SIDEREUS NUNCIIUS
or
THE SIDEREAL MESSENGER

GALILEO GALILEI

Translated with
introduction, conclusion, and notes by

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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

and public mathematician of the University of Padua,
with the help of a spyglass2 lately devised2 by him,
about the face of the Moon, countless fixed stars,
the Milky Way, nebulose stars,
but especially about
do 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 STARS4

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 Opere, 1917. See also Stillman Drake, Galileo at Work, 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 not coined until 1611. See p. 112, below.

3. Galileo used the Latin word repetitum, from the verb repetere. 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, as demonstrated by the passage on pp. 36–37, below. See Edward Rosen, “Did Galileo Claim He Invented the Telescope?” Proceedings of the American Philosophical Society 98 (1954): 201–13.

4. Galileo referred to Jupiter's satellites as both "planets" and "stars." In the old terminology, based on Aristotelian cosmology, both terms were correct. See also note 31, p. 15.
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, "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 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]

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 Pyramida's 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 crumble, defiled; / 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, 1933), 95–96.
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’s 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) that had appeared in his time the Julian star, it mocked the hope of so much desire by disappearing shortly. But now, Most Serene Prince, we are able to augment truer and more felicitous things for Your Highness, for scarcely have the immortal graces of your

7. Both the Greek cometa 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 Sidereus Nuncius’s biographies of the first twelve caesars made during Galileo’s lifetime, we read, in the 88th section of the life of Julius Cæsar: “He died in the 66 year of his age and was canonized among the Gods, not only by their voice who decreed such honour unto him, but also by the persuasion of the common people. For at those Games and plays which were the first that Augustus his heir exhibited for him thus deified, there shone a blazing starre for seven daies together, rising about the eleventh house of the daye; and believing it to be the soule of Caesar received up into heaven. For this cause also upon his Image there is a starre set to the verie Crewne of his head.” See Sidereus Nuncius History of Twelve Caesars translated into English by Philemon Holland anno 1606, 3 vols. (London: David Nutt, 1899): 1:80. See also Wilhelm Gundel and Hans Georg Gundel, Astronomia: Die Astronomische Literatur in der Antike und ihre Geschichte, bekeilt 6, Sachhoff: Arthis (Wiesbaden: Franz Steiner, 1960), 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. This is the horizon, the point of the ecliptic rising at the eastern horizon marking the beginning of the first house.
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 demony 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, 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's ancestors to whose eternal glory the monuments of all histories testify, 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.

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, 1610.

Your Highness's most loyal servant,

Galileo Galilei

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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.

SIDEREUS NUNCIUS

The undersigned Gentlemen, Heads of the Council of Ten, having received certification from the Reformers of the University of Padua, 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. Valarezzo  Heads of the Council of Ten
Nicole Bon
Luinardo Marcello

The Secretary of the Most Illustrious Council of Ten
Bartholomaeus Cominus

1610, on 8 March. 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 MEDICEAN 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 expose to our eyes innumerable others never seen before, which exceed tenfold the number of old and known ones.

It is most beautiful and pleasing to the eye to look upon the lunar body, distant from us about sixty terrestrial diameters, 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 nine-hundred times, and the solid body about twenty-seven thousand times larger than when observed only with the

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.


19. The distance of the Moon was commonly known to be about sixty terrestrial miles. In the manuscript as well as the printed version of Sidereus Nuncius, Galileo mistakenly uses diameters, as he does in his letter of 2 January 1610 (Opera, 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.
naked eye. 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, have their periods around a certain star 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 no 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 10 months ago a rumor came to our ears that a spyglass had been made by a certain Dutchman 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.

And first I prepared a lead tube in whose ends I fitted two glasses, 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. Afterward I made another more perfect one for myself that showed objects more than sixty times larger. 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

20. Galileo implies here that in these observations he used an instrument that magnified thirty times. In his letter of 3 January 1609, he stated that he was about to finish a thirty-powerd instrument (Opera, 102227), 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. See p. 13, note 31, above.


24. See pp. 4–5, above.

25. 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.

26. The Latin word ueselium was here clearly meant to denote a common spectacle lens.

27. This was the greatest magnification that could be achieved with a spyglass made with lenses for sale in the shops of spectacle makers.

28. This is the instrument Galileo presented to the Venetian Senate. See pp. 6–8, above.
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, 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 behoves 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 four hundred 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 one or two minutes. 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. Now let us review the observations made by us during the past 2 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

32. 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), 121-65, at 153-60.

33. Galileo never published such a theory.
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. 51 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, 52 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, 53 when the Moon displays herself to us with brilliant horns, 54 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 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 2 or 3 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;\(^{38}\) the appearance of which is also shown in the above figure. For toward the lower horn\(^{39}\) 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 2 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 dilute. 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.\(^{40}\) 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

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\(^{38}\) 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."

\(^{39}\) On a modern Moon map this would be the upper horn. While Galileo's telescope showed an erect (right-side up) image, modern instruments show an inverted (upside-down) image and for this reason modern Moon maps are drawn upside down.

\(^{40}\) For Kepler's discussion of this aspect, see p. 95, below.
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. 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 appear-

41. 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 Alphonsus. For a discussion of this problem, see the articles cited in note 23, p. 9, above.
ance, 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 crests 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 gulls 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. 12 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

12. 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.
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 2 months 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. 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.

Accordingly, on the seventh day of January of the present year 1610, 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:

73. 7 January to 2 March 1610.
74. 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 Sabin, ed. Sullivan Drake (Urbana: University of Illinois Press, 1960), 1.
75. 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.
76. All dates used by Galileo are Gregorian.
77. See pp. 11-14, above.
79. See pp. 12-13, above.
80. 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 Meeus, “Galileo’s First Records.”
81. See pp. 15-16, above.

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. Even though at this point I had by no means turned my thought to the mutual motions of these stars, 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. The
third, as I thought, was hidden behind Jupiter.\textsuperscript{82} 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:

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image}
\caption{The arrangement of stars observed on the eleventh day.}
\end{figure}

There were only two stars on the east,\textsuperscript{83} 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 seemed 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.\textsuperscript{84} 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 star was larger than the western one, but both were very conspicuous and bright.\textsuperscript{85} Both were two minutes\textsuperscript{86} 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.\textsuperscript{87} Three were on the west and one on the east. They formed a very nearly straight line, 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

\textsuperscript{82} On this night, Satellites 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 Meeus, “Galileo’s First Records.”

\textsuperscript{83} 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, \textit{Telescopes, Times, and Tactics} (Chicago: University of Chicago Press, 1983), 214–19.

\textsuperscript{84} 87. 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.