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FROM *OCCHIALE* TO PRINTED PAGE: THE MAKING OF GALILEO'S *SIDEREUS NUNCIUS*

OWEN GINGERICH, Harvard-Smithsonian Center for Astrophysics, and

ALBERT VAN HELDEN, Utrecht University

> It is necessary that you make my excuses to their Highnesses since the book is not printed with the magnificence befitting the magnitude of the subject, for the lack of time did not permit it, and I did not want to prolong the publication lest I run the risk that perhaps someone else might have discovered the same and preceded me. And therefore I have published it in the form of an *avviso*, written for the most part while the previous parts were being printed, with the intent of reprinting it as soon as possible with many additions of other observations.[1]
>
> (Galileo to Cosimo's personal secretary, 19 March 1610)

The publication of Galileo's *Sidereus nuncius* or *Sidereal messenger* in March 1610 was perhaps the single most unexpected event in the Scientific Revolution of the sixteenth and seventeenth centuries. Not only were the astronomical observations reported there entirely unanticipated and arresting in their impact, but their rapid preparation and printing, all in just over six weeks, was a record for any significant scientific book of that period.

In this article we will analyse some of the ways in which Galileo assembled and presented his observational materials. Galileo's earliest astronomical observation for which a record exists took place on 30 November 1609 (the crescent Moon), and the last dated observation in the book occurred on 2 March 1610 (the satellites of Jupiter), less than two weeks before the book's actual publication date. We shall start with Galileo's observations of Jupiter (beginning 7 January 1610) because it was undoubtedly this series that precipitated his publication. His record of the little "stars" around Jupiter is possibly the most exciting single manuscript page in the history of science.

The most complete observational record of Galileo's Jovian observations begins on folio 30 of the manuscript pages assembled in the late nineteenth century by the distinguished Galilean researcher Antonio Favaro into the volume classified as Galileiana 48 in the National Library in Florence. We shall argue (contrary to Stillman Drake) that this is Galileo's original and primary record of these epoch-making observations. A full transcription and translation of the first page is appended to this article. The basis for our contention is two-fold: the nature of the text itself, and the subtle differences in the shade of the ink and the nib of the quill on successive days, which suggests that the entries, after the first few, were made each day.

Galileo first observed Jupiter from Padua on Sunday, 7 January 1610. The planet shone brightly in the southeast sky in the constellation Taurus soon after sunset, but Galileo did not record the time of the observation. He later stated that he had used an improved spyglass (the name "telescope" having not yet been proposed),

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which some researchers, on the basis of Galileo's remarks in *Sidereus nuncius*, have concluded was his new 30-power *perspiculum*, but which was probably (as Stillman Drake argued[2]) a stopped-down 20-power instrument. We have no information about how Galileo mounted the device. In any event, he was surprised to see what he took to be three fixed stars arranged in a straight line near the planet, one to the west and two to the east of Jupiter. He was sufficiently impressed that he immediately added a small sketch of what he had seen to a letter he had been writing.[3] Whether the letter was actually sent is unknown, but as we shall see, its discussion of the lunar surface provided the foundation for the first part of the *Sidereus nuncius*.

On the following evening, "guided by what fate I know not" as he later recalled, he looked again at Jupiter, and was surprised to find the planet to the left of all three small stars — surprised because he had assumed that Jupiter was in retrograde and should have been moving to the right. His immediate impulse, recorded in his notes, was to declare the calculators wrong. Puzzled, he was eager to check the situation the next evening, but clouds blocked the view. On 10 January the skies had cleared, and Galileo found only two stars, this time to the left of the planet (see Appendix). Clearly something very interesting was going on around Jupiter.

By Thursday evening, 11 January, Galileo must have realized that he would have to keep regular notes on the status of the little stars, so he wrote down what he remembered of the previous configurations (Figure 1). He recorded the patterns, not particularly accurately with regard to the detailed spacing of the stars, in a paragraph at the top of a fresh sheet of paper, indicating both by words and by a diagram that on the previous night (10 January) the third star had probably been blocked by the planet. Now, on the 11th, he included a more accurate diagram of the arrangement than on the previous nights, and a more detailed description of what he saw, concluding that three moving stars accompanied Jupiter. In his subsequent printed account he would go further, with a subtle Copernican hint, writing that the three stars wandered around Jupiter like Venus and Mercury around the Sun, and that, as many further observations would show, there are four wandering stars making their revolutions about Jupiter. (Note that the word 'satellite' was not in his vocabulary, as it had not yet been invented by Kepler.)

Stillman Drake, in an analysis that we find unconvincing, decided that the entire page of notes had been copied from a now-lost original document, and that in the copying Galileo had erroneously transposed his conclusion about the three moving stars that accompanied Jupiter from the following evening's record.[4] We can find no adequate grounds for such a claim. In fact, the writing for the following night's entry, 12 January, is subtly different, clearly finer, and arguably written at a different time. Galileo at first observed one star on each side of the planet, but as the sky became darker and he observed more diligently, he noticed another star very close to the east side of the planet. In his published version he sharpened his account, stating "In the third hour a third little star, not at all seen earlier, also began to appear".[5] And at this point he also wrote down, at the bottom of the page, Jupiter's longitude and latitude

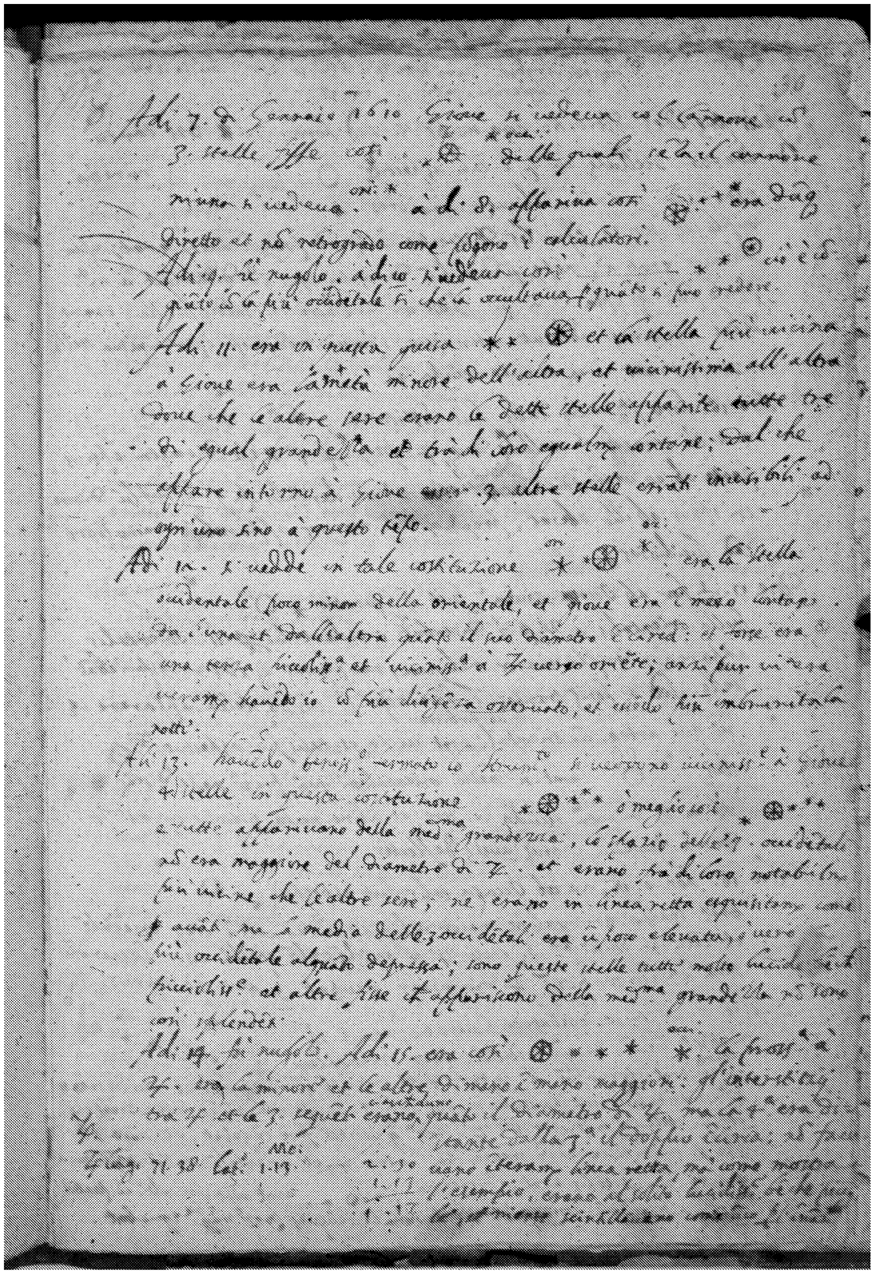


FIG. 1. Galileo's initial page of Jupiter observations. Galileiana 48, f. 30, Biblioteca Nazionale Centrale, Florence.

on 12 January as given in Giovanni Antonio Magini's *Ephemerides*.[6]

On the 13th yet another surprise awaited Galileo. This time four little stars appeared, and he diagramed them twice, trying a second time for a more accurate representation of their spacing. There had, in fact, been four satellites available to Galileo on the 8th, but the fourth one was so far to the east that he had missed it. And on the 11th two satellites crowded so close to the west side of Jupiter that they were lost in the glare of the planet.[7]

The final entry on the page, with a wider quill nib, records that the 14th was cloudy and that on the 15th the four satellites fell in a straight line to the west of the planet. But on this evening, unusually, Galileo stayed up with his *occhiale* until midnight, and by this time one of the four satellites had disappeared into the glare of the planet. The early observation was the last he recorded in Italian. On the verso of the sheet, after the final two lines in Italian, all the further observations including those made later that same night are in Latin. This dramatic transition must signal Galileo's understanding that he now had discoveries worthy of an international audience. In fact, the final two lines in Italian refer not to the observations, but to the way he proposed to make the illustrations: "They will be cut in wood, all on one block, the stars white and the rest black, and then the blocks will be sawn [into strips]." Thus, just over a week after his initial observation, he knew that he had to publish this astounding novelty.[8]

Within two weeks Galileo was in Venice consulting with the printer Thomas Baglioni[9] and leaving the first batch of manuscript text for his *Sidereus nuncius*, in which he described what he now called his *perspiculum* and opened his discussion of his lunar observations (to which we will turn presently). Drawings of the Moon from which the engravings were to be made must have accompanied the text. The title page, dedication, and license would come later, but on the very first page of the text itself he announced the discovery of four planets hitherto unseen, which he called the *Cosmica Sydera* or "Cosmic Stars" — carefully avoiding any mention of Jupiter, nor did he yet give the printer any of the Jupiter pages. For the moment the fact that the new wanderers accompanied Jupiter would be Galileo's closely guarded secret.[10] In a letter of 30 January to Belisario Vinta, the personal secretary to Cosimo de' Medici, after relating his discoveries about the Moon and the Milky Way, Galileo described his discovery of Jupiter's moons as follows:

> ... I have discovered four new planets, and I have observed their proper and particular motions, different among each other and from all the other motions of the other stars; and these new planets move around another very large star, not otherwise than Venus and Mercury, and perhaps the other known planets as well, move around the Sun.[11]

Not until some time after 16 February did Baglioni receive the first batch of Jovian material. Galileo must have sworn the printer to secrecy, for he still had not tipped his hand with respect to Jupiter's moons. Even in writing to Vinta a few days earlier to ask whether to call the new planets *Cosmici* or *Medicea*, Jupiter was still

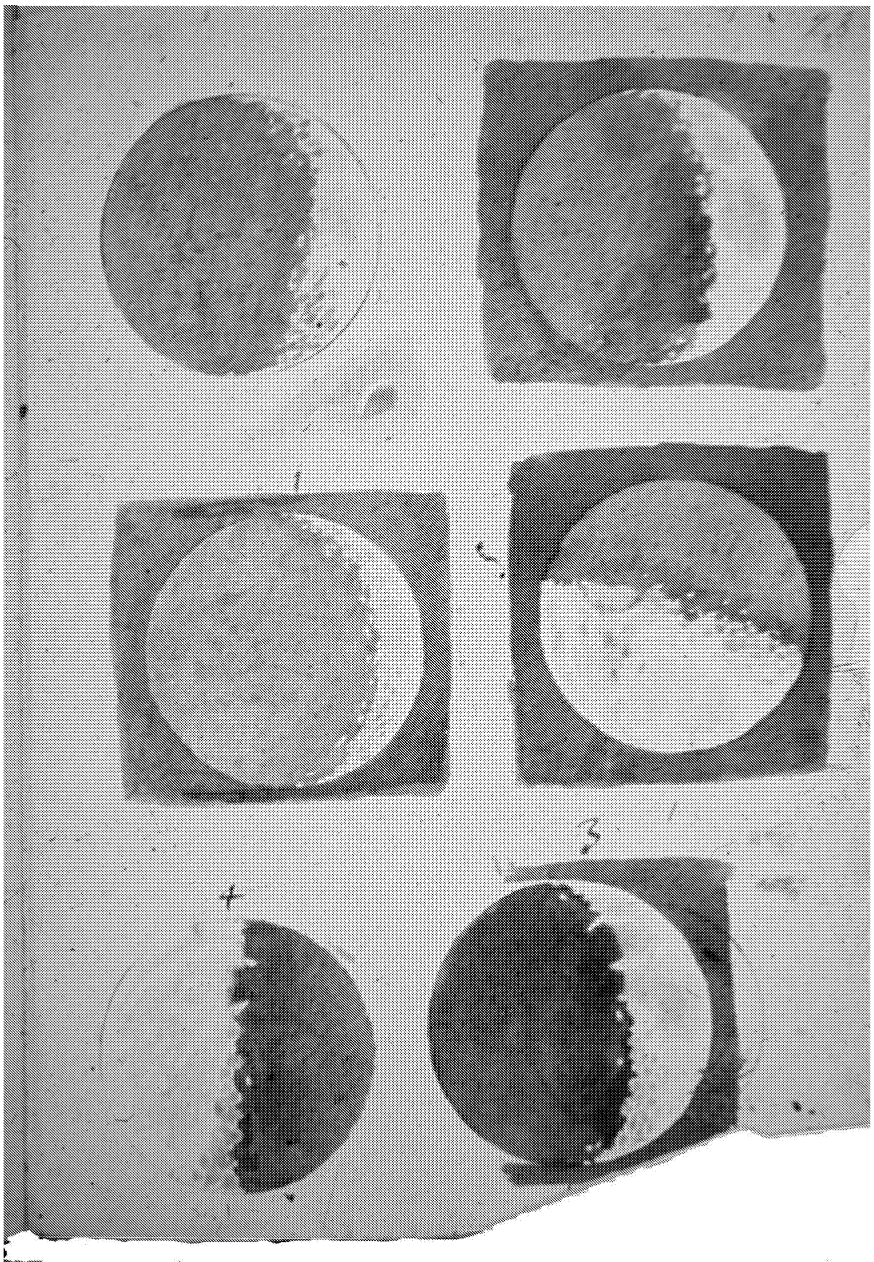


FIG. 2. Galileo's original watercolour sheet of inkwash images. Galileiana 48, f. 28, Biblioteca Nazionale Centrale, Florence.

not mentioned.[12] The word of Galileo's discoveries spread rapidly, and, for example, on 12 March the wealthy patron Marc Welser wrote from Augsburg to Christopher Clavius in Rome that he had heard of Galileo's discoveries with the new *visorio*, including four new planets, but he did not connect these with Jupiter.[13]

The manuscript for the second set of pages began by reviewing the new items that had been considered in the first part of the book: observations of the Moon, of the fixed stars, and the explanation of the Milky Way — the Galaxy, as Galileo called it. But not all of that text was yet in the printer's hands, so apparently Galileo instructed Baglioni to temporarily skip over one signature (that is, four numbered folio leaves) to accommodate the section he was still working on. Meanwhile, he had observed the Pleiades on 31 January and the belt and sword of Orion on 7 February, showing how many more stars the optical tube revealed compared to the unaided eye. Both of these observations are attested in the journal that included the records of Jupiter's little stars.[14] Galileo must have furnished full-size diagrams for the wood blocks. His drawing for the Orion stars survives among the papers in the Florence library,[15] and the block cutter followed it quite accurately.

* * *

Unlike the long dated sequence of Jupiter observations in Galileo's journal, the archive for the lunar observations consists of just two single sheets of watercolour paper with undated images of the Moon. At first glance it seems preposterous to suppose that this was Galileo's entire repository of lunar drawings, but we shall argue that these images suffice to account for the complete basis of the lunar portion of the *Sidereus nuncius.* It has been possible to extract a considerable amount of information from these inkwash drawings, and we will first review the literature leading to their interpretation.

An important key to their understanding came through a demonstration by Elizabeth Cavicchi, who, by making inkwash drawings of the Moon with her own telescope, showed that Galileo could have made his inkwash renditions of the Moon while observing it.[16] Previously we had assumed that the existing drawings had been compiled later as an archival record, but a closer examination of the two sheets of watercolour paper gives evidence that in fact they were the original sketches made at the telescope. In particular, the at-first-glance almost random placement of the images on the first sheet makes sense as an original record (Figure 2). In this interpretation (Figure 3) Galileo placed the sheet horizontally as he drew the earliest image of the crescent Moon (hanging in the western sky) in the upper, central position, followed the same night (30 November 1609) by a second image placed immediately to right as well as a detail of one of the craters. The following night, with the Moon higher in the sky and more toward the south, Galileo rotated the paper by 90° and drew the third image as shown. On the third consecutive evening (2 December 1609) he added the fourth image, in the lower right-hand corner. Perhaps because a small piece of the watercolour paper was snipped off from this corner, he moved the image to the left

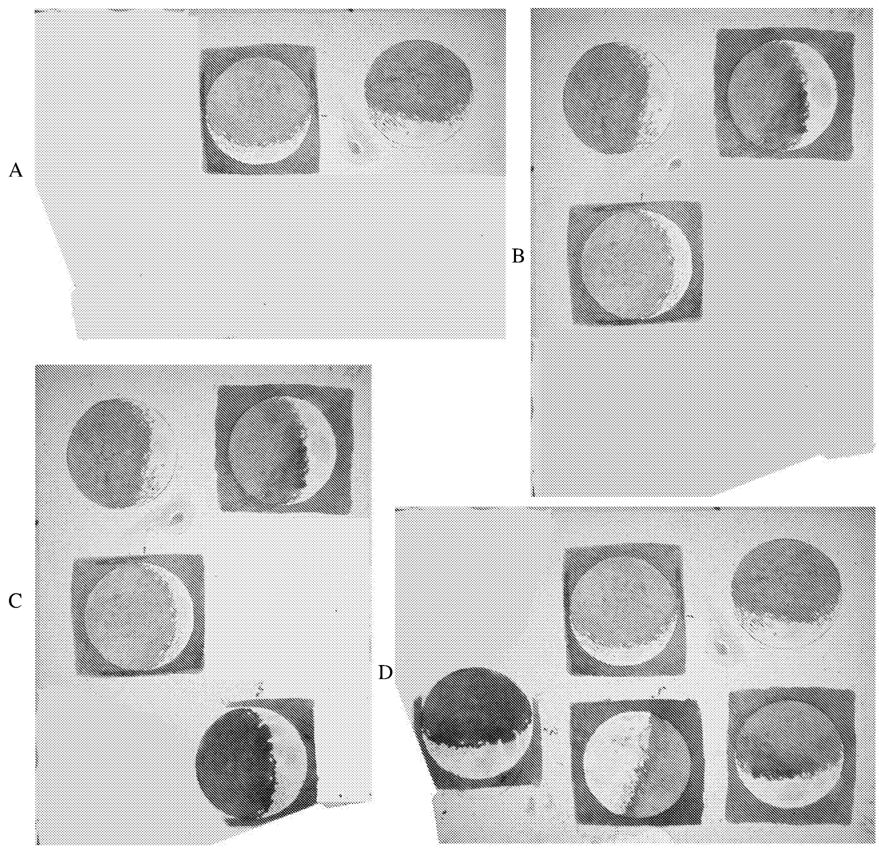


FIG. 3. Reconstructed progressive views of Galileo's sheet of lunar images. A: 30 November 1609. B: 1 December 1609. C: 2 December 1609. D: 17 December 1609.

compared to his original circle. He now laid the sheet aside for nearly two weeks, returning to a morning observation of the waning Moon on 17 December 1609. The one full space remaining lay between two earlier images, so he rotated the sheet to its original orientation and sketched the Moon as it appeared to the south in the pre-dawn sky. On the following morning he returned and filled the remaining, slightly cramped space with a fairly accurately timed view of the last quarter Moon, once more turning the sheet vertically to capture the image.

A reasonable chronology of these images has been established only in relatively recent years. This process, begun by the late Guglielmo Righini, involved the use of the engravings shown in *Sidereus nuncius* as well as the inkwash drawings. After examining the four engraved images for their astronomical information and comparing them with calculated lunar positions and phases for the second half of 1609, Righini concluded that the engravings represent four observations made between 2 October and 18 December 1609. Tentative as Righini's conclusions were, his point, forcefully argued, was that, given the limited time-frame within which these observations could have been made, Galileo's representations of the Moon, however flawed, contain sufficient information to date the observations when all factors are taken into account.[17]

In a comment on this paper, Owen Gingerich argued that we should be extremely cautious with Galileo's renditions of the Moon and not, for instance, rely on their accuracy so much (as Righini did) as to conclude that Galileo unknowingly recorded the Moon's libration.[18] Gingerich pointed out that the conditions that led Righini to choose 2 October 1609 as the date of Galileo's first drawing of the four- or five-day old Moon also applied on 29 January 1610, a date well within the frame of possible ones.

The exchange between Righini and Gingerich prompted Stillman Drake to re-examine the question of chronology in a paper published in this journal in 1976.[19] To Righini's purely astronomical approach Drake added his biographical knowledge. Drake pointed out that in view of the events in Padua in the summer and autumn of 1609 it is unlikely that the observation of the four- or five-day old Moon could have been made as early as 2 October 1609, and on the basis of Gingerich's comment he concluded that it must have been made on 29 January 1610. Drake accepted Righini's other datings and concluded that the lunar observations presented in *Sidereus nuncius* were made between 1 December 1609 and 29 January 1610.

It was at this point that Ewen Whitaker, one of the world's foremost selenographers, decided to re-examine the entire issue.[20] Whitaker compared the inkwashes and the engravings and concluded that, combined, they represented observations made on seven different nights. The first six of these were made between 30 November and 18 December 1609; the last isolated drawing found on the second sheet of watercolour paper was made on 19 January 1610. Whitaker's chronology has not been challenged and, except for the date of the second of the engravings, we take it as definitive. Apart from the dating of the four- or five-day old Moon, Righini's chronology was roughly confirmed by Whitaker.

If our hypothesis is correct, namely, that the inkwash drawings are the primary original archive of lunar images exploited by Galileo, we are faced with several puzzles. Were these the *only* images Galileo worked with, and if so, how can we understand the differences between the seven inkwash drawings and the four engravings published in the *Sidereus nuncius.* This will lead to a discussion of Galileo's purposes in using the pictures of the Moon versus his depiction of the Jovian moons.

It is quite possible that these seven drawings are the result of an explicit and planned research project with publication in mind. This would mean that Galileo had observed the Moon earlier and had perhaps made a few rough sketches that have not survived, and that at the end of November 1609 he prepared himself with the proper paper and brushes and set to work to depict the Moon during a cycle of its waxing and waning. In such a case, the context of discovery would now be in the past, and the context of justification begun. This would explain why, for example, he included a well-defined detailed image of a crater on the very first night of his inkwash record. The fact that he made two drawings the first night with entirely different backgrounds suggests that he was experimenting to find the most effective mode of presentation. We could then speculate that he had already begun writing a tract on the appearance of the Moon and that he was putting together the visuals.

Among scientists, the modern view of the accuracy of the engravings of the Moon in *Sidereus nuncius* is exemplified by Zdeněk Kopal, who has written on several occasions: "A mere glance at [Figure 2] will convince us that Galileo was not a great astronomical observer; or else that the excitement of so many telescopic discoveries made by him at that time had temporarily blurred his skill or critical sense; for none of the features recorded on this (and other drawings) of the Moon can be safely identified with any known markings of the lunar landscape."[21] Such a criticism goes back to the seventeenth century, when on this subject Johannes Hevelius, the father of selenography, wrote: "Galileo lacked a sufficiently good telescope, or he could not be sufficiently attentive to those observations of his, or, most likely, he was ignorant of the art of picturing and drawing, which art serves this work greatly and no less than acute vision, patience, and toil."[22] By comparing Figure 4(b) with a modern photograph of the same phase of the Moon (Figure 4(a)), we can easily see the problem.[23] We will deal with Galileo's purpose in presenting the Moon in this

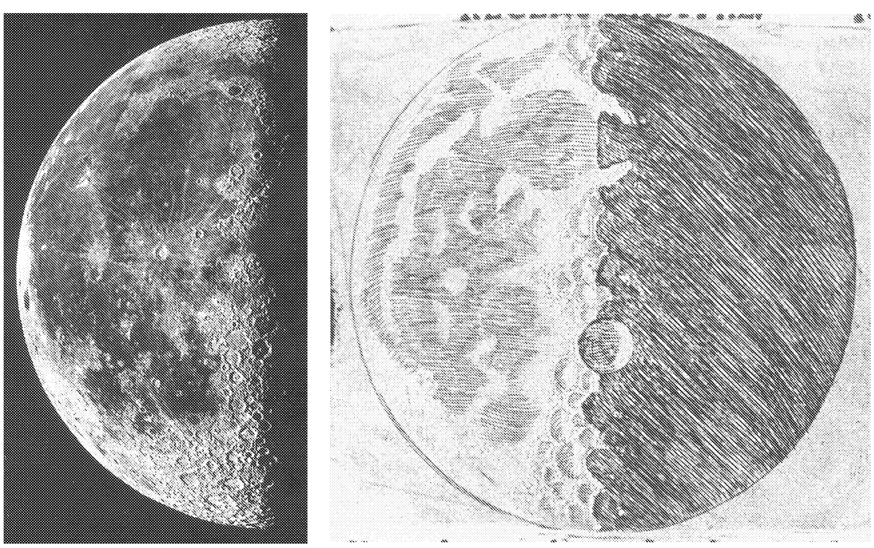


FIG. 4. (a) Photograph of the Moon at last quarter, Lick Observatory; (b) engraving of the Moon at last quarter, from *Sidereus nuncius*.

way in *Sidereus nuncius* below. For the present, it should be apparent from these figures that Galileo's published Moon does not quite look like our Moon, but that his unpublished inkwashes are somewhat more faithful.

Having established that Galileo could have made his inkwashes during his observations of the Moon, we are left with the problem of why, in his engravings in *Sidereus nuncius*, he distorted the picture and presented a large "spot" or crater on the terminator that is clearly not there, or at least not so large and dramatic. In order to resolve this problem, we must pay attention to Galileo's purpose. The fact is that, distorted as his engravings appear, they are the first naturalistic representations of any heavenly body ever published in an astronomy book. Hevelius's supposition that Galileo did not have good enough instruments or that he was lacking in artistic skills is falsified by the wash drawings. Moreover, as Samuel Edgerton has argued, for a mathematician Galileo was, in fact, unusually skilled in the art of *disegno*, and it was perhaps this skill that allowed him from the beginning to see relief on the Moon's surface.[24] Further, it is true that Galileo did not lavish the care on his lunar observations that Hevelius was to bring to the subject three decades later. His lunar research was done in about a month; Hevelius took five years.

The gulf that separates Hevelius from Galileo is not so much one of instruments, skill, or care, as one of purpose. Hevelius's aim was to depict the Moon's face as accurately as possible — to map it; Galileo's was to convince his reader that the Moon's surface was rough and uneven. The art of *disegno* in which Galileo was so well trained not only meant drawing accurately but also arranging objects to suit the purpose of the exercise (our idea of "design"). In Baroque art a drawing or painting was always a reference to something; it always illustrated a theme or text. In *Sidereus nuncius* the engravings referred to the argument about the Moon's surface. They were visual aids to the text, not maps or illustrations that could stand on their own feet. The accuracy was in the words, not the pictures. Had Galileo's purpose been to represent to Moon accurately, his contemporaries surely would have commented on the size of the large spot. In the engravings it is, in fact, so large, that it should have been visible with the naked eye. But Galileo's readers and critics did not comment on this fact because they shared with him the tenets of Italian Baroque art and understood the traditional mode of philosophical discourse. In the drawings of Thomas Harriot, who did not see the world through Italian Baroque eyes, there is a silent commentary on Galileo's distortions.[25]

In order for Galileo to convince the reader that the Moon's surface was rough like the Earth's, he had to make the argument that the shape of spots changed in accordance with the angle of illumination. He had to show changes over time. This he did brilliantly in his verbal descriptions, and he illustrated these by showing how in one spot, enlarged for this particular purpose (we would have done it with an inset), the changing illumination caused the dark outlines to shift. They were therefore shadows, and their changing shapes corresponded exactly to the changing angle of illumination. From this perspective it is not astonishing that Galileo subtly adjusted his inkwash drawing labelled 3, which was made a day before quadrature, to produce a first quarter image to pair with the third quarter illustration on the facing page in his *Sidereus nuncius*; both images show the huge illustrative crater. It is only on this engraving that we depart from Whitaker's dating.

It can be argued that Galileo could have made this same argument visually by including a long series of gradually changing views and making them larger, thus avoiding distortion and creating a visual argument parallel to his verbal argument. Such a course would perhaps have been less puzzling to us. It may very well have been an option Galileo considered, as we shall see in a moment. But two factors argue against such an approach: time and money. As best as we can determine, all of Galileo's lunar observations were made between 30 November and 17 December 1609, except for one in January 1610 when the Moon was near a fixed star. Up to the end of 1609 Galileo may very well have planned a more leisurely publication process, one that would involve many more lunar observations. But beginning on 7 January 1610 his attention was riveted on the small stars near Jupiter, and within a week he knew that he had to rush into print. The information he had gathered about the Moon would have to do. Furthermore, engravings were very expensive, and although Galileo had been actively trying to obtain patronage from the Medici, he could not turn to them at this point for financial help. As Mario Biagioli has argued, that would have been an unacceptable patronage strategy. His message from the stars had to be a completely disinterested gift to Cosimo II in order for it to have the desired result.[26] Galileo therefore had neither the time nor the funds to include an elaborate visual sequence about the Moon in his book. It is interesting to note that when, on 19 March 1610, Galileo sent copies of *Sidereus nuncius* to the Tuscan court together with the telescope with which he had discovered Jupiter's moons, he mentioned his desire to prepare a second, Tuscan, edition that would include precisely such a sequence of lunar phases.[27] As the Grand Duke's Mathematician and Philosopher he would have the time and resources for such an ambitious undertaking.

One further point needs to be made about Galileo's purpose. Whitaker begins his article as follows: "One of the basic precepts impressed upon all astronomical tyros, be they professional or amateur, is the necessity of dating and timing all observations, no matter how trivial they may seem to be at the time. One can, perhaps, forgive Galileo for failing to observe this precept with his pioneering lunar observations."[28] We would argue that there is nothing to forgive Galileo for. The body of *Sidereus nuncius* falls neatly into several parts. If we ignore for the moment the introductory material on the telescope, we see that there are two main parts, one about the Moon and the other about the satellites of Jupiter, separated by a brief section on the fixed stars and planets. The section about the Moon is almost a separate little treatise, and there is evidence to suggest that this was written very early. We find most of its points in abbreviated fashion in Galileo's letter written on 7 January 1610, the night he first observed Jupiter. It seems reasonable to suppose that up to the time he discovered Jupiter's satellites Galileo was working without the great urgency that the satellites impressed on him, toward a publication about the Moon and its earthlike nature. But arguing about the nature, that is the essence, of the Moon was not an astronomical (i.e., mathematical) but rather a cosmological (i.e., philosophical) undertaking according to the disciplinary boundaries of his day. When he was observing the Moon and preparing his argument, Galileo was not acting as an astronomer and was therefore not obliged to date his observations. In the parlance of the time, he was arguing about the Moon's essence, its earthlike nature, which was independent of its position or other mathematical (accidental) attributes. It is therefore not surprising that Whitaker remarked about the accuracy of Galileo's drawings and engravings: "... I have been surprised to find that they are more accurate in their *qualitative* portrayal of actual phases (their geometrical accuracy is clearly much poorer) than I had hitherto thought."[29] In other words, when Whitaker wore his quantitative selenographer's cap he could only conclude that Galileo's renditions of the Moon were not accurate; when, however, he put on his qualitative artistic cap he came to the opposite conclusion. This incommensurability is analogous to the division between the mathematical and philosophical subjects in Galileo's day. Philosophy (of which what we call cosmology was a part) was a qualitative endeavour. In his qualitative rendering of the Moon Galileo was wonderfully successful and, yes, even accurate.

* * *

In contrast to the presentation of the lunar drawings, or later, the elegant engravings of sunspots that appeared in his *Istoria e dimostrazioni intorno alle macchie solari* (1613),[30] both of which involved the physical nature of an astronomical body, the Jovian satellites required a much less elegant pictorial presentation, in fact, one that could be achieved by simple typesetting. Galileo approached his observations of Jupiter's moons very differently from those of the Moon. Since they were indistinguishable from fixed stars, their essence (planets, not stars) could only be concluded from their changing positions. Logging their positions was therefore crucial, and Galileo dated his observations accordingly. In this section of the book he was acting much more like a *puro astronomo* as opposed to an *astronomo philosofo*, to use his own words.[31]

Galileo's 13 February query to Vinta about the naming of the Jovian moons presumably went by the weekly courier to Florence the following day (Monday) and reached the Duke's secretary on Saturday. Vinta replied on Sunday, and Galileo must have got the disconcerting news by Saturday, 26 February: it was not a good idea to call the new planets "Cosmian" because readers would assume they were simply cosmic planets and would not realize that they were named in honour of Cosimo de' Medici. Since folio 5 bearing the designation "Cosmica Sydera" had already been printed, the word *Cosmica* had to be covered over in all 550 copies with a printed label reading *Medicea.*

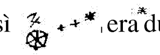
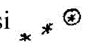
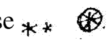
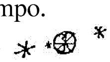
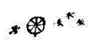
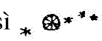
The printing of the *Sidereus nuncius* was now rushing toward its conclusion. The material intended for the skipped signature D was a patchwork of insertions upon insertions.[32] One of the last sections to be added was Galileo's calculation of the height of a mountain on the Moon. He had thought how to do this by measuring the distance of an isolated illuminated peak in the dark section beyond the terminator when the visible disk was half bright at quarter Moon. There was no need to observe the Moon again. He could simply measure his wash drawing of 18 December 1609, the image labelled 4 on his sheet of six images. Galileo remarked that the distance of an illuminated peak "sometimes exceeds 1/20 part of the diameter", which is a little stretch but reasonable for that image. But with this insertion the text and illustrations substantially overran the allotted quartet of folio leaves, that is, the eight pages of signature D that had been left open between f. 12 and up to f. 17 where the printing of the Jupiter material had begun.

The text that spilled over the numbered folios 13 to 16 had to go onto two more unnumbered folio leaves. Unfortunately this left a gap at the end of the second unnumbered leaf, and Galileo had to figure out how to fill that empty space. This he solved by adding wood blocks of Praesepe and the nebulous head of Orion, which illustrated his contention that fuzzy nebulae and the milkiness of the Milky Way could be explained by congeries of faint stars. He had not previously mapped these areas, however, and no record of such observations survives in his journal. Apparently he rushed out one evening, mapped the stars in these nebulae, and sent the diagrams straight to the block cutter. Neither diagram is as elegant as the large ones of the belt and sword of Orion or of the Pleiades, but there was a time crunch, and the smaller diagrams filled the remaining space.

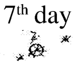
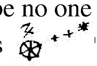
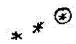
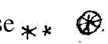
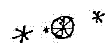
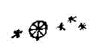
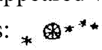
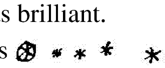
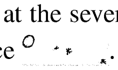
Almost simultaneously Galileo was adding a few more days of Jovian observations to his series. Like the diagrams of the head of Orion and Praesepe, they are not attested in his observing journal, for the observations seem to have gone straight to the printer. Galileo found them especially interesting because on 26 February through 2 March Jupiter passed near a small fixed star in Taurus.[33] The 2 March observation was the final piece for the text, and Baglioni had to use numerous Latin abbreviations on the final page of the text to make it fit.

What remained for the printer were the four leaves of the front matter: the title page and the dedication to Cosimo de' Medici. The *Sidereus nuncius* had received its license from the Venetian authorities on 1 March, and had been properly registered on 8 March. At some point Galileo had used part of the empty space on his second sheet of watercolour paper on which the final lunar drawing appeared to prepare a birth horoscope for the teen-aged Cosimo.[34] The astronomer referred in passing to several horoscopic details in his appropriately flattering dedication to the young duke — after all, it was a thinly disguised but dynamite job application for a position at the Medicean court. The dedication was dated 12 March, and the next day Galileo wrote to Vinta from Venice that copies of the book were now available. No doubt Baglioni was very happy to see this rushed project go out the door. From the time Galileo had brought him the first manuscript pages, just over six weeks had elapsed. It was, indeed, an astonishing performance. And Galileo got the job.

APPENDIX: GALILEO'S RECORD OF OBSERVATIONS OF JUPITER'S SATELLITES, 7–14 JANUARY 1610 (OPERE, III, 427–8)

A di 7. di Gennaio 1610 Giove si vedeva col Cannone con 3. stelle fisse così  delle quali senza il cannone niuno si vedeva. à di 8. appariva così  era dunque diretto et non retrogrado come pongono i calculatori.
A di 9. fu nugolo. à di 10. si vedeva cosi  ciò è congiunto con la più occidentale si che la occultava per quanto si puo credere. Adi 11. era in questa guise  . et la stella più vicina à Giove era la metà minore dell'altra, et vicinissima all'altra dove che le altre sere erano le dette stelle apparite tutte tre di egual grandezza et trà di loro egualmente lontane: dal che appare intorno à Giove esser .3. altre stelle erranti invisibili ad ogn'uno sin à questo tempo.
A di 12. si vedde in tale costituzione  era la stella occidentale poco minor della orientale, et giove era in mezo lontane da l'una et dall'altra quanto il suo diametro in circa: et forse era una terza piccolissima et vicinissima à ♃ verso oriente; anzi pur vi era veramente havendo io con più diligenza osservato, et essendo più imbrunita la notte.
A di 13. havendo benissimo fermato lo strumento si vveddono vicinissime à Giove 4. stella in questa costituzione  o meglio così  e tutte apparivano della medesima grandezza, lo spazio delle .3. occidentali non era maggiore del diametro di ♃. et erano frà di loro notabilmente più vicine che le altre sere; ne erano in linea retta esquisitamente come per avanti ma la media delle .3 occidentali eran un poco elevata, ò vero la più occidentale alquanto depressa; sono queste stelle tutte molto lucide benche picciolissime et altre fisse che appariscono della medesima grandezza non sono così splendenti.
A di 14. fù nugolo. A di 15. era così  la prossima à ♃. era la minore et le altre di mano in mano maggiori: gl'interstizzii tra ♃ et le 3. sequenti erano in ciascheduno quanto il diametro di ♃. ma la 4a. era distante dalla 3a. il doppio incirca: non facevano interamente linea retta, mà come mostra l'esempio, erano al solito lucidissime benché piccole, et niente scintillavano come anco per l'inanzi faransi intagliar in legno tutte in un pezzo, et le stelle bianche il resto nero e poi si segherannno i pezzi.
Fuit praecedens constitutio hora noctis 3. sed hora 7 tres tantum aderant stellulae cum ♃ in tali aspectu  minima erat iovi vicinior parva, reliquae 2 maiores duplo. et inter se aequales. distantia à 4 ad proxima aucta erat; ipsa vicinior erat secundae nempe per dimidium diametri ♃ 3.a distabat à 2.a paulo plus quam ipsa 2.a a ♃. Post vero aliam horam 2. mediae stellulae erant ad huc viciniores adeo ut inter ipsas spacium mediaret ipsa minima stella minus; scilicet circa minuta secunda 40.

Translation

On the 7th day of January 1610, Jupiter was seen with the tube with three fixed stars, thus:  Without the tube no one had seen them.
On the 8th day it appeared thus  It was therefore direct and not retrograde as the calculators suppose.
On the 9th day it was cloudy.
On the 10th day it appeared thus: . It was in conjunction with the westernmost one, so that it occulted it as far as can be ascertained.
On the 11th day it was in this guise , and the star nearest to Jupiter was half as small as the other, and very close to the other, whereas the other evening the said stars had appeared all three of equal size and equally far from each other. From this it appears that around [near] Jupiter there are three other errant stars invisible to every one up till this time.
On the 12th day it appeared in this formation: . The eastern star was a bit smaller than the western one, and Jupiter was in the middle between the one and the other, removed from each by about its diameter. And perhaps there was a third, very small and very close to Jupiter toward the East or rather it was there indeed, because I observed with greater diligence, and the night was darker.
On the 13th day, after I had fixed the instrument very well, there appeared very close to Jupiter four stars in this formation  or better like this: , and all appeared of the same size. The space between the 3 western ones was not larger than the diameter of Jupiter, and with respect to each other they were noticeably closer than the other evening; and they were not precisely in a straight line as before, but the middle one of the three western ones was a bit higher [elevated], or rather, the westernmost one was somewhat lower. These stars are all very bright, although very small, and other fixed stars that are the same size are not as brilliant.
On the 14th day it was cloudy. On the 15th day it was like this . The one next to ♃ was the smallest and the others sequentially larger. The distances between ♃ and the three in sequence were each equal to the diameter of ♃, but the fourth one was about twice as far from the third. They did not form an entirely straight line, but [were arranged] as the drawing shows. They were, as usual, very bright but small and, as before, also did not scintillate at all. They will be cut in wood, all on one block, the stars white and the rest black, and then the blocks will be sawn [into strips].
That was the formation at the third hour of the night, but at the seventh hour only three little stars were present with Jupiter, in this appearance . The little one closest to Jupiter was smallest, the other two twice as large and equal to each other. The distance from Jupiter to the nearest one had increased; this one was closer to the

second, that is at half a diameter of Jupiter. The third was distant from the second by a bit more than the second was from Jupiter. After another hour, the two little middle stars were so close to each other that between them there remained a space smaller than that smallest star, that is about 40″.

Acknowledgments

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Opere: *Le Opere di Galileo Galilei. Edizione Nazionale*. Edited by Antonio Favaro (20 vols, Florence, 1890–1909; reprinted 1929–39 and 1964–66).

1. Galileo to Belisario Vinta, 19 March 1610, *Opere*, x, 300.
2. Stillman Drake, "Galileo's first telescopic observations", *Journal for the history of astronomy*, vii (1976), 153–68, espec. pp. 158–9.
3. Galileo to ?, 7 January 1610, *Opere*, x, 273–8, p. 277. Favaro thought the letter was addressed to Antonio de' Medici; Stillman Drake thinks it is more probable that the addressee was Enea Piccolimini (*Galileo at work* (Chicago, 1978), 143–4). Drake has translated the entire letter in the article cited in ref. 2.
4. Drake, *Galileo at work*, 148–52.
5. Galileo Galilei, *Sidereus nuncius or the Sidereal messenger*, translated by Albert Van Helden (Chicago, 1989), 67.
6. G. A. Magini, *Ephemerides coelestium motuum* (Venice, 1582), f. 444v. Note that for his horoscope of Cosimo II de Medici, prepared at about the same time, Galileo also used these *Ephemerides* (see Owen Gingerich, *Journal for the history of astronomy*, xxi (1990), 369).
7. Currently, there are several computer programs that will give the formation of Jupiter's Galilean satellites for any given date; we have used Barbara Becker's results from the Redshift program. Earlier, the calculations for the first week of Galileo's observations were made by Jean Meeus, "Galileo's first records of Jupiter's satellites", *Sky and telescope*, xxiv (1963), 137–9.
8. Stillman Drake, "Galileo gleanings XIII", *Physis*, iv (1962), 342–4: "... decision to publish ... made precisely at that time."
9. Galileo to Belisario Vinta, 30 January 1610, *Opere*, x, 280–1.
10. Galileo's continuing desire to maintain a monopoly on astronomical discoveries is chronicled in Mario Biagioli, "Replication or monopoly? The economics of invention and discovery in Galileo's observations of 1610", *Science in context*, xiii (2000), 547–93; reprinted in *Galileo in context*, edited by Jürgen Renn (Cambridge, 2001), 277–320.
11. *Ibid*., 280.
12. Galileo to Belisario Vinta, 14 February 1610, *ibid.*, 283.
13. Marc Welser to Christopher Clavius, 12 March 1610, *ibid*., 288.
14. *Opere*, iii, 432–3.
15. *Ibid*., 49. See also 50.
16. Elizabeth Cavicchi, "Painting the Moon", *Sky and telescope*, lxxxii (1991), 313–15.
17. Guglielmo Righini, "New light on Galileo's lunar observations", in *Reason, experiment, and mysticism in the Scientific Revolution*, edited by Maria Luisa Righini Bonelli and William R. Shea (New York, 1975), 59–76. See also Guglielmo Righini, *Contributo alla interpretazione scientifica dell'opera astronomica di Galileo* (Monografia, Istituto e Museo di Storia della Scienza,

Florence, 1978, no. 2).
18. Owen Gingerich, "Dissertatio cum Professore Righini et Sidereo Nuncio", in Righini Bonelli and Shea (eds), *op. cit.* (ref. 17), 77–88.
19. Drake, *op. cit.* (ref. 2).
20. Ewen A. Whitaker, "Galileo's lunar observations and the dating of the composition of 'Sidereus Nuncius'", *Journal for the history of astronomy*, ix (1978), 155–69.
21. Zdeněk Kopal, *The Moon* (Dordrecht, 1969), 225; Kopal and Robert W. Carder, *Mapping of the Moon, past and present* (Dordrecht, 1974), 4.
22. Johannes Hevelius, *Selenographia sive Lunae descriptio* (Gdansk, 1647), 205.
23. Galileo's telescopes had a field of view of about one-quarter of a degree and could therefore show only one-quarter of the lunar surface in one view. This was a handicap in efforts to map the Moon and it goes some way toward explaining inaccuracies, including those of Hevelius himself, before about 1650, when the astronomical telescope with its much larger field of view replaced the Galilean telescope in astronomical research.
24. Samuel Y. Edgerton, "Galileo, Florentine 'Disegno' and the 'Strange Spottednesse' of the Moon", *Art journal*, xliv (1984), 225–32. See also Albert van Helden and Mary G. Winkler, "Representing the heavens: Galileo and visual astronomy", *Isis*, lxxxiii (1992), 195–217, and "Johannes Hevelius and the visual language of astronomy", in *Renaissance and revolution: Humanists, scholars, craftsmen, and natural philosophers in early modern Europe*, ed. by J. V. Field and Frank A. J. L. James (Cambridge, 1994), 97–116.
25. *Ibid.*; Terrie Bloom, "Borrowed perceptions: Harriot's maps of the Moon", *Journal for the history of astronomy*, ix (1978), 117–22.
26. Mario Biagioli, *Galileo courtier: The practice of science in the culture of absolutism* (Chicago, 1993), *passim.*
27. Galileo, *op. cit.* (ref. 1).
28. Whitaker, *op. cit.* (ref. 20), 155.
29. *Ibid.*, 158.
30. See Mario Biagioli, "Picturing objects in the making: Scheiner, Galileo and the discovery of sunspots", *Ideals and cultures of knowledge in early modern Europe*, ed. by Wolfgang Detel and Claus Zittel (Berlin, 2002), 39–96.
31. Galileo Galilei, *Istoria e dimostrazioni intorno alle macchie solari e loro accidenti* (1613), *Opere*, v, 71–249, esp. p. 102.
32. The patchwork of insertions can be unpacked by following Galileo's system of special symbols in the manuscript printed in *Opere*, iii, 17–47.
33. HD 32811 = SAO 76962 = Hip 23784.
34. The horoscope was first dated by Gingerich, *op. cit.* (ref. 18), 88, and subsequently Guglielmo Righini pointed out that the date matched Cosimo's birthday, "L'Oroscopo Galileiano di Cosimo de' Medici", *Annali dell'Istituto e Museo di Storia della Scienza di Firenze*, i (1976), 29–36.