everyone,
but especially philosophers and astronomers,
the things that were observed by
GALILEO GALILEI,
Florentine patrician[1]
and public mathematician of the University of Padua,
with the help of a spyglass[2] lately devised[3] by him,
about the face of the Moon, countless fixed stars,
the Milky Way, nebulous stars,
but especially about
four planets
flying around the star of Jupiter at unequal intervals
and periods with wonderful swiftness;
which, unknown by anyone until this day,
the first author detected recently
and decided to name
MEDICEAN STARS[4]

MOST SERENE

COSIMO II DE' MEDICI

FOURTH GRAND DUKE OF TUSCANY[5]

A most excellent and kind service has been performed by those who defend from envy the great deeds of excellent men and have taken it upon themselves to preserve from oblivion and ruin names deserving of immortality. Because of this, images sculpted in marble or cast in bronze are passed down for the memory of posterity; because of this, statues, pedestrian as well as equestrian, are erected; because of this, too, the cost of columns and pyramids, as the poet says,[6] rises to the stars; and because of this, finally, cities are built distinguished by the names of those who grateful posterity thought should be commended to eternity. For such is the condition of the human mind that unless continuously struck by images of things rushing into it from the outside, all memories easily escape from it.

Others, however, looking to more permanent and long-lasting things, have entrusted the eternal celebration of the greatest men not to marbles and metals

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but rather to the care of the Muses and to incorruptible monuments of letters. But why do I mention these things as though human ingenuity, content with these [earthly] realms, has not dared to proceed beyond them? Indeed, looking far ahead, and knowing full well that all human monuments perish in the end through violence, weather, or old age, this human ingenuity contrived more incorruptible symbols against which voracious time and envious old age can lay no claim. And thus, moving to the heavens, it assigned to the familiar and eternal orbs of the most brilliant stars the names of those who, because of their illustrious and almost divine exploits, were judged worthy to enjoy with the stars an eternal life. As a result, the fame of Jupiter, Mars, Mercury, Hercules, and other heroes by whose names the stars are addressed will not be obscured before the splendor of the stars themselves is extinguished. This especially noble and admirable invention of human sagacity, however, has been out of use for many generations, with the pristine heroes occupying those bright places and keeping them as though by right. In vain Augustus' affection tried to place Julius Caesar in their number, for when he wished to name a star (one of those the Greeks call *Cometa* and we call hairy)[7] that had appeared in his time the Julian star, it mocked the hope of so much desire by disappearing shortly.[8] But now, Most Serene Prince, we are able to augur truer and more felicitous things for Your Highness, for scarcely have the immortal graces of your soul begun to shine forth on earth than bright stars offer themselves in the heavens which, like tongues, will speak of and celebrate your most excellent virtues for all time. Behold, therefore, four stars reserved for your illustrious name, and not of the common sort and multitude of the less notable fixed stars, but of the illustrious order of wandering stars, which, indeed, make their journeys and orbits with a marvelous speed around the star of Jupiter, the most noble of them all, with mutually different motions, like children of the same family, while meanwhile all together, in mutual harmony, complete their great revolutions every twelve years about the center of the world, that is, about the Sun itself.[9] Indeed, it appears that the Maker of the Stars himself, by clear arguments, admonished me to call these new planets by the illustrious name of Your Highness before all others. For as these stars, like the offspring worthy of Jupiter, never depart from his[10] side except for the smallest distance, so who does not know the clemency, the gentleness of spirit, the agreeableness of manners, the splendor of the royal blood, the majesty in actions, and the breadth of authority and rule over others, all of which qualities find a domicile and exaltation for themselves in Your Highness? Who, I say, does not know that all these emanate from the most benign star of Jupiter, after God the source of all good? It was Jupiter, I say, who at Your Highness' birth, having already passed through the murky vapors of the horizon, and occupying the midheaven[11] and illuminating the eastern angle[12] from his royal house, looked down upon Your most fortunate birth from that sublime throne and poured out all his splendor and grandeur into the most pure air, so that with its first breath Your tender little body and Your soul, already decorated by God with noble ornaments, could drink in this universal power and authority. But why do I use probable arguments when I can deduce and demonstrate it from all but necessary reason? It pleased Almighty God that I was deemed not unworthy by Your serene parents to undertake the task of instructing Your Highness in the mathematical disciplines, which task I fulfilled during the past four years, at that time of the year when it is the custom to rest from more severe studies. Therefore, since I was evidently influenced by divine inspiration to serve Your Highness and to receive from so close the rays of your incredible clemency and kindness, is it any wonder that my soul was so inflamed that day and night it reflected on almost nothing else than how I, most desirous of Your glory (since I am not only by desire but also by origin and nature under Your dominion), might show how very grateful I am toward You. And hence, since under Your auspices, Most Serene Cosimo, I discovered these stars unknown to all previous astronomers, I decided by the highest right to adorn them with the very august name of Your family. For since I first discovered them, who will deny me the right if I also assign them a name and call them the Medicean Stars,[13] hoping that perhaps as much honor will be added to these stars by this appellation as was brought to other stars by the other heroes? For, to be silent about Your Most Serene Highness' ancestors to whose eternal glory the monuments of all histories testify,[14] Your virtue alone, Great Hero, can, by Your name, impart immortality to these stars. Indeed, who can doubt that You will not only meet but also surpass by a great margin the highest expectation raised by the most happy beginning of Your reign, so that when You have surpassed Your peers You will still contend with Yourself, which self and greatness You are daily surpassing.

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Therefore, Most Merciful Prince, acknowledge this particular glory reserved for You by the stars and enjoy for a very long time these divine blessings carried down to You not so much from the stars as from the Maker and Ruler of Stars, God.

Written in Padua on the fourth day before the Ides of March,[15] 1610.

Your Highness' most loyal servant,

Galileo Galilei

The undersigned Gentlemen, Heads of the Council of Ten,[16] having received certification from the Reformers of the University of Padua,[17] by report from the Gentlemen deputized for this matter, that is, from the Most Reverend Father Inquisitor and from circumspect Secretary of the Senate, Giovanni Maraviglia, with an oath, that in the book entitled *Sidereus Nuncius* by Galileo Galilei there is nothing contrary to the Holy Catholic Faith, Principles, or good customs, and that it is worthy of being printed, allow it a license so that it can be printed in this city.

Written on the first day of March 1610.

M. Ant. Valaresso
Nicolo Bon
Lunardo Marcello
} Heads of the Council of Ten

The Secretary of the Most Illustrious Council of Ten
Bartholomaeus Cominus

1610, on March 8. Registered in the book on p. 39.

Ioan. Baptista Breatto
Coadjutor of the Congregation on Blasphemy

ASTRONOMICAL MESSAGE

Containing and Explaining Observations Recently Made,
With the Benefit of a New Spyglass, About the
Face of the Moon, the Milky Way, and Nebulous
Stars, about Innumerable Fixed Stars and also Four
Planets hitherto never seen, and named
COSMIC STARS

In this short treatise I propose great things for inspection and contemplation by every explorer of Nature. Great, I say, because of the excellence of the things themselves, because of their newness, unheard of through the ages, and also because of the instrument with the benefit of which they make themselves manifest to our sight.

Certainly it is a great thing to add to the countless multitude of fixed stars visible hitherto by natural means and expose to our eyes innumerable others never seen before, which exceed tenfold the number of old and known ones.[18]

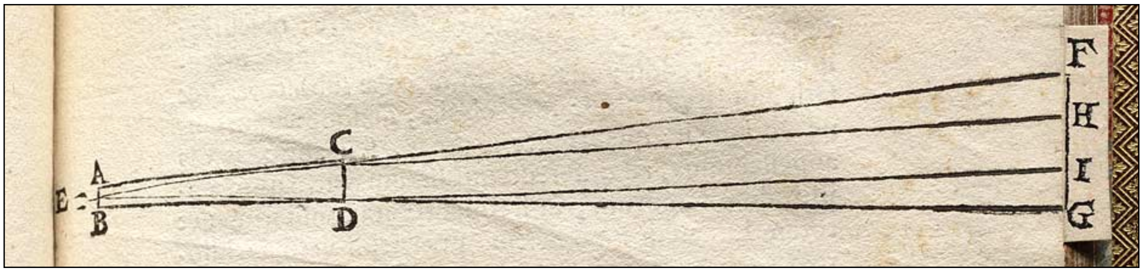
It is most beautiful and pleasing to the eye to look upon the lunar body, distant from us about sixty terrestrial diameters,[19] from so near as if it were distant by only two of these measures, so that the diameter of the same Moon appears as if it were thirty times, the surface 900 times, and the solid body about 27,000 times larger than when observed only with the naked eye.[20] Anyone will then understand with the certainty of the senses that the Moon is by no means endowed with a smooth and polished surface, but is rough and uneven and, just as the face of the Earth itself, crowded everywhere with vast prominences, deep chasms, and convolutions.

Moreover, it seems of no small importance to have put an end to the debate about the Galaxy or Milky Way and to have made manifest its essence to the senses as well as the intellect; and it will be pleasing and most glorious to demonstrate clearly that the substance of those stars called nebulous up to now by all astronomers is very different from what has hitherto been thought.

But what greatly exceeds all admiration, and what especially impelled us to give notice to all astronomers and philosophers, is this, that we have discovered four wandering stars, known or observed by no one before us. These, like Venus and Mercury around the Sun,[21] have their periods around a certain star[22] notable among the number of known ones, and now precede, now follow, him, never digressing from him beyond certain limits. All these things were discovered and observed a few days ago by means of a glass contrived by me after I had been inspired by divine grace.

Perhaps more excellent things will be discovered in time, either by me or by others, with the help of a similar instrument, the form and construction of which, and the occasion of whose invention, I shall first mention briefly, and then I shall review the history of the observations made by me.

About ten months ago a rumor came to our ears that a spyglass had been made by a certain Dutchman[23] by means of which visible objects, although far removed from the eye of the observer, were distinctly perceived as though nearby. About this truly wonderful effect some accounts were spread abroad, to which some gave credence while others denied them. The rumor was confirmed to me a few days later by a letter from Paris from the noble Frenchman Jacques Badovere. This finally caused me to apply myself totally to investigating the principles and figuring out the means by which I might arrive at the invention of a similar instrument, which I achieved shortly afterward on the basis of the science of refraction.[24] And first I prepared a lead tube in whose ends I fitted two glasses,[25] both plane on one side while the other side of one was spherically convex and of the other concave. Then, applying my eye to the concave glass, I saw objects satisfactorily large and close. Indeed, they appeared three times closer and nine times larger than when observed with natural vision only.[26] Afterward I made another more perfect one for myself that showed objects more than sixty times larger.[27] Finally, sparing no labor or expense, I progressed so far that I constructed for myself an instrument so excellent that things seen through it appear about a thousand times larger and more than thirty times closer than when observed with the natural faculty only. It would be entirely superfluous to enumerate how many and how great the advantages of this instrument are on land and at sea. But having dismissed earthly things, I applied myself to explorations of the heavens. And first I looked at the Moon from so close that it was scarcely two terrestrial diameters distant. Next, with incredible delight I frequently observed the stars, fixed as well as wandering,[28] and as I saw their huge number I began to think of, and at last discovered, a method whereby I could measure the distances between them. In this matter, it behooves all those who wish to make such observations to be forewarned. For it is necessary first that they prepare a most accurate glass that shows objects brightly, distinctly, and not veiled by any obscurity, and second that it multiply them at least four hundred times and show them twenty times closer. For if it is not an instrument such as that, one will try in vain to see all the things observed in the heavens by us and enumerated below. Indeed, in order that anyone may, with little trouble, make himself more certain about the magnification of the instrument, let him draw two circles or two squares on paper, one of which is 400 times larger than the other, which will be the case when the larger diameter is twenty times the length of the other diameter. He will then observe from afar both sheets fixed to the same wall, the smaller one with one eye applied to the glass and the larger one with the other, naked eye. This can easily be done with both eyes open at the same time. Both figures will then appear of the same size if the instrument multiplies objects according to the desired proportion. After such an instrument has been prepared, the method of measuring distances is to be investigated, which is achieved by the following procedure. For the sake of easy comprehension, let *ABCD* be the tube and *E* the eye of the observer. When there are no glasses in the tube, the rays proceed to the object *FG* along the straight lines *ECF* and *EDG*, but with the glasses put in they proceed along the refracted lines *ECH* and *EDI*. They are indeed squeezed together and where before, free, they were directed to the object *FG*, now they only grasp the part *HI*.



Then, having found the ratio of the distance *EH* to the line *HI*, the size of the angle subtended at the eye by the object *HI* is found from the table of sines, and we will find this angle to contain only some minutes, and if over the glass *CD* we fit plates perforated some with larger and some with smaller holes, putting now this plate and now that one over it as needed, we form at will angles subtending more or fewer minutes. By this means we can conveniently measure the spaces between stars separated from each other by several minutes with an error of less than 1 or 2 minutes.[29] Let it suffice for the present, however, to have touched on this so lightly and to have, so to speak, tasted it only with our lips, for on another occasion we shall publish a complete theory of this instrument.[30] Now let us review the observations made by us during the past two months, inviting all lovers of true philosophy to the start of truly great contemplation.

Let us speak first about the face of the Moon that is turned toward our sight, which, for the sake of easy understanding, I divide into two parts, namely a brighter one and a darker one. The brighter part appears to surround and pervade the entire hemisphere, but the darker part, like some cloud, stains its very face and renders it spotted. Indeed, these darkish and rather large spots are obvious to everyone, and every age has seen them. For this reason we shall call them the large or ancient spots, in contrast with other spots, smaller in size and occurring with such frequency that they besprinkle the entire lunar surface, but especially the brighter part. These were, in fact, observed by no one before us.[31] By oft-repeated observations of them we have been led to the conclusion that we certainly see the surface of the Moon to be not smooth, even, and perfectly spherical, as the great crowd of philosophers have believed about this and other heavenly bodies, but, on the contrary, to be uneven, rough, and crowded with depressions and bulges. And it is like the face of the Earth itself, which is marked here and there with chains of mountains and depths of valleys. The observations from which this is inferred are as follows.

On the fourth or fifth day after conjunction,[32] when the Moon displays herself to us with brilliant horns,[33] the boundary dividing the bright from the dark part does not form a uniformly oval line, as would happen in a perfectly spherical solid, but is marked by an uneven, rough, and very sinuous line, as the figure shows. For several, as it were, bright excrescences extend beyond the border between light and darkness into the dark part, and on the other hand little dark parts

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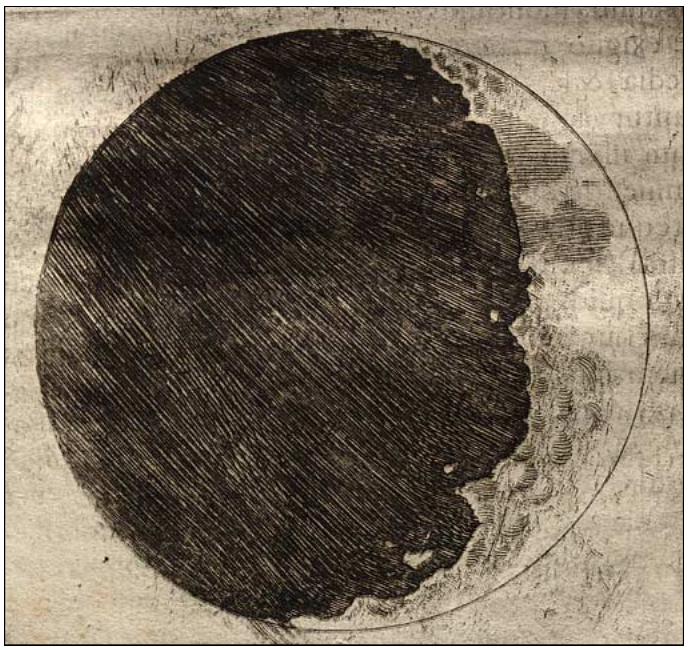
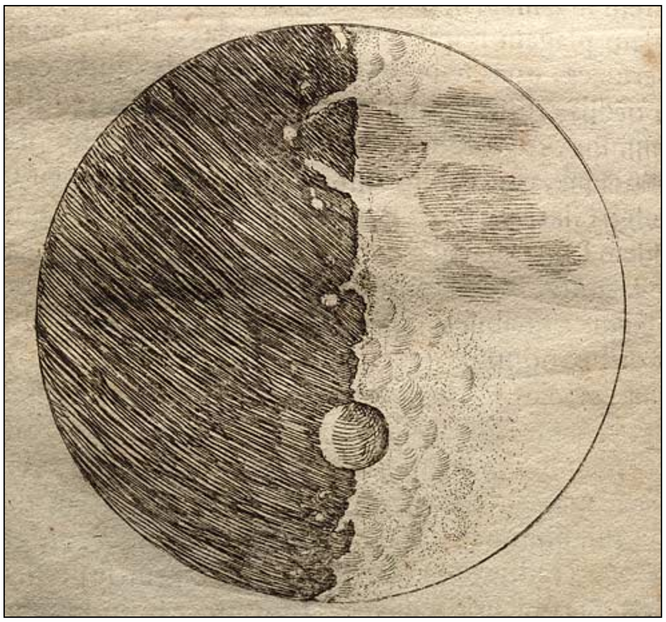
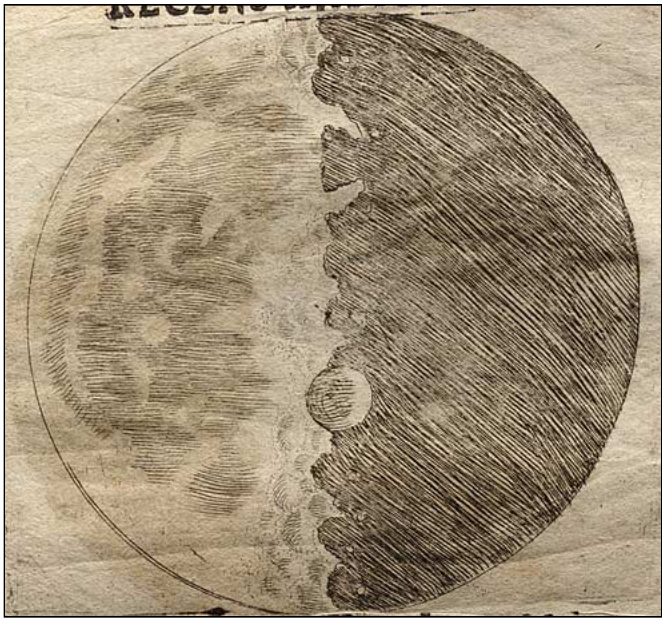
enter into the light. Indeed, a great number of small darkish spots, entirely separated from the dark part, are distributed everywhere over almost the entire region already bathed by the light of the Sun, except, at any rate, for that part affected by the large and ancient spots. We noticed, moreover, that all these small spots just mentioned always agree in this, that they have a dark part on the side toward the Sun while on the side opposite the Sun they are crowned with brighter borders like shining ridges. And we have an almost entirely similar sight on Earth, around sunrise, when the valleys are not yet bathed in light but the surrounding mountains facing the Sun are already seen shining with light. And just as the shadows of the earthly valleys are diminished as the Sun climbs higher, so those lunar spots lose their darkness as the luminous part grows.



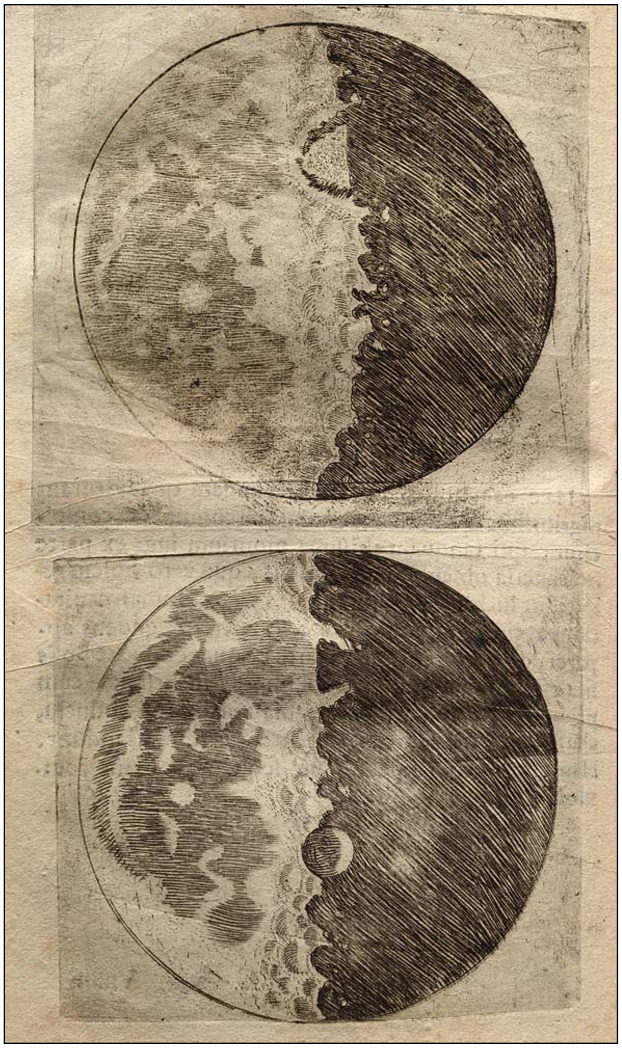
Not only are the boundaries between light and dark on the Moon perceived to be uneven and sinuous, but, what causes even greater wonder, is that very many bright points appear within the dark part of the Moon, entirely separated and removed from the illuminated region and located no small distance from it. Gradually, after a small period of time, these are increased in size and brightness. Indeed, after two or three hours they are joined with the rest of the bright part, which has now become larger. In the meantime, more and more bright points light up, as if they are sprouting, in the dark part, grow, and are connected at length with that bright surface as it extends farther in this direction. An example of this is shown in the same figure. Now, on Earth, before sunrise, aren't the peaks of the highest mountains illuminated by the Sun's rays while shadows still cover the plain? Doesn't light grow, after a little while, until the middle and larger parts of the same mountains are illuminated, and finally, when the Sun has risen, aren't the illuminations of plains and hills joined together? These differences between prominences and depressions in the Moon, however, seem to exceed the terrestrial roughness greatly, as we shall demonstrate below. Meanwhile, I would by no means be silent about something deserving notice, observed by me while the Moon was rushing toward first quadrature,[34] the appearance of which is also shown in the above figure. For toward the lower horn[35] a vast dark gulf projected into the bright part. As I observed this for a long time, I saw it very dark. Finally, after about two hours, a bit below the middle of this cavity a certain bright peak began to rise and, gradually growing, it assumed a triangular shape, still entirely removed and separated from the bright face. Presently three other small points began to shine around it until, as the Moon was about to set, this enlarged triangular shape, now made larger, joined together with the rest of the bright part, and like a huge promontory, surrounded by the three bright peaks already mentioned, it broke out into the dark gulf. Also, in the tips of both the upper and lower horns, some bright points emerged, entirely separated from the rest of the light, as shown in the same figure. And there was a great abundance of dark spots in both horns, especially in the lower one. Of these, those closer to the boundary between light and dark appeared larger and darker while those farther away appeared less dark and more diluted. But as we have mentioned above, the dark part of the spot always faces the direction of the Sun and the brighter border surrounds the dark spot on the side turned away from the Sun and facing the dark part of the Moon. This lunar surface, which is decorated with spots like the dark blue eyes in the tail of a peacock, is rendered similar to those small glass vessels which, plunged into cold water while still warm, crack and acquire a wavy surface, after which they are commonly called ice-glasses. The large [and ancient] spots of the Moon, however, when broken up in a similar manner, are not seen to be filled with depressions and prominences, but rather to be even and uniform, for they are only here and there sprinkled with some brighter little places. Thus, if anyone wanted to resuscitate the old opinion of the Pythagoreans that the Moon is, as it were, another Earth, its brighter part would represent the land surface while its darker part would more appropriately represent the water surface. Indeed, for me there has never been any doubt that when the terrestrial globe, bathed in sunlight, is observed from a distance, the land surface will present itself brighter to the view and the water surface darker.

Moreover, in the Moon the large spots are seen to be lower than the brighter areas, for in her waxing as well as waning, on the border between light and dark, there is always a prominence here or there around these large spots, next to the brighter part, as we have taken care to show in the figures; and the edges of the said spots are not only lower, but more uniform and not broken by creases or roughnesses. Indeed, the brighter part stands out very much near the ancient spots, so that both before the first and near the second quadrature some huge projections arise around a certain spot in the upper, northern part of the Moon, both above and below it, as the adjoining figures show.





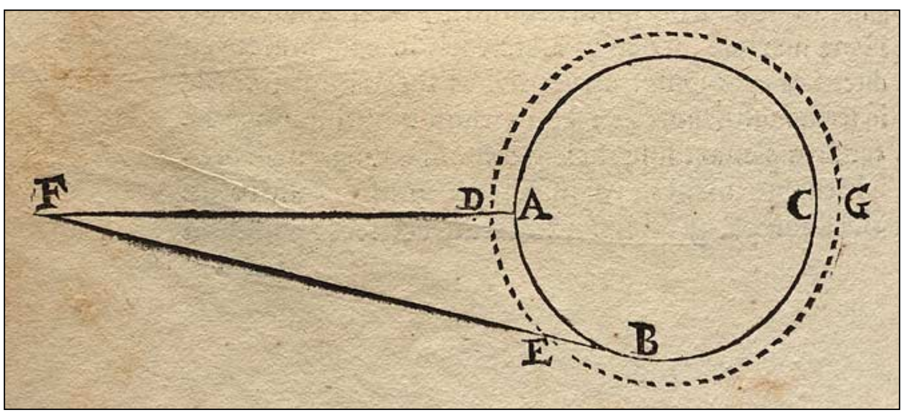
Before the second quadrature this same spot is seen walled around by some darker edges which, like a ridge of very high mountains turned away from the Sun, appear darker; and where they face the Sun they are brighter. The opposite of this occurs in valleys whose part away from the Sun appears brighter, while the part situated toward the Sun is dark and shady. Then, when the bright surface has decreased in size, as soon as almost this entire spot is covered in darkness, brighter ridges of mountains rise loftily out of the darkness. The following figures clearly demonstrate this double appearance.



There is another thing that I noticed not without some admiration and that I may not omit. The area around the middle of the Moon is occupied by a certain cavity larger than all others and of a perfectly round figure.[36] I observed this near both quadratures, and I have portrayed it as far as possible in the second figure above. It offers the same aspect to shadow and illumination as a region similar to Bohemia would offer on Earth, if it were enclosed on all sides by very high mountains, placed around the periphery in a perfect circle. For on the Moon it is surrounded by such lofty ranges that its side bordering on the dark part of the Moon is observed bathed in sunlight before the dividing line between light and shadow reaches the middle of the diameter of that circle. But in the manner of the other spots, its shaded part faces the Sun while its bright part is situated toward the dark part of the Moon, which, I advise for the third time, is to be esteemed as a very strong argument for the roughnesses and unevennesses scattered over the entire brighter region of the Moon. Its darker spots are always those that border on the boundary between light and dark, while the farther ones appear both smaller and less dark, so that finally, when the Moon is at opposition and full, the darkness of the depressions differs from the brightness of the prominences by a modest and quite small degree.

These things we have reviewed are observed in the brighter regions of the Moon. In the large spots, however, such a difference between depressions and prominences is not seen to be the same, as we are driven to conclude by necessity in the brighter part on account of the change of shapes caused by the changing illumination of the Sun's rays as it regards the Moon from many different positions. In the large spots there are some darkish areas, as we have shown in the figures, but yet those always have the same appearance, and their darkness is not increased or abated. Rather, they appear, with a very slight difference, now a little darker, now a little lighter, as the Sun's rays fall on them more or less obliquely. Moreover, they join with nearby parts of the spots in a gentle bond, their boundaries mingling and running together. Things happen differently, however, in the spots occupying the brighter part of the Moon, for like sheer cliffs sprinkled with rough and jagged rocks, these are divided by a line which sharply separates shadow from light. Moreover, in those larger spots certain other brighter areas—indeed, some very bright ones—are seen. But the appearance of these and the darker ones is always the same, with no change in shape, light, or shadow. It is thus known for certain and beyond doubt that they appear this way because of a real dissimilarity of parts and not merely because of inequalities in the shapes of their parts and shadows moving diversely because of the varying illumination by the Sun. This does happen beautifully in the other, smaller, spots occupying the brighter part of the Moon; day by day these are altered, increased, diminished, and destroyed, since they only derive from the shadows of rising prominences.

But I sense that many people are affected by great doubt in this matter and are so occupied by the grave difficulty that they are driven to call into doubt the conclusion already explained and confirmed by so many appearances. For if that part of the Moon's surface which more brilliantly reflects the solar rays is filled with innumerable contortions, that is, elevations and depressions, why is it that in the waxing Moon the limb facing west, in the waning Moon the eastern limb, and in the full Moon the entire periphery are seen not uneven, rough, and sinuous, but exactly round and circular, and not jagged with prominences and depressions? And especially because the entire edge consists of the brighter lunar substance which, we have said, is entirely bumpy and covered with depressions, for none of the large [ancient] spots reach the very edge, but all are seen to be clustered far from the periphery. Since these appearances present an opportunity for such serious doubt, I shall put forward a double cause for them and therefore a double explanation of the doubt. First, if the prominences and depressions in the lunar body were spread only along the single circular periphery outlining the hemisphere seen by us, then the Moon could indeed, nay it would have to, show itself to us in the shape of, as it were, a toothed wheel, that is, bumpy and bounded by a sinuous outline. If, however, there were not just one chain of prominences distributed only along a single circumference, but rather very many rows of mountains with their clefts and sinuosities were arranged about the outer circuit of the Moon—and these not only in the visible hemisphere but also in the one turned away from us (yet near the boundary between the hemispheres)—then the eye, observing from afar, could by no means perceive the distinction between the prominences and depressions. For the interruptions in the mountains arranged in the same circle or the same chain are hidden by the interposition of row upon row of other prominences, and especially if the eye of the observer is located on the same line with the peaks of those prominences. Thus on Earth the ridges of many mountains close together appear to be arranged in a flat surface if the observer is far away and situated at the same altitude. So [also] in a billowy sea the high tips of the waves appear stretched out in the same plane, even though between the waves there are very many troughs and gulfs so deep that not only the keels but also the upper decks, masts, and sails of tall ships are hidden. Since, therefore, in the Moon itself and around its perimeter there is a complex arrangement of prominences and depressions, and the eye, observing from afar, is located in about the same plane as their peaks, it should be surprising to no one that, with the visual rays skimming them, they show themselves in an even and not at all wavy line.[37] To this reason another can be added, namely, that, just as around the Earth, there is around the lunar body a certain orb of denser substance than the rest of the ether, able to receive and reflect a ray of the Sun, although not endowed with so much opacity that it can inhibit the passage of vision (especially when it is not illuminated). That orb, illuminated by the solar rays, renders and represents the lunar body in the figure of a larger sphere, and, if it were thicker, it could limit our sight so as not to reach the actual body of the Moon. And it is indeed thicker around the periphery of the Moon; not absolutely thicker I say, but thicker as presented to our [visual] rays that intersect it obliquely. Therefore it can inhibit our vision and, especially when it is luminous, hide the periphery of the Moon exposed to the Sun. This is seen clearly in the adjoining figure, in which the lunar body *ABC*



is surrounded by the vaporous orb *DEG.* The eye at *F* reaches the middle parts of the Moon, as at *A*, through the shallower vapors *DA*, and toward its extreme parts an abundance of deeper vapors, *EB*, blocks our sight from its boundary. An indication of this is that the part of the Moon bathed in light appears greater in circumference than the remaining dark orb. And someone will perhaps find this cause reasonable to explain why the larger spots of the Moon are nowhere seen to extend to the outer edge, although it is to be expected that some of them would also be found near it. It seems plausible, then, that they are inconspicuous because they are hidden under thicker and brighter vapors.[38]

From the appearances already explained, I think it is sufficiently clear that the brighter surface of the Moon is sprinkled all over with prominences and depressions. It remains for us to speak of their magnitudes, demonstrating that the terrestrial roughnesses are far smaller than the lunar ones. I say smaller, speaking absolutely, not merely in proportion to the sizes of their globes. This is clearly shown in the following manner.

As has often been observed by me, with the Moon in various aspects to the Sun, some peaks within the dark part of the Moon appear drenched in light, although very far from the boundary line of the light. Comparing their distance from that boundary line to the entire lunar diameter, I found that this interval sometimes exceeds the twentieth part of the diameter. Assuming this, imagine the lunar globe, whose great circle is *CAF*, whose center is *E*, and whose diameter is *CF*, which is to the Earth's diameter as 2 to 7. And since according to the most exact observations the terrestrial diameter contains 7,000 Italian miles,[39] *CF* will be 2,000 miles, *CE*

1,000, and the twentieth part of the whole of *CF* will be 100 miles. Now let *CF* be the diameter of the great circle

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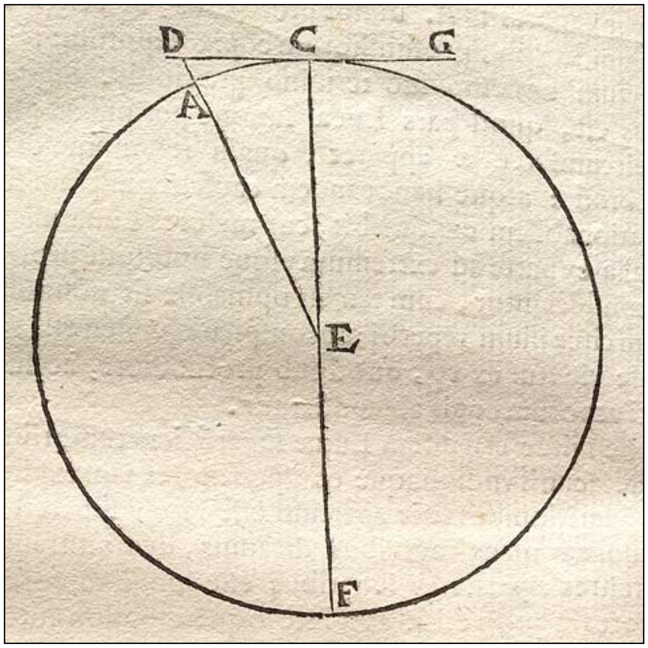

dividing the luminous from the dark part of the Moon (because of the very great distance of the Sun from the Moon this circle does not differ sensibly from a great circle), and let *A* be distant from point *C* one-twentieth part of it. Draw the semidiameter *EA*, which, when extended, intersects the tangent *GCD* (which represents a ray of light) at *D*. The arc *CA* or the straight line *CD* will therefore be 100 parts of the 1,000 represented by *CE*, and the sum of the squares of *CD* and *CE* is 1,010,000, which is equal to the square of *ED*. The whole of *ED* will therefore be more than 1,004,[40] and *AD* more than 4 parts of the 1,000 represented by *CE*. Therefore the height *AD* on the Moon, which represents some peak reaching all the way up to the Sun's rays *GCD* and removed from the boundary line *C* by the distance *CD*, is higher than 4 Italian miles.[41] But on Earth no mountains exist that reach even to a perpendicular height of 1 mile.[42] It is evidence, therefore, that the lunar prominences are loftier than the terrestrial ones.

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In this place I wish to explain the cause of another lunar phenomenon worthy of notice. This phenomenon was observed by us not recently but rather many years ago, shown to some close friends and pupils, explained, and given a causal demonstration. But since the observation of it is made easier and more noticeable with the aid of the glasses, I thought it not unsuitable to be repeated here, and especially so that the relationship and similarity between the Moon and Earth may appear more clearly.

When, both before and after conjunction,[43] the Moon is found not far from the Sun, she offers to our sight not only that part of her globe that is adorned with shining horns, but also a certain thin, faint periphery that is seen to outline the circle of the dark part (that is, the part turned away from the Sun) and to separate it from the darker field of the ether itself. But if we examine the matter more closely, we will see not only the extreme edge of the dark part shining with a faint brightness, but the entire face of the Moon—that part, namely, that does not yet feel the brightness of the Sun—made white by some not inconsiderable light.[44] At first glance, however, only a slender shining circumference appears on account of the darker parts of the sky bordering it, while, on the contrary, the rest of the surface appears darker because the nearness of the shining horns makes our sight dark. But if one chooses a place for oneself so that those bright horns are concealed by a roof or a chimney or another obstacle between one's sight and the Moon (but positioned far away from the eye), the remaining part

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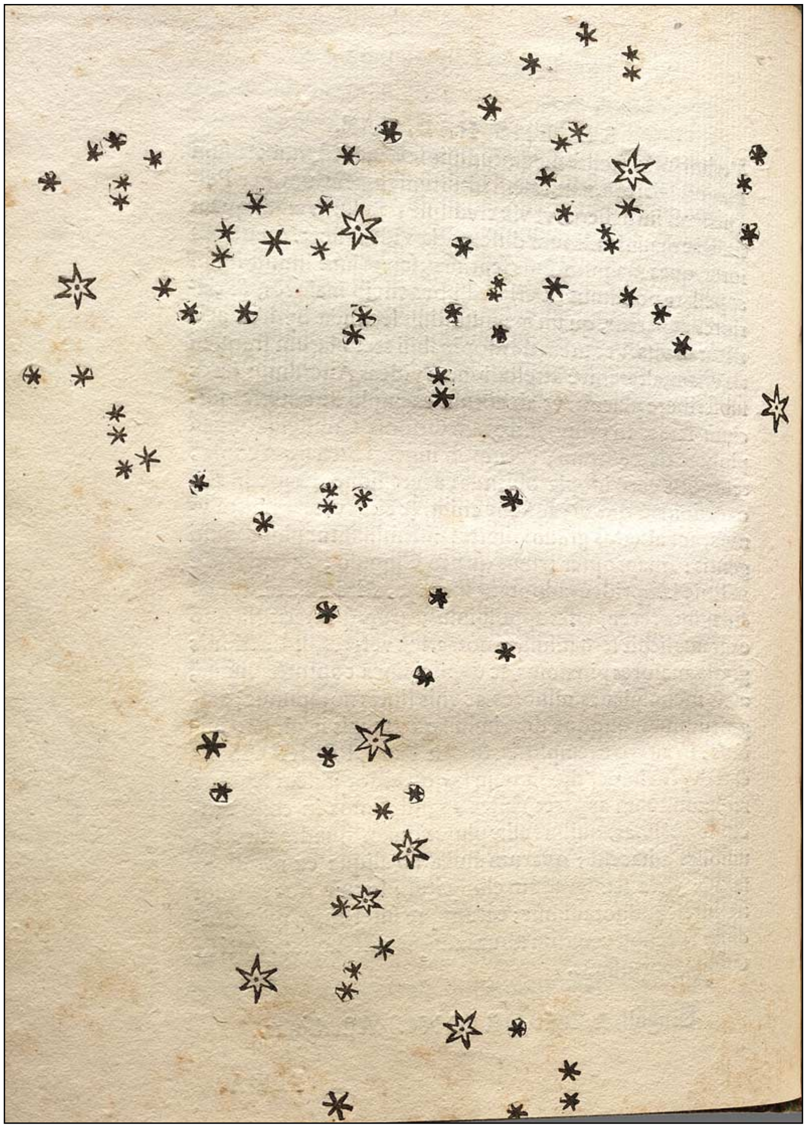
of the lunar globe is left exposed to one's view, and then one will discover that this region of the Moon, although deprived of sunlight, also shines with a considerable light, and especially when the chill of the night has already increased through the absence of the Sun. For in a darker field the same light appears brighter. It is moreover ascertained that this secondary brightness (as I call it) of the Moon is greater the less distant the Moon is from the Sun, for as she becomes more distant from him it is decreased more and more so that after the first quadrature and before the second it is found weak and very doubtful, even though it is seen in a darker sky, while at the sextile[45] and smaller elongations it shines in a wonderful way although in the twilight. Indeed, it shines so much that with the aid of a precise glass the large spots can be distinguished in her. This marvelous brightness has caused no small astonishment to those applying themselves to philosophy, and some have put forward one reason and some another as the cause to be assigned to it. Some have said that it is the intrinsic and natural brightness of the Moon herself;[46] others that it is imparted to it by Venus, or by all the stars;[47] and yet others have said that it is imparted by the Sun who penetrates the Moon's vast mass with his rays.[48] But such inventions are refuted with little difficulty and demonstrated to be false. For if this kind of light were either the Moon's own or gathered from the stars, she would retain it and show it especially during eclipses when she is placed in a very dark sky. This is not borne out by experience, however, for the light that appears in the Moon during an eclipse is much weaker, somewhat reddish, and almost coppery,[49] while this light is brighter and whiter. The light that appears during an eclipse is, moreover, changeable and movable, for it wanders across the lunar face so that the part closer to the edge of the circle of the Earth's shadow is always seen brighter while the rest is darker. From this we understand with complete certainty that this light comes about because of the proximity of the solar rays falling upon some denser region which surrounds the Moon on all sides. Because of this contact a certain dawn light is spread over nearby areas of the Moon, just as on Earth twilight is spread in the morning and evening. We will treat this matter at greater length in a book on the system of the world.[50] To declare, on the other hand, that this light is imparted by Venus is so childish as to be unworthy of an answer. For who is so ignorant as not to know that near conjunction and within the sextile aspect it is entirely impossible for the part of the Moon turned away from the Sun to be seen from Venus? But it is equally inconceivable that this light is due to the Sun, who with his light penetrates and fills the solid body of the Moon. For it would never be diminished, since a hemisphere of the Moon is always illuminated by the Sun except at the moment of a lunar eclipse. Yet the light is diminished when the Moon hastens toward quadrature and is entirely dimmed when she has gone beyond quadrature. Since, therefore, this secondary light is not intrinsic and proper to the Moon, and is borrowed neither from any star nor from the Sun, and since in the vastness of the world no other body therefore remains except the Earth, I ask what are we to think? What are we to propose—that the lunar body or some other dark and gloomy body is bathed by light from the Earth? But what is so surprising about that? In an equal and grateful exchange the Earth pays back the Moon with light equal to that which she receives from the Moon almost all the time in the deepest darkness of the night. Let us demonstrate the matter more clearly. At conjunction, when she occupies a place between the Sun and the Earth, the Moon is flooded by solar rays on her upper hemisphere that is turned away from the Earth. But the lower hemisphere turned toward the Earth is covered in darkness, and therefore it in no way illuminates the terrestrial surface. As the Moon gradually recedes from the Sun, some part of the inferior hemisphere turned toward us is soon illuminated and she turns somewhat white but thin horns toward us and lightly illuminates the Earth.

The illumination of the Sun grows on the Moon as she approaches quadrature, and on Earth the reflection of her light increases. The brightness of the Moon is extended further, beyond a semicircle, and lights up our clear nights. Finally, the entire face of the Moon that regards the Earth is illuminated with a very bright light from the opposed Sun, and the Earth's surface shines far and wide, perfused by lunar splendor. Afterward, when the Moon is waning, she emits weaker rays toward us, and the Earth is weakly illuminated; and as the Moon hastens toward conjunction, dark night comes over the Earth. In this sequence, then, in alternate succession, the lunar light bestows upon us her monthly illuminations, now brighter, now weaker. But the favor is repaid by the Earth in like manner, for when the Moon is found near the Sun around conjunction, she faces the entire surface of the hemisphere of the Earth exposed to the Sun and illuminated by vigorous rays, and receives reflected light from her. And therefore, because of this reflection, the inferior hemisphere of the Moon, although destitute of solar light, appears of considerable brightness. When the Moon is removed from the Sun by a quadrant, she only sees the illuminated half of the terrestrial hemisphere, that is, the western one, for the other, the eastern half, is darkened by night. The Moon is therefore less brightly illuminated by the Earth, and her secondary light accordingly appears more feeble to us. For if you place the Moon at opposition to the Sun, she will face the hemisphere of the interposed Earth that is entirely dark and steeped in the shadow of night. If therefore, such an opposition were an eclipse, the Moon would receive absolutely no illumination, being deprived alike of solar and terrestrial radiation. In its various aspects to the Sun and Earth, the Moon receives more or less light by reflection from the Earth as she faces a larger or smaller part of the illuminated terrestrial hemisphere. For the relative positions of those two globes are always such that at those times when the Earth is most illuminated by the Moon the Moon is least illuminated by the Earth, and vice versa. Let these few things said here about this matter suffice. We will say more in our *System of the World*, where with very many arguments and experiments a very strong reflection of solar light from the Earth is demonstrated to those who claim that the Earth is to be excluded from the dance of the stars, especially because she is devoid of motion and light. For we will demonstrate that she is movable and surpasses the Moon in brightness, and that she is not the dump heap of the filth and dregs of the universe, and we will confirm this with innumerable arguments from nature. [51]

Up to this point we have discussed the observations made of the lunar body. We will now report briefly on what has been observed by us thus far concerning the fixed stars. And first, it is worthy of notice that when they are observed by means of the spyglass, stars, fixed as well as wandering, are seen not to be magnified in size in the same proportion in which other objects, and also the Moon herself, are increased.[52] In the stars,[53] the increase appears much smaller so that you may believe that a glass capable of multiplying other objects, for example, by a ratio of 100 hardly multiplies stars by a ratio of 4 or 5. The reason for this is that when the stars are observed with the naked eye, they do not show themselves according to their simple and, so to speak, naked size, but rather surrounded by a certain brightness and crowned by twinkling rays, especially as the night advances. Because of this they appear much larger than if they were stripped of these extraneous rays, for the visual angle is determined not by the primary body of the star but by the widely surrounding brilliance. You will perhaps understand this more clearly from this: that stars emerging in the first twilight at sunset, even if they are of the first magnitude, appear very small, and Venus herself, when she presents herself to our view in broad daylight,[54] is perceived so small that she hardly appears to equal a little star of the sixth magnitude. Things are different for other objects and the Moon herself, which, whether she is observed at midday or in the deepest darkness, appears always of the same size to us. Stars are therefore seen unshorn in the midst of darkness, but daylight can shear them of their hair—and not only daylight but also a thin little cloud that is interposed between the star and the eye of the observer. The same effect is also achieved by dark veils and colored glasses, by the opposition and interposition of which the surrounding brightness will desert the stars. The spyglass likewise does the same thing: for first it takes away the borrowed and accidental brightness from the stars and thereupon it enlarges their simple globes (if indeed their figures are globular), and therefore they appear increased by a much smaller ratio, for stars of the fifth or sixth magnitude seen through the spyglass are shown as of the first magnitude.

The difference between the appearance of planets and fixed stars also seems worthy of notice. For the planets present entirely smooth and exactly circular globes that appear as little moons, entirely covered with light, while the fixed stars are not seen bounded by circular outlines but rather as pulsating all around with certain bright rays.[55] With the glass they appear in the same shape as when they are observed with natural vision, but so much larger that a little star of the fifth or sixth magnitude appears to equal the Dog Star,[56] which is the largest of all fixed stars.

Indeed, with the glass you will detect below stars of the sixth magnitude such a crowd of others that escape natural sight that it is hardly believable. For you may see more than six further gradations of magnitude. The largest of these, which we may designate as of the seventh magnitude, or the first magnitude of the invisible ones, appear larger and brighter with the help of the glass than stars of the second magnitude seen with natural vision.[57] But in order that you may see one or two illustrations of the almost inconceivable crowd of them, and from their example form a judgment about the rest of them, I decided to reproduce two star groups. In the first I had decided to depict the entire constellation of Orion, but overwhelmed by the enormous multitude of stars and a lack of time, I put off this assault until another occasion.[58] For there are more than five hundred new stars around the old ones, spread over a space of 1 or 2 degrees. For this reason, to the three in Orion's belt and the six in his sword[59] that were observed long ago, I have added eighty others seen recently, and I have retained their separations as accurately as possible. For the sake of distinction, we have depicted the known or ancient ones larger and outlined by double lines, and the other inconspicuous ones smaller and outlined by single lines. We have also preserved the distinction in size as much as possible. In the second example we have depicted the six stars of the Bull[60] called the Pleiades (I say six since the seventh almost never appears)[61] contained within very narrow limits in the heavens. Near these lie more than forty other invisible stars, none of which is farther removed from the aforementioned six than scarcely half a degree. We have marked down only thirty-six of these, preserving their mutual distances, sizes, and the distinction between old and new ones, as in the case of Orion.



[Asterism of the belt and sword of Orion.]

[Constellation of the Pleiades.]

What was observed by us in the third place is the nature or matter of the Milky Way itself, which, with the aid of the spyglass, may be observed so well that all the disputes that for so many generations have vexed philosophers are destroyed by visible certainty, and we are liberated from wordy arguments.[62] For the Galaxy is nothing else than a congeries of innumerable stars distributed in clusters. To whatever region of it you direct your spyglass, an immense number of stars immediately offer themselves to view, of which very many appear rather large and very conspicuous but the multitude of small ones is truly unfathomable.

And since that milky luster, like whitish clouds, is seen not only in the Milky Way, but dispersed through the ether, many similarly colored patches shine weakly; if you direct a glass to any of them, you will meet with a dense crowd of stars.

Moreover—and what is even more remarkable—the stars that have been called "nebulous" by every single astronomer up to this day are swarms of small stars placed exceedingly closely together.[63] While each individual one escapes our sight because of its smallness or its very great distance from us, from the commingling of their rays arises that brightness ascribed up to now to a denser part of the heavens capable of reflecting the rays of the stars or Sun.[64] We have observed some of these, and we wanted to reproduce the asterisms of two of them.

In the first there is the nebula called Orion's Head, in which we have counted twenty-one stars.[65]

The second figure contains the nebula called Praesepe, which is not a single star but a mass of more than forty little stars. In addition to the ass-colts we have marked down thirty-six stars, arranged as follows:[66]

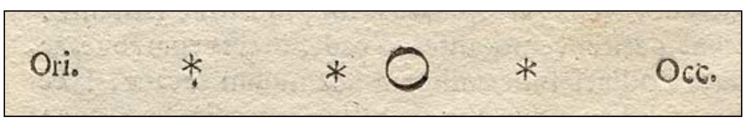
Nebula of Orion.

Nebula of Praesepe.

We have briefly explained our observations thus far about the Moon, the fixed stars, and the Milky Way. It remains for us to reveal and make known what appears to be most important in the present matter: four planets never seen from the beginning of the world right up to our day, the occasion of their discovery and observation, their positions, and the observations made over the past two months[67] concerning their behavior and changes. And I call on all astronomers to devote themselves to investigating and determining their periods. Because of the shortness of time, it has not been possible for us to achieve this so far.[68] We advise them again, however, that they will need a very accurate glass like the one we have described at the beginning of this account, lest they undertake such an investigation in vain.[69]

Accordingly, on the seventh day of January of the present year 1610,[70] at the first hour of the night, when I inspected the celestial constellations through a spyglass, Jupiter presented himself. And since I had prepared for myself a superlative instrument, I saw (which earlier had not happened because of the weakness of the other instruments) that three little stars were positioned near him—small but yet very bright. Although I believed them to be among the number of fixed stars, they nevertheless intrigued me because they appeared to be arranged exactly along a straight line and parallel to the ecliptic, and to be brighter than others of equal size. And their disposition among themselves and with respect to Jupiter was as follows:[71]

East



West

That is, two stars were near him on the east and one on the west; the more eastern one and the western one appeared a bit larger than the remaining one. I was not in the least concerned with their distances from Jupiter, for, as we said above, at first I believed them to be fixed stars. But when, on the eighth, I returned to the same observation, guided by I know not what fate, I found a very different arrangement. For all three little stars were to the west of Jupiter and closer to each other than the previous night, and separated by equal intervals, as shown in the adjoining sketch.[72] Even though at this point I had by no means turned my thought to the mutual motions of these stars,

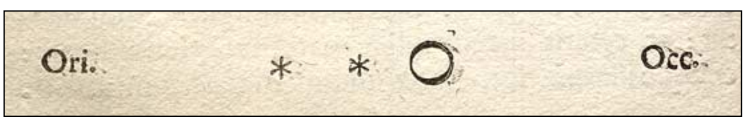
East

West

yet I was aroused by the question of how Jupiter could be to the east of all the said fixed stars when the day before he had been to the west of two of them. I was afraid, therefore, that perhaps, contrary to the astronomical computations, his motion was direct and that, by his proper motion, he had bypassed those stars. For this reason I waited eagerly for the next night. But I was disappointed in my hope, for the sky was everywhere covered with clouds.

Then, on the tenth, the stars appeared in this position with regard to Jupiter. Only two stars were near him, both to the east.

East



West

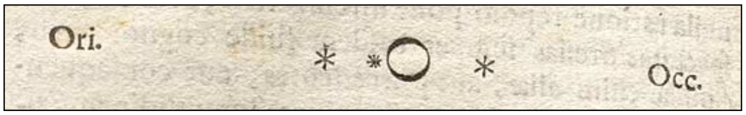
The third, as I thought, was hidden behind Jupiter.[73] As before, they were in the same straight line with Jupiter and exactly aligned along the zodiac. When I saw this, and since I knew that such changes could in no way be assigned to Jupiter, and since I knew, moreover, that the observed stars were always the same ones (for no others, either preceding or following Jupiter, were present along the zodiac for a great distance), now, moving from doubt to astonishment, I found that the observed change was not in Jupiter but in the said stars. And therefore I decided that henceforth they should be observed more accurately and diligently.

And so, on the eleventh, I saw the following arrangement:

East  West

There were only two stars on the east,[74] of which the middle one was three times as far from Jupiter than from the more eastern one, and the more eastern one was about twice as large as the other, although the previous night they had appeared about equal. I therefore arrived at the conclusion, entirely beyond doubt, that in the heavens there are three stars wandering around Jupiter like Venus and Mercury around the Sun. This was at length seen clear as day in many subsequent observations, and also that there are not only three, but four wandering stars making their revolutions about Jupiter. The following is an account of the changes in their positions, accurately determined from then on. I also measured the distances between them with the glass, by the procedure explained above. I have added the times of the observations, especially when more than one were made on the same night, for the revolutions of these planets are so swift that the hourly differences can often be perceived as well.

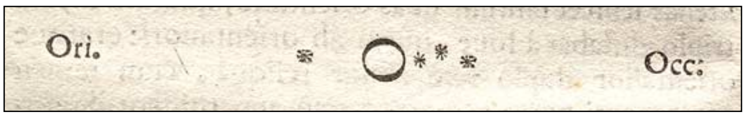
Thus, on the twelfth, at the first hour of the following night, I saw the stars arranged in this manner. The more eastern

East


West

star was larger than the western one, but both were very conspicuous and bright.[75] Both were 2 minutes[76] distant from Jupiter. In the third hour a third little star, not at all seen earlier, also began to appear. This almost touched Jupiter on the eastern side and was very small. All were in the same straight line and aligned along the ecliptic.

On the thirteenth, for the first time four little stars were seen by me in this formation with respect to Jupiter.[77] Three were on the west and one on the east. They formed a very nearly straight line,

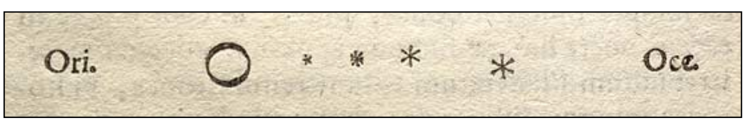
East


West

but the middle star of the western ones was displaced a little to the north from the straight line. The more eastern one was 2 minutes distant from Jupiter; the intervals between the remaining ones and Jupiter were only 1 minute. All these stars displayed the same size, and although small they were nevertheless very brilliant and much brighter than fixed stars of the same size.

On the fourteenth, the weather was cloudy.

On the fifteenth, in the third hour of the night, the four stars were positioned with respect to Jupiter as shown in the next figure.

East


West

They were all to the west and arranged very nearly in a straight line, except that the third one from Jupiter was raised a little bit to the north. The closest one to Jupiter was the smallest of all, and the rest consequently appeared larger. The intervals between Jupiter and the next three stars were all equal and of 2 minutes; and the most eastern one was 4 minutes from the closest one to it. They were very brilliant and did not twinkle, as indeed was always the case, both before and afterward. But in the seventh hour only three stars were present in this arrangement

East  West

with Jupiter. They were indeed precisely[78] in the same straight line. The closest one to Jupiter was very small and removed from him by 3 minutes; the second was 1 minute distant from this one; and the third from the second 4 minutes and 30 seconds. After another hour, however, the two little stars in the middle were still closer to each other, for they were removed from each other by barely 30 seconds.

On the sixteenth, in the first hour of the night, we saw three stars arranged in this order. Two flanked Jupiter,

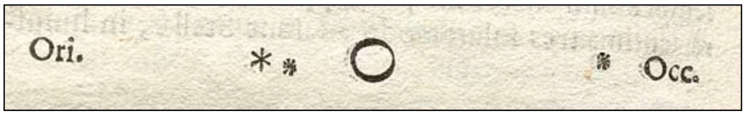
East  West

40 seconds removed from him on either side, and the third was 8 minutes from Jupiter in the west. The one closer to Jupiter appeared not larger but brighter than the farther one.

On the seventeenth, 30 minutes after sunset, the configuration was thus. There was only one star on the east,

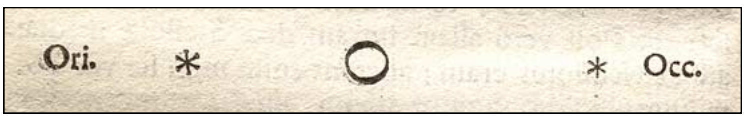
East  West

3 minutes from Jupiter. Likewise, one was 11 minutes from Jupiter to the west. The eastern one appeared twice as large as the western one. There were no more than these two. But after four hours, that is, around the fifth hour of the night, on the eastern side a third began to emerge, which, I suspect, had earlier been united with the first one. The formation was thus.

East  West

The middle star, extremely close to the eastern one, was only 20 seconds from it, and it was displaced a little bit to the south of the line drawn through the outermost stars and Jupiter.

On the eighteenth, 20 minutes after sunset, the appearance was thus. The eastern star was larger than the western one

East  West

and 8 minutes distant from Jupiter, while the western one was 10 minutes from Jupiter.

On the nineteenth, at the second hour of the night, the formation was like this. There were three stars exactly on a straight line

East  West

through Jupiter, one to the east, 6 minutes distant; between Jupiter and the first western one was an interval of 5 minutes, while this star was 4 minutes from the more western one. At this time I was uncertain whether between the eastern star and Jupiter there was a little star, very close to Jupiter, so that it almost touched him. And at the fifth hour, I clearly saw this little star now occupying a place precisely in the middle between Jupiter and the eastern star, so that the formation was as follows:

East  West

Further, the newly perceived star was very small; yet by the sixth hour it was almost equal in magnitude to the others.

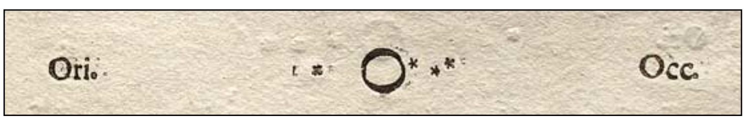
On the twentieth, at 1 hour, 15 minutes, a similar configuration appeared. There were three little stars so small that they could hardly

East  West

be perceived. They were not more than 1 minute from Jupiter and each other. I was uncertain whether on the west there were two or three little stars. Around the sixth hour they were arranged in this manner:

East  West

The eastern one was twice as far from Jupiter as before, that is, 2 minutes; the middle one to the west was 40 seconds from Jupiter but 20 seconds from the western one. At length, in the seventh hour, three little stars were seen to the west; the nearest was

East  West

20 seconds from him; between this one and the westernmost one there was an interval of 40 seconds; and between these another was seen, displaced a little to the south

and not more than 10 seconds from the westernmost one.

On the twenty-first, at 30 minutes, there were three little stars to the east, equally spaced from each other and Jupiter.

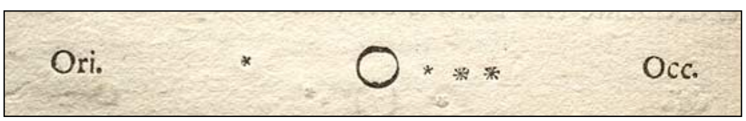
East  West

The intervals were estimated to be 50 seconds. There was also a star to the west, 4 minutes from Jupiter. The closest one to Jupiter to the east was the smallest of all. The rest were somewhat larger and equal to each other.

On the twenty-second, at the second hour, the configuration was similar. The distance from the eastern one to Jupiter

East  West

was 5 minutes; the distance from Jupiter to the westernmost one was 7 minutes; the two western stars in the middle were 40 seconds from each other while the nearer one was 1 minute from Jupiter. The little stars in the middle were smaller than the outermost ones, but they were on the same straight line extended along the length of the zodiac except that of the three western ones the middle one was displaced a bit to the south. But at the sixth hour of the night they appeared

East  West

in this arrangement. The eastern one was very small and, as before, 5 minutes distant from Jupiter; the three western ones were separated equally from Jupiter and each other, and the spaces were nearly 1 minute, 20 seconds each;

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and the star closer to Jupiter than the other two appeared smaller; and they all appeared to lie exactly on the same straight line.

On the twenty-third, 40 minutes after sunset, the configuration of stars was about like this:

East

West

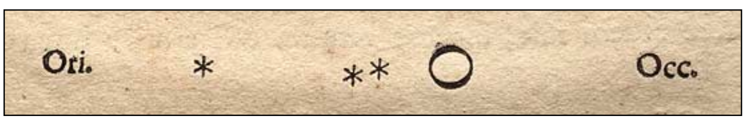
There were three stars in a straight line with Jupiter along the length of the zodiac, as they have always been; two were to the east and one to the west. The easternmost one was 7 minutes from the next one, this one 2 minutes, 40 seconds from Jupiter, and Jupiter 3 minutes, 20 seconds from the western one; and they were all about equal in magnitude. But at the fifth hour the two stars which earlier were closest to Jupiter were no longer visible, hiding behind Jupiter in my opinion; and the appearance was as follows:

East

West

On the twenty-fourth, three stars appeared, all to the east, and nearly in the same straight line with Jupiter, for the middle one

East



West

deviated slightly to the south. The star closest to Jupiter was 2 minutes from him, the next one 30 seconds from this one, and the easternmost one 9 minutes from that one; and all were very bright. But at the sixth hour only two

East

West

stars presented themselves in this arrangement, that is, precisely on a straight line with Jupiter. The nearer one was removed from Jupiter by 3 minutes while the other one was 8 minutes from this one. If I am not mistaken, the two middle little stars observed earlier had united into one.

On the twenty-fifth, at 1 hour, 40 minutes, the formation was thus:

East  West

There were only two stars to the east, and those fairly large. The easternmost was 5 minutes from the middle one, and the middle one 6 minutes from Jupiter.

On the twenty-sixth, at 0 hours, 40 minutes, the formation of stars was like this. For three stars were observed,

East  West

of which two were to the east and one to the west. This last one was 5 minutes from him, while the middle one in the east was 5 minutes, 20 seconds from him. The easternmost was 6 minutes from the middle one. They were on the same straight line and of the same magnitude. Then at the fifth hour the arrangement was nearly the same, differing only in this, that

East  West

near Jupiter a fourth star had emerged on the east, smaller than the rest, at that time 30 seconds removed from Jupiter but elevated a little to the north above the straight line, as shown in the adjoining figure.

On the twenty-seventh, at 1 hour after sunset, only a single

PAGE 22R

star was perceived, and that one to the east, in this arrangement:

East 

West

It was very small and 7 minutes removed from Jupiter.

On the twenty-eighth and twenty-ninth, nothing could be observed because of interposed clouds.

On the thirtieth, at the first hour of the night, the stars were observed arranged in this order. One was to the east,

East 

West

2 minutes, 30 seconds from Jupiter, and two were to the west, of which the one closest to Jupiter was 3 minutes from him and the other 1 minute from this one. The outermost stars and Jupiter were arranged in a straight line, and the middle star was elevated a little to the north. The westernmost star was smaller than the others.

On the last day [of January], at the second hour, two stars appeared to the east and one to the west. The middle of the eastern ones

East 

West

was 2 minutes, 20 seconds from Jupiter, the easternmost one 30 seconds from the middle one. The western star was 10 minutes from Jupiter. They were nearly in the same straight line, only the eastern one, closest to Jupiter, was a little bit elevated to the north. But at the fourth hour the two to the east were still closer to each

East 

West

other, for they were only 20 seconds apart. In these observations the western star appeared very small.

On the first day of February, at the second hour of the night, the formation was similar. The eastern star was

East  West

6 minutes from Jupiter and the western one 8. To the east a very small star was 20 seconds distant from Jupiter. They traced out a precisely straight line.

On the second, the stars appeared in this order. A single star to the east was 6 minutes from Jupiter;

East  West

Jupiter was 4 minutes distant from the nearer one to the west; and between this one and the westernmost star there was an interval of 8 minutes. They were precisely in a straight line and of nearly the same magnitude. But at the seventh hour there were four stars, among

East  West

which Jupiter occupied the middle position. Of these stars the easternmost one was 4 minutes from the next, this one 1 minute, 40 seconds from Jupiter, Jupiter 6 minutes from the western one closest to him, and this one 8 minutes from the westernmost one. They were all together on the same straight line extended along the line of the zodiac.

On the third, at the seventh hour, the stars were arranged in this sequence. The eastern one was 1 minute, 30 seconds from Jupiter;

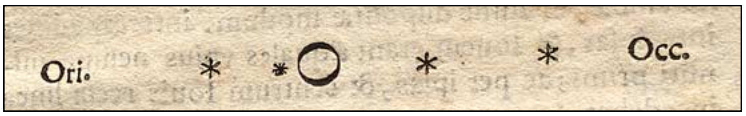
the closest western one 2 minutes; and the other western one was

East 

West

10 minutes removed from this one. They were absolutely on the same straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars around Jupiter, two to the east and two to the west,

East 

West

and arranged precisely on a straight line, as in the adjoining figure. The easternmost was distant 3 minutes from the next one, while this one was 40 seconds from Jupiter; Jupiter was 4 minutes from the nearest western one, and this one 6 minutes from the westernmost one. Their magnitudes were nearly equal; the one closest to Jupiter appeared a little smaller than the rest. But at the seventh hour the eastern stars were only 30 seconds apart. Jupiter

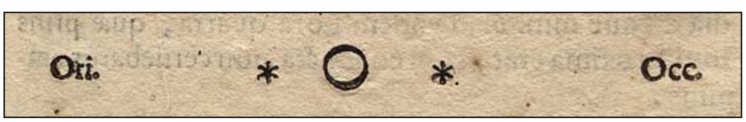
East 

West

was 2 minutes from the nearer eastern one, while he was 4 minutes from the next western one, and this one was 3 minutes from the westernmost one. They were all equal and extended on the same straight line along the ecliptic.

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared

East 

West

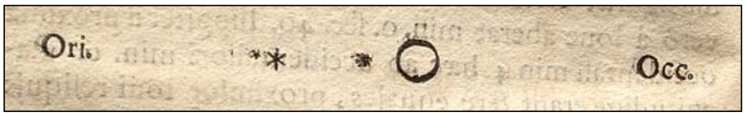
flanking Jupiter, as is seen in the adjoining figure. The eastern one was 2 minutes and the western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

On the seventh, two stars stood near Jupiter, both to the east,

East  West

arranged in this manner. The intervals between them and with Jupiter were equal, that is, 1 minute, and a straight line ran through them and the center of Jupiter.

On the eighth, at the first hour, three stars were present,

East  West

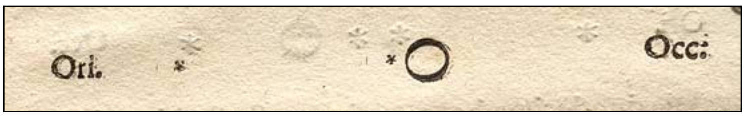
all to the east, as in the figure. The small star closest to Jupiter was 1 minute, 20 seconds distant from him; the middle star was 4 minutes from this one and rather large; and the very small easternmost star was 20 seconds from that one. I was of two minds whether the one closest to Jupiter was only one, or two little stars, for it seemed now and then that there was another star near it, toward the east, extremely small, and separated from it by only 10 seconds. They were all extended on the same straight line along the zodiac. But at the third hour the star closest to Jupiter nearly touched him. It was only 10 seconds from him, while the others had moved farther from Jupiter, for the middle one was 6 minutes away from Jupiter. Finally, at the fourth hour, the one that before was closest to Jupiter, united with him, was seen no longer.

On the ninth, at 30 minutes, two stars were near Jupiter to the east and one to the west, in this formation.

East  West

The easternmost star, which was rather small, was 4 minutes from the next one; the larger middle star was 7 minutes distant from Jupiter; Jupiter was 4 minutes removed from the western star, which was small.

On the tenth, at 1 hour, 30 minutes, two very small stars, both to the east, appeared in this arrangement.

East  West

The farther one was 10 minutes from Jupiter and the nearer one 20 seconds. They were on the same straight line. But in the fourth hour the star close to Jupiter did not appear any longer and the other appeared so diminished that it could hardly be perceived, although the air was very clear, and it was farther from Jupiter than it had been before, since it was now 12 minutes distant.

On the eleventh, at the first hour, two stars were present to the east and one to the west. The western one was

East  West

4 minutes from Jupiter; the nearer one to the east was likewise 4 minutes away from Jupiter, while the easternmost star was 8 minutes from this one. They were moderately conspicuous and on the same straight line. But at the third hour

East  West

a fourth star appeared close to Jupiter to the east, smaller than the other ones, separated from Jupiter by 30 seconds and slightly displaced to the north from the straight line drawn through the rest of the stars. They were all most brilliant and very conspicuous. But at the fifth hour plus a half the star closest to Jupiter to the east, already more remote from him, had attained a position in the middle between him and the more eastern star close to itself. And they were all precisely on the same straight line and of the same magnitude, as can be seen in the adjoining figure.

East

West

On the twelfth, at 40 minutes, two stars were present to the east and likewise two to the west. The farther one to the east

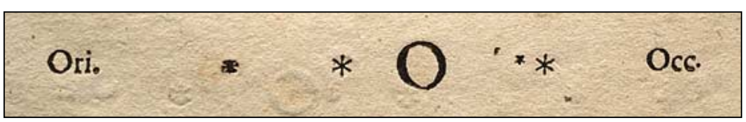
East

West

was 10 minutes from Jupiter while the more remote star to the west was 8 minutes away. They were both rather conspicuous. The other two stars were very close to Jupiter and very small, especially the eastern one, which was 40 seconds distant from Jupiter, while the western one was 1 minute away. But at the fourth hour the little star that was close to Jupiter to the east no longer appeared.

On the thirteenth, at 30 minutes, two stars appeared to the east and two also to the west. The eastern star closer to Jupiter,

East



West

fairly conspicuous, was 2 minutes from him, and the more eastern one, appearing smaller, was 4 minutes removed from this one.

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The western star farther from Jupiter, exceedingly conspicuous, was separated from him by 4 minutes. Between it and Jupiter fell a small starlet closer to the westernmost star, since it was not more than 30 seconds from it. They were all precisely on the same straight line along the length of the ecliptic.

On the fifteenth (for on the fourteenth the sky was covered by clouds), at the first hour, the position of the stars was as follows. That is, there were three stars to the east, but none

East  West

were seen to the west. The star to the east closest to Jupiter was 50 seconds from him, the next one was 20 seconds from this one, and the easternmost star 2 minutes from this one. And it was larger than the others, for the two nearer ones were exceedingly small. But at about the fifth hour, of the stars

East  West

close to Jupiter only one was seen, 30 seconds distant from Jupiter. The elongation of the more eastern one from Jupiter was increased, for it was then 4 minutes. But at the sixth hour, in addition to the two positioned to the east, as was stated a moment ago,

East  West

one little star, exceedingly small, was seen toward the west, 2 minutes removed from Jupiter.

On the sixteenth, at the sixth hour, they were in the following arrangement. That is, one star was 7 minutes away from Jupiter to the east,

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Jupiter 5 minutes from the next star to the west, and this one 3 minutes from the remaining western one. They were all

East  West

of about the same magnitude, fairly conspicuous, and exactly on the same straight line drawn along the zodiac.

On the seventeenth, at the first hour, two stars were present, one to the east 3 minutes from Jupiter and another to the west, distant

East  West

10 minutes. This star was somewhat smaller than the eastern one. But at the sixth hour the eastern one was closer to Jupiter and was only 50 seconds distant from him. The western star was farther, that is, 12 minutes. In both observations they were on the same straight line, and both were rather small, especially the one to the east in the second observation.

On the eighteenth, at the first hour, three stars were present, of which two were to the west and one to the east. The eastern star

East  West

was 3 minutes from Jupiter, the closest one to the west 2 minutes, and the remaining more westerly star was 8 minutes from the middle one. All were precisely on the same straight line and of nearly the same magnitude. But at the second hour the stars closer to Jupiter were removed from Jupiter by equal spaces, for the western one [of these] was now also 3 minutes away from him. But at the sixth hour a fourth star appeared between the eastern one and Jupiter in the following configuration. The easternmost star was 3 minutes from the next one, this star

1 minute, 50 seconds from Jupiter, Jupiter 3 minutes from the next western star,

East

West

and this one 7 minutes from the westernmost star. They were nearly equal, only the eastern one close to Jupiter was a bit smaller, and they were all on the same straight line parallel to the ecliptic.

On the nineteenth, at 40 minutes, only two stars, rather large, were seen to the west of Jupiter and precisely

East

West

arrayed with Jupiter on the same straight line drawn along the ecliptic. The nearer star was 7 minutes from Jupiter and 6 minutes from the westernmost star.

On the twentieth, the sky was cloudy.

On the twenty-first, at 1 hour, 30 minutes, three little stars, rather small, were observed in this arrangement. The eastern star

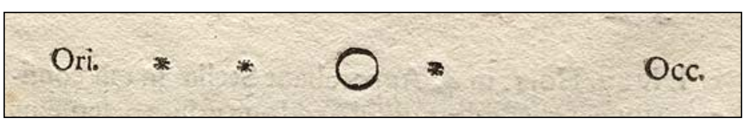
East

West

was 2 minutes from Jupiter, Jupiter 3 minutes from the next western one, and this star 7 minutes from the westernmost one. They were precisely in the same straight line, parallel to the ecliptic.

On the twenty-fifth, at 1 hour, 30 minutes (for during the three preceding nights the sky was covered by clouds), three stars appeared,

East



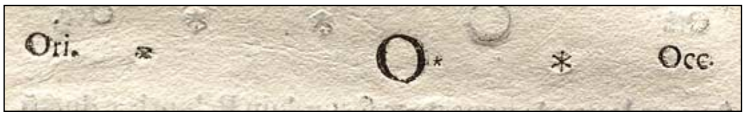
West

two to the east, whose distances between themselves and from Jupiter were equal at 4 minutes. To the west one star was 2 minutes from Jupiter. They were precisely on the same straight line extending along the ecliptic.

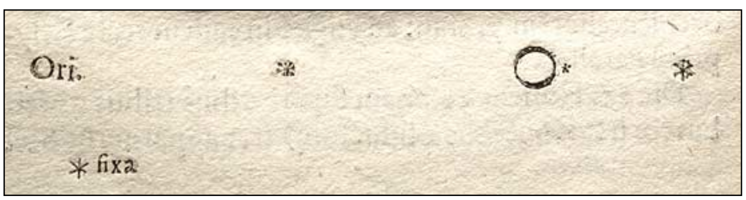
On the twenty-sixth, at 30 minutes, only two stars were present. One was to the east 10 minutes from Jupiter, and the other was to the west

East  West

6 minutes distant. The eastern star was somewhat smaller than the western one. But at the fifth hour three stars appeared. Besides the two

East  West

already noted, a third was perceived close to Jupiter, to the west and very small, which earlier had been hidden behind Jupiter, and it was 1 minute from him. The eastern star appeared farther than before, being 11 minutes from Jupiter. On this night I decided for the first time to observe the progress of Jupiter and his adjacent planets along the length of the zodiac by reference to some fixed star, for a fixed star was observed to the east, 11 minutes from the easternmost planet and displaced somewhat to the south in the following manner:[79]

East  West

On the twenty-seventh, at 1 hour, 4 minutes,[80] the stars appeared in this configuration. The easternmost star was 10 minutes from Jupiter, the next star, close to Jupiter, 30 seconds; the next one, to the west, was

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2 minutes, 30 seconds from Jupiter, and the westernmost star was 1 minute distant from this one.

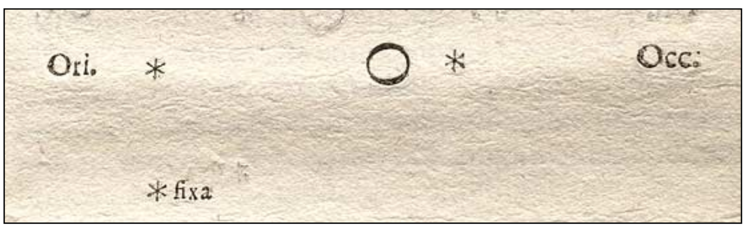
East

West

The stars nearer Jupiter appeared small, especially the eastern one, but the outermost stars were very conspicuous, especially the western one. And they formed a straight line exactly drawn along the ecliptic. The progress of these planets toward the east was clearly discerned through a comparison with the aforesaid fixed star, for Jupiter with his attendant planets was closer to it, as can be seen in the adjoining figure. But at the fifth hour the eastern star near Jupiter was 1 minute away from him.

On the twenty-eighth, at the first hour, only two stars were seen, an eastern one 9 minutes, and a western one 2 minutes from Jupiter. They were

East



West

fairly conspicuous and on the same straight line. This line was perpendicularly intersected by a line from the fixed star to the eastern planet, as shown in the figure. But at the fifth hour a third little star was perceived to the east

East

West

2 minutes distant from Jupiter in this arrangement.

On the first of March, at 40 minutes, four stars were perceived, all to the east.

The nearest star to Jupiter was 2 minutes from him, the next star 1 minute from this one, and the third 20 seconds, and it was

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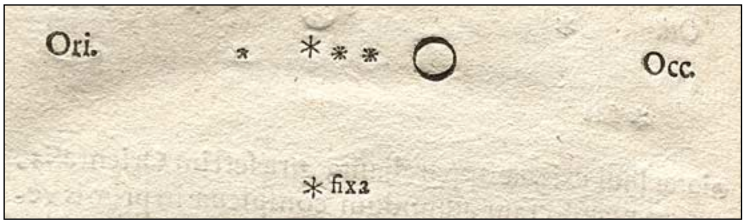
East  West

brighter than the rest. The fourth star was 4 minutes from this one, and it was smaller than the rest. They formed nearly a straight line except that the third star from Jupiter was elevated a little. The fixed star formed an equilateral triangle with Jupiter and the easternmost star, as shown in the figure.

On the second, at 40 minutes, three planets were present, two to the east and one to the west, in this configuration.

East  West

The easternmost planet was 7 minutes from Jupiter, while this one was 30 seconds from the next planet. The western planet was 2 minutes removed from Jupiter. And the outermost planets were brighter and larger than the other one, which appeared very small. The easternmost planet appeared somewhat elevated toward the north above the straight line drawn through Jupiter and the other ones. The fixed star already noted was 8 minutes distant from the western planet along the line drawn to that planet perpendicular to the straight line extended through all the planets, as the figure shows.

I decided to add these comparisons of Jupiter and his adjacent planets with the fixed star

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so that from them anyone could see that the progress of these planets, in longitude as well as latitude, agrees exactly with the motions that are derived from the tables.[81]

These are the observations of the four Medicean planets recently, and for the first time, discovered by me. From them, although it is not yet possible to calculate their periods, something worthy of notice may at least be said. And first, since they sometimes follow and at other times precede Jupiter by similar intervals, and are removed from him toward the east as well as the west by only very narrow limits, and accompany him equally in retrograde and direct motion, no one can doubt that they complete their revolutions about him while, in the meantime, all together they complete a 12-year period about the center of the world. Moreover, they whirl around in unequal circles, which is clearly deduced from the fact that at the greatest separations from Jupiter two planets could never be seen united while, on the other hand, near Jupiter two, three, and occasionally all four planets are found crowded together at the same time. It is further seen that the revolutions of the planets describing smaller circles around Jupiter are faster.[82] For the stars closer to Jupiter are often seen to the east when the previous day they appeared to the west, and vice versa, while from a careful examination of its previously accurately noted returns, the planet traversing the largest orb appears to have a semimonthly period.[83] We have moreover an excellent and splendid argument for taking away the scruples of those who, while tolerating with equanimity the revolution of the planets around the Sun in the Copernican system, are so disturbed by the attendance of one Moon around the Earth while the two together complete the annual orb around the Sun that they conclude that this constitution of the universe must be overthrown as impossible.[84] For here we have only one planet revolving around another while both run through a great circle around the Sun: but our vision offers us four stars wandering around Jupiter like the Moon around the Earth while all together with Jupiter traverse a great circle around the Sun in the space of twelve years.[85] Finally, we must not neglect the reason why it happens that the Medicean stars, while completing their very small revolutions around Jupiter, are themselves now and then seen twice as large. We can in no way seek the cause in terrestrial vapors, for the stars appear larger and smaller when the sizes of Jupiter and nearby fixed stars are seen completely unchanged. It seems inconceivable, moreover, that they approach and recede from the Earth by such a degree around the perigees and apogees[86] of their orbits as to cause such large changes. For smaller circular motions can in no way be responsible, while an oval motion (which in this case would have to be almost straight) appears to be both inconceivable and by no account harmonious with the appearances.[87] I gladly offer what occurs to me in this matter and submit it to the judgment and censure of right-thinking men. It is well known that because of the interposition of terrestrial vapors the Sun and Moon appear larger but the fixed stars and planets smaller. For this reason, near the horizon the luminaries appear larger[88] but the stars [and planets] smaller and generally inconspicuous, and they are diminished even more if the same vapors are perfused by light. For that reason the stars [and planets] appear very small by day and during twilight, but not the Moon, as we have already stated above. From what we have said above as well as from those things that will be discussed more amply in our system, it is moreover certain that not only the Earth but also the Moon has its surrounding vaporous orb. And we can accordingly make the same judgment about the remaining planets, so that it does not appear inconceivable to put around Jupiter an orb denser than the rest of the ether around which the Medicean planets are led like the Moon around the sphere of the elements. And at apogee, by the interposition of this orb, they are smaller, but when at perigee, because of the absence or attenuation of this orb, they appear larger.[89] Lack of time prevents me from proceeding further. The fair reader may expect more about these matters soon.

1. Galileo came from a Florentine family that can be traced back to the thirteenth century. His ancestors included several members of the governing council of the Florentine Republic and a celebrated physician. His family tree can be found in *Le Opere di Galileo Galilei*, ed. Antonio Favaro (Florence: G. Barbera, 1890–1909; reprinted 1929–39, 1964–66) 19:17. See also Stillman Drake, *Galileo at Work: His Scientific Biography* (Chicago: University of Chicago Press, 1978), 448.
2. The Latin word used here is *perspicillum.* Galileo used the Italian word *occhiale* to describe the instrument. I have translated these terms as *spyglass* throughout. The word *telescope* was unveiled only in 1611.
3. Galileo used the Latin word *reperti*, from the verb *reperio.* This word can mean both *invented* and *devised.* Although Galileo was often accused of claiming he actually invented (in our sense) the telescope, this is clearly a calumny. See Edward Rosen, "Did Galileo Claim He Invented the Telescope?" *Proceedings of the American Philosophical Society* 98 (1954): 304–12.
4. Galileo referred to Jupiter's satellites as both "planets" and "stars." In the old terminology, based on Aristotelian cosmology, both terms were correct.
5. Cosimo II de' Medici (1590–1621) was the grandson of Cosimo I, the first of the family to bear the title of Grand Duke. He ascended the throne in 1609 upon the death of his father, Ferdinand I.
6. The reference is to the *Elegies* of the Roman poet Sextus Propertius, who lived in the last half of the first century B.C. Book 3, no. 2, is on the power of song and reads in part: "For not the heaven-raised Pyramids' expense, / Nor Jove's house which, at Ellis, mimics heaven, / Nor Mausulus, his tomb's magnificence, / By Death's supreme indemnity forgiven. / To filching fire or rain their crowns submit, / By Time's stroke, and their weight, they crash, defied. / Not so shall pass the fame by poet's wit / Achieved; for that endures in deathless pride." See E.H.W. Meyerstein, *The Elegies of Propertius* (London: Oxford University Press, 1935), 95–96.
7. Both the Greek *cometes* and Latin *crinitus* mean *hairy.* The original meaning was thus *hairy star*, describing the appearance of these celestial objects.
8. In an English translation of Suetonius' biographies of the first twelve caesars made during Galileo's lifetime, we read, in the 88th section of the life of Julius Caesar: "He died in the 56 yeare of his age and was canonized among the Gods, not onely by their voice who decreed such honour unto him, but also by the perswasion of the common people. For at those Games and playes which were the first that Augustus his heire exhibited for him thus deified, there shone a blazing starre for seven dayes together, arising about the eleventh houre of the daye; and beleeved it was to be the soule of Caesar received up into heaven. For this cause also uppon his Image there is a starre set to the verie Crowne of his head." See *Suetonius History of Twelve Caesars translated into English by Philemon Holland anno 1606*, 2 vols. (London: David Nutt, 1899), 1:80. See also Wilhelm Gundel and Hans Georg Gundel, *Astrologumena: Die Astrologische Literatur in der Antike und ihre Geschichte*, beiheft 6, *Sudhoffs Archiv* (Wiesbaden: Franz Steiner, 1966), 127–28.

9. Clearly Galileo is referring here to the Copernican system.
10. While in recent times it has become customary in the English language to refer to heavenly bodies with the personal pronoun *it*, until the nineteenth century the Sun, Mercury, Mars, Jupiter, and Saturn were referred to as *he* and the Moon and Venus as *she*.
11. The midheaven is the intersection of the ecliptic and the meridian.
12. This is the *horoscopus*, the point of the ecliptic rising at the eastern horizon marking the beginning of the first house.
13. The telescope inaugurated a new chapter in celestial discovery. By claiming the right to name his discoveries, Galileo set a trend that others were to follow, with varying degrees of success, into the twentieth century. Systems of naming celestial objects are now regulated by international agreement, and names are often assigned by a committee of the International Astronomical Union.
14. For a history of the Medici family, see Ferdinand Schevill, *The Medici* (New York: Harcourt, Brace & Co., 1949; New York: Harper, 1960); and J.R. Hale, *Florence and the Medici: The Pattern of Control* (London: Thames & Hudson, 1977).
15. In formal letters such as this one, writers often used the Roman manner of designating days of the month, in which days were counted backward from the kalends, nones, or ides, beginning with the day of the kalends, nones, or ides itself. The ides occurred on the fifteenth day of March, May, July, and October, and on the thirteenth day of all other months. The fourth day before the Ides of March is therefore March 12th.
16. The Council of Ten, first instituted in 1310 as a committee of public safety and made a permanent institution in 1335, dealt with all criminal and moral matters. It also exercised power in foreign affairs, finance, and war. Its heads granted permission to print books.
17. The *Riformatori dello Studio di Padova* constituted the body of overseers of the university. Since 1517 it had been made up of three members of the Venetian senate. The *riformatori* were charged by the government with censorship of the press in the Venetian territories. They made recommendations to the Council of Ten. See Paul F. Grendler, "The Roman Inquisition and the Venetian Press, 1540–1605," *Journal of Modern History* 47 (1975): 48–65; reprinted in *Culture and Censorship in Late Renaissance Italy and France* (London: Variorum Reprints, 1981), no. 9.
18. In the star catalog in his *Almagest*, Ptolemy listed 1022 stars. See G.J. Toomer, ed., *Ptolemy's Almagest* (London: Duckworth, 1984), 341–99.
19. The distance of the Moon was commonly known to be about sixty terrestrial *radii*. In the manuscript as well as the printed version of *Sidereus Nuncius*, Galileo mistakenly uses *diameters*, as he does in his letter of January 7, 1610 (*Opere*, 10:273, 277). A slip of the pen therefore appears to be ruled out. See Edward Rosen, "Galileo on the Distance between the Earth and the Moon," *Isis* 43 (1952): 344–48.

20. Galileo implies here that in these observations he used an instrument that magnified thirty times. In his letter of January 7, 1610, he stated that he was about to finish a thirty-powered instrument (*Opere*, 10:277), but there is no evidence that he made much use of this instrument. See Drake, *Galileo at Work*, 147–48.
21. In the traditional Ptolemaic scheme, all planets were thought to orbit the Earth. In a well-known variation of this scheme that may well have been suggested in Greek antiquity, Mercury and Venus were thought to orbit the Sun. This explained the fact that they never stray far from the Sun.
22. In the cosmology of Aristotle, heavenly bodies were absolutely different from earthly objects. All heavenly bodies were made of the same celestial substance and were therefore called stars. The vast majority, the "fixed stars," rotated about the earth in unchanging formation, providing the background against which the seven "wandering stars" were plotted as they moved through the zodiac. Our word *planet* derives from the Greek word for "wanderer."
23. The Latin word *Belga* should be translated as *Dutchman* or *Netherlander.* See "A Note on the Word 'Belgium,' " in Pieter Geyl, *The Netherlands in the Seventeenth Century, Part I, 1609–1648* (London: Ernest Benn, 1961), 260–62.
24. As a professor of mathematical subjects, Galileo was thoroughly grounded in the optical theory of his day. This theory could not, however, give him much guidance in duplicating the invention. In *The Assayer* of 1623, Galileo more fully described the process by which he figured out how to make his first spyglass. See Stillman Drake and C.D. O'Malley, *The Controversy on the Comets of 1618* (Philadelphia: University of Pennsylvania Press, 1960), 211–13.
25. The Latin word *perspicillum* was here clearly meant to denote a common spectacle lens.
26. This was the greatest magnification that could be achieved with a spyglass made with lenses for sale in the shops of spectacle makers.
27. This is the instrument Galileo presented to the Venetian senate.
28. That is, stars and planets.
29. The relationship between the size of the aperture of the objective lens and the field of view of the instrument is, in fact, rather more complicated than Galileo implies here, and for this reason all efforts to turn this form of telescope into a measuring instrument failed. See John North, "Thomas Harriot and the First Telescopic Observations of Sunspots," in John W. Shirley, ed., *Thomas Harriot; Renaissance Scientist* (Oxford: Clarendon Press, 1974), 129–65, at 158–60.
30. Galileo never published such a theory.
31. In fact, in August 1609 Thomas Harriot in England had turned a six-powered spyglass on the Moon—not much better that what could be seen with the naked eye.
32. That is, conjunction with the Sun, when the Moon is invisible because its illuminated hemisphere is turned away from the Earth. The current astronomical term is "new moon." It is at this point that solar eclipses can occur.
33. That is, the Moon shows only a thin crescent of light.

34. The Moon or a planet is at quadrature when its angular separation from the Sun is 90 degrees. The first quadrature of the Moon after new moon is called "first quarter."
35. On modern Moon maps, until recently, this would be the upper horn. While Galileo's telescope showed an erect (upright) image, modern instruments show an inverted (upside-down) image and for this reason modern Moon maps are drawn upside down. Note, however, that since spacecraft started sending back erect planetary images, more and more Moon maps are not inverted.
36. It was not Galileo's purpose to make an accurate map of the Moon, but rather to illustrate its Earth-like nature. It is therefore often difficult to identify features on his drawings. In the case of this obviously exaggerated "cavity," the best guess is that it represents the crater Albategnius.
37. Although Galileo's argument is cogent, successive mountain ranges do not make the Moon's outline perfectly smooth. With modern instruments the remaining unevennesses can easily be observed.
38. This argument was later abandoned by Galileo: it is not to be found in his *Dialogue concerning the Two Chief World Systems* of 1632, in which he treats the appearance of the Moon in great detail.
39. Galileo was using convenient numbers and fractions here. The diameters of the Earth and Moon had been known with surprising accuracy since antiquity. See Albert Van Helden, *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley* (Chicago: University of Chicago Press, 1985), 4–27.
40. The square root of 1,010,000 is almost exactly 1,005, which would make Galileo's argument even stronger.
41. There was no Italian mile strictly speaking. The miles of Florence, Venice, and Rome were all within 10% of the modern English mile.
42. Efforts to determine the heights of mountains by geometrical means began in Greek antiquity. These first estimates were generally of the order of a mile. Later speculations varied widely, and it appears that Galileo relied on earlier sources. See Florian Cajori, "History of Determinations of the Heights of Mountains," *Isis* 12 (1929): 482–514; and C.W. Adams, "A Note on Galileo's Determination of the Height of Lunar Mountains," *Isis* 17 (1932): 427–29.
43. With the Sun.
44. This phenomenon was called *lumen cinereum* or "ashen light" of the Moon. It is now referred to as Earth-shine.
45. That is, when the angular separation between Sun and Moon is 60 degrees.
46. For example, Erasmus Reinhold. See his edition of Peurbach's *Theoricae Novae Planetarum* (Wittenberg, 1553), ff. 164^{v}–165^{r}. See also Johannes Kepler, *Gesammelte Werke* (Munich: C.H. Beck, 1937–), 2:221–22.
47. This was maintained by Tycho Brahe, in his *Astronomiae Instauratae Progymnasmata* (1602), according to Kepler. See *Gesammelte Werke*, 2:223; and Edward Rosen, *Kepler's Conversation with Galileo's Sidereal Messenger* (New York: Johnson Reprint Corp., 1965), 119–20.

48. Vitello, *Perspectiva*, iv, 77. See *Opticae Thesaurus*, ed. Friedrich Risner (Basel, 1572; reprint, New York: Johnson Reprint Corp., 1972), p. 151 of *Vitellionis Opticae.*
49. The reddish color of the Moon during a lunar eclipse is now attributed to refraction of sunlight by the Earth's atmosphere. Sunlight that grazes the Earth is refracted and illuminates the Moon slightly. But in the passage through the Earth's atmosphere the wavelengths at the blue end of the spectrum are scattered, so that only wavelengths near the red end of the spectrum pass through. This same absorption makes the Sun appear red at sunrise and sunset.
50. See *Dialogue concerning the Two Chief World Systems—Ptolemaic and Copernican*, tr. Stillman Drake (Berkeley: University of California Press, 1967), 67–99.
51. Ibid.
52. The first estimates of the apparent diameters of fixed stars and planets were made in antiquity. These estimates, which were much too high, were faithfully followed by all successors of Ptolemy until the telescope showed them to be in error. See Van Helden, *Measuring the Universe.*
53. That is, fixed stars as well as planets.
54. The Latin is *circa meridiem*, that is, around noon. Only on rare occasions, when Venus is at its greatest elongation from the Sun (about 45 degrees) and therefore at its brightest and when the seeing conditions are very good, can an observer with keen sight who knows exactly where to look see Venus with the naked eye around noon. Such occasions are so infrequent, however, that it is more likely Galileo simply meant an hour or so after sunrise or before sunset.
55. Up to this point the only observable differences between fixed stars and planets had been in their motions and in the fact that the former twinkle while the latter do not.
56. Sirius.
57. These figures present a problem. A difference of 5 magnitudes in brightness represents a factor of 100 in the amount of light gathered, or a tenfold increase in aperture. The light gathered by the eye is governed by the aperture of the pupil, and the dark-adapted pupil has a diameter of about 1/3 inch. This would mean that Galileo's spyglass had an aperture of well over 3 inches, and we know this was not the case. The apertures of his instruments were stopped down to 1 inch or less. We can only conclude, therefore, that when Galileo made this estimate, his pupil was not yet adapted to the dark, and was therefore considerably smaller than 1/3 inch.
58. Nothing in his papers suggests that Galileo ever made a map of the entire constellation.
59. Galileo does not show the nebula in the sword of Orion, which is a naked-eye object. It is registered as a star, without the qualification "cloudy," in the star catalogs of Ptolemy and Copernicus. For this reason it has been suggested that this nebula has changed during historical time: see Thomas G. Harrison, "The Orion Nebula: Where in History Is It?" *Quarterly Journal of the Royal Astronomical Society* 25 (1984): 65–79. For an assessment of this argument, see

Owen Gingerich, "The Mysterious Nebulae, 1610–1924," *Journal of the Royal Astronomical Society of Canada* 81 (1987): 113–27. The nebula was first observed by Peiresc in 1611: see Pierre Humbert, *Un amateur: Peiresc,* 1580–1637 (Paris: Desclée, de Brouwer et cie., 1933), 42, and Seymour L. Chapin, "The Astronomical Activities of Nicolas Claude Fabri de Peiresc," *Isis* 48 (1957): 19–20. Note that the section containing the descriptions of star formations was added at a very late stage, for the four pages containing them are added between pp. 16^v and 17^r and are unnumbered. We may surmise that Galileo was silent on this nebula because he was convinced that it could be resolved into individual stars with more powerful instruments and in the meantime did not wish to vitiate his argument.

60. Taurus.
61. The Pleiades group is an open cluster consisting of several thousand stars, about 400 light-years from Earth. Six of its stars are brighter than the fifth magnitude, and a total of nine are brighter than the sixth magnitude. With the naked eye observers therefore see either six or nine (and sometimes even more), depending on their eyesight, but never seven.
62. For a review of pre-Galilean notions concerning the Milky Way, see Stanley L. Jaki, *The Milky Way: An Elusive Road for Science* (New York: Science History Publications; Newton Abbot, UK: David & Charles, 1973), 1–101.
63. The six nebulous stars listed in Ptolemy's star catalogue, and the five listed by Copernicus, can, in fact, all be resolved into stars. As it turned out, there is nebular matter in the universe. The question was not settled, however, until the advent of spectroscopy in the second half of the nineteenth century.
64. This notion was first put forward by Albertus Magnus in the thirteenth century; see Jaki, *The Milky Way*, 41. It was the explanation given by Christopher Clavius (1537–1612) in his influential *Commentary on the Sphere of Sacrobosco* (1570), which went through numerous editions during Galileo's lifetime. See *In Sphaeram Joannis de Sacro Bosco Commentarius* (Rome, 1570), 376–77.
65. This is the area near λ, ϕ^1, and ϕ^2 Orionis. Galileo no doubt chose this area because it is listed in Ptolemy's star catalogue as nebulous. See Toomer, *Ptolemy's Almagest*, 382.
66. The two large stars depicted here are γ and δ Cancri, called the *Aselli*, or ass-colts, in antiquity. The nebulous area between them, NGC 2632 = M44, is Praesepe, the Manger or Beehive. It is listed by Ptolemy as nebulous. See *Ptolemy's Almagest*, 366.
67. January 7 to March 2, 1610.
68. In 1612 Galileo published periods for all four satellites. They were virtually the same as the modern values. See *Discourse on Bodies in Water*, tr. Thomas Salusbury, ed. Stillman Drake (Urbana: University of Illinois Press, 1960), 1.
69. Especially in the case of the satellites of Jupiter, it was necessary to have a telescope that magnified fifteen times or more and was especially adapted for celestial use.
70. All dates used by Galileo are Gregorian.

71. Satellites I and II were very close together, just to the east of Jupiter. Galileo saw them as one. See Jean Meeus, "Galileo's First Records of Jupiter's Satellites," *Sky and Telescope* 24 (1962): 137–39.
72. On this night, satellite IV was at its farthest distance from Jupiter to the east, and it escaped Galileo because of the smallness of the field of view of his spyglass. See ibid.
73. On this night, Satellite I was so close to Jupiter on the west that it was lost in the planet's glare. Satellites II and III were very close to each other and Galileo saw them as one, just to the east of the planet. See ibid.
74. Satellites I and II had just ended their transits in front of the planet and were still too close to be discerned by Galileo. See ibid.
75. Note that Galileo initially saw only two of the satellites, III on the east and II on the west. Satellites I and IV were both on the east and rather close to Jupiter. Apparently Galileo could not see either one until satellite I moved farther away from the planet. See ibid.
76. Galileo took Jupiter's angular diameter to be about 1 arcminute, and he used this measure to estimate the distances of the satellites. In his drawings and in *Sidereus nuncius*, however, he showed the planet's disk as being about twice as large while keeping the distances of the satellites the same. The drawings are thus out of proportion. See Stillman Drake, *Telescopes, Tides, and Tactics* (Chicago: University of Chicago Press, 1983), 214–19.
77. It was thus on this day that Galileo recognized that there were four moons. During the previous observations he had been prevented by various circumstances from seeing all four moons at once.
78. I have translated the Latin *ad unguem* as "precisely" throughout this section.
79. This is a seventh-magnitude star, just below the ecliptic, at R.A. 5 hours, 4 minutes and decl. +22°.4, in the constellation Taurus.
80. Galileo clearly meant "40 minutes," but this is not a printer's error: the manuscript also has "4 minutes" (*Opere*, 3:44).
81. Jupiter had passed its station at the end of January and was slowly moving from west to east. Its daily motion in longitude was about 4 arcminutes at the end of February. See Bryant Tuckerman, *Planetary, Lunar and Solar Positions A.D. 2 to A.D. 1649 at Five-Day and Ten-Day Intervals*, American Philosophical Society, *Memoirs* 59 (1964): 823.
82. Kepler's third law, relating the mean radii of the orbits of the planets to their periods, was not published until 1619.
83. The actual period is about 16 days, 18 hours.
84. This was one of the arguments against the Copernican hypothesis. If the Earth is a planet, why should it be the only planet to have a moon? Alternatively, how could there be two centers of rotation in the universe?

85. This passage in its entirety removes an important objection against the Copernican theory, for Jupiter's moons demonstrate that our Moon can revolve around a moving Earth. It has been suggested, however, that it is an argument against the geo-heliocentric system of Tycho Brahe. See Wade L. Robison, "Galileo on the Moons of Jupiter," *Annals of Science* 31 (1974): 165–69.
86. Apogee and perigee are the points at which a heavenly body is farthest from, and closest to, the Earth, and Galileo is using the terms here in their literal meanings.
87. Although the orbits of Jupiter's satellites are virtually circles, technically they are ellipses. Elliptical astronomy was introduced by Johannes Kepler in his *Astronomia nova* of 1609.
88. In fact, atmospheric refraction makes the vertical diameter of these bodies smaller than the horizontal diameter. The large sizes of the Moon and Sun when close to the horizon are optical illusions.
89. The variations in brightness reported by Galileo cannot be accounted for by the varying brightness of individual satellites. Since in Galileo's reports satellites were seen dim only when they were close to Jupiter, this effect must be ascribed to a combination of the glare of the planet and the poor resolution of Galileo's telescope.