Galileo, Florentine "Disegno," and the "Strange Spottednesse" of the Moon

By Samuel Y. Edgerton, Jr.

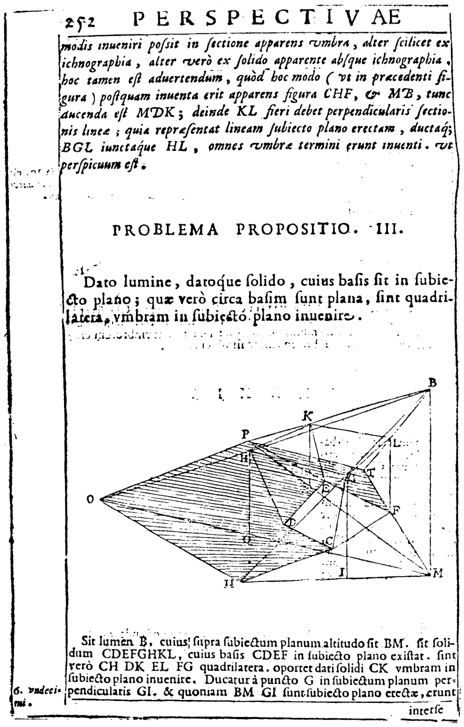
"Painting . . . compels the mind of the painter to transform itself into the very mind of nature, to become an interpreter between nature and art. It explains the causes of nature's manifestations as compelled by her laws."[1] So wrote Leonardo da Vinci, and, as Kenneth Keele has argued in an exciting new book, it was Leonardo's artistic training, particularly in linear perspective, that provided him with so many precocious insights concerning the underlying scientific structures of the universe.[2] Indeed, Leonardo believed that all the forms and functions of the world could be explained geometrically following the principle of the perspective pyramid.[3] The more he applied perspective principles to his pictorial descriptions of the world, the more he became convinced that many of the prevailing explanations were in error. Although Leonardo's own analyses were often too geometric and mechanistic, his constant observations of analogies between different phenomena, like the coursing of water through the earth and the flow of blood through the veins and arteries, moved him ever closer to making major scientific discoveries.

After Leonardo's death in 1519, his spirit of ingenious interchange between art and science lived on in Renaissance Europe, even though few scientists had access to the Florentine polymath's original manuscripts. The sixteenth century is replete with cooperative enterprises between scientists and artists—Vesalius and Jan van Kalcar, Otto Brunfels and Hans von Weiditz, to name but a few—that managed to rediscover much of Leonardo's science through the medium of perspective drawing. I should like now to show that the seventeenth-century scientist Galileo Galilei (1564–1642) also imbibed deeply of Leonardo's method when in 1610 he described the true nature of the lunar surface, seen for the first time through his modest telescope. This revolutionary discovery was made in Venice, Galileo's temporary residence, yet it surely responded not only to Leonardo but to the whole artistic tradition of Florence, his native city. Galileo also drew his own pictures of the moon, and I shall argue that we have here a clear case of cause and effect between the practice of Italian Renaissance art and the development of modern experimental science.

The Florence of the late sixteenth century, which gave Galileo intellectual nurture during his formative years, was extraordinarily self-conscious and proud of its great artistic tradition. The Medici grand dukes who became Galileo's patrons were particularly aware and exploited that tradition skillfully for their own political purposes. In 1562, under the auspices of Grand Duke Cosimo I, Giorgio Vasari founded the Accademia del Disegno, the first artists' "academy" ever created to function as an association of intellectuals rather than of mere artisans. Vasari's aim was not only to foster higher social status for artists but also to provide a center where young painters and sculptors could learn "drawing," the proper foundation for all the visual arts including architecture. By "drawing," Vasari meant composition, anatomy, and perspective—particularly the last, which also included chiaroscuro, or the rendering of light and shadow. The Academy even provided for a professional mathematician, an outside *visitatore,* to teach the elements of Euclidian geometry and perspective to aspiring artists. It is noteworthy that Galileo applied for that post in 1589.[4] He was not hired, but his intention at such an early age is indicative of his lifelong interest in the relation between art and science.

Furthermore, Galileo maintained a close personal relationship with a prominent Florentine painter, Lodovico Cardi called Cigoli, who was a member of the Academy. Erwin Panofsky has already examined their correspondence, which had to do with, among other things, a discussion of Mannerism.[5] Galileo expressed strong opposition to the vagaries of the Mannerist style and favored the return of art to classical, geometrically solid forms. Cigoli, in turn, lauded Galileo's own skill in perspective drawing, even acknowledging that in that geometric art Galileo was his "master."[6] Indeed, Galileo's increasing interest and ability in the art of drawing led finally, in 1613, to his own admittance to the prestigious Accademia del Disegno.[7]

The study of perspective in the sixteenth century appealed to a wide range of mathematicians who otherwise had no interest in the visual arts. Numbers of illustrated books were printed on the subject, particularly in Germany, where, under the influence of Albrecht Dürer, the issue of perspective projection fascinated such scientists as Johannes Kepler.[8] In Italy, too, mathematicians such as Federico Commandino and Guidobaldo del Monte published perspective books. The latter was one of Galileo's strongest supporters, procuring for the young scientist his first teaching position, the mathematics chair at the University of Pisa in 1589. Guidobaldo's *Perspectivae libri sex* (Pe-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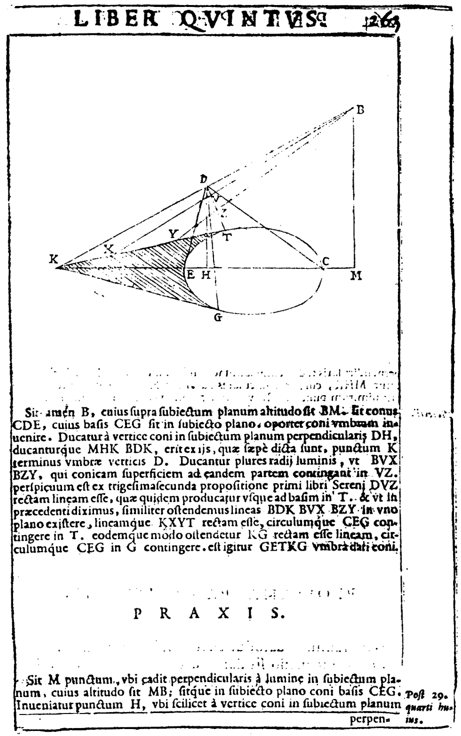
modis inueniri possit in sectione apparens vmbra, alter scilicet ex ichnographia, alter verò ex solido apparente absque ichnographia, hoc tamen est aduertendum, quòd hoc modo (vt in præcedenti figura) postquam inuenta erit apparens figura CHF, & MB, tunc ducenda est MDK; deinde KL fieri debet perpendicularis sectionis lineæ; quia repræsentat lineam subiecto plano erectam, ductaq; BGL iunctaque HL, omnes vmbræ termini erunt inuenti. vt perspicuum est.

PROBLEMA PROPOSITIO. III.

Dato lumine, datoque solido, cuius basis sit in subiecto plano; quæ verò circa basim sunt plana, sint quadrilatera, vmbram in subiecto plano inuenire.

Sit lumen B, cuius supra subiectum planum altitudo sit BM. sit solidum CDEFGHKL, cuius basis CDEF in subiecto plano existat. sint verò CH DK EL FG quadrilatera. oportet dati solidi CK vmbram in subiecto plano inuenire. Ducatur à puncto G in subiectum planum perpendicularis GI. & quoniam BM GI sunt subiecto plano erectæ, erunt interse

Fig. 1 Irregular solid casting a shadow on a plane. Guidobaldo del Monte, *Perspectivae libri sex,* Pesaro, 1600.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Sit lumen B, cuius supra subiectum planum altitudo sit BM. Et conus CDE, cuius basis CEG sit in subiecto plano. oportet coni vmbram inuenire. Ducatur à vertice coni in subiectum planum perpendicularis DH, ducanturque MHK BDK, erit ex iis, quæ sæpè dicta sunt, punctum K terminus vmbræ verticis D. Ducantur plures radij luminis, vt BVX BZY, qui coniceam superficiem ad eandem partem contingant in VZ. perspicuum est ex trigesimasecunda propositione primi libri Sereni DVZ rectam lineam esse, quæ quidem producatur vsque ad basim in T. & vt in præcedenti diximus, similiter ostendemus lineas BDK BVX BZY in vno plano existere, lineamque KXYT rectam esse, circulumque CEG contingere in T. eodemque modo ostendetur KG rectam esse lineam, circulumque CEG in G contingere. est igitur GETKG vmbra dati coni.

PRAXIS.

Sit M punctum, vbi cadit perpendicularis à lumine in subiectum planum, cuius altitudo sit MB; sitque in subiecto plano coni basis CEG. Inueniatur punctum H, vbi scilicet à vertice coni in subiectum planum perpen- Post 29. quarti huius.

Fig. 2 Cone casting a shadow on a plane. Guidobaldo del Monte, *Perspectivae libri sex,* Pesaro, 1600.


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Fig. 3 "Mazzocco." Daniel Barbaro, *La pratica della prospettiva,* Venice, 1568/9, p. 125.

saro, 1600), containing a whole section (Book Five) on how cones and irregular geometric solids cast shadows on flat and inclined planes ***(Figs. 1 and 2),*** would certainly have been studied by Galileo.[9] He would surely have also been familiar with the old Florentine perspective problem of the *mazzocchio,* that complex, geometrically framed headpiece popular in Quattrocento millinery fashion which so fascinated Paolo Uccello, Piero della Francesca, and Botticelli. The *mazzocchio* problem had in fact been reviewed and expanded upon by Daniel Barbaro in his *La pratica della prospettiva* (Venice, 1568) ***(Fig. 3),*** a text often consulted by members of the Florentine Academy.[10] This book offered even more complicated variations, such as reticulated spheres with raised protuberances ***(Figs. 4 and 5).*** Students were expected to draw the shades and shadows cast on these irregular objects by bright light from a single source. A group of similar problems was set by a well-known German treatise composed at the same time, Wenzel Jamnitzer's *Perspectiva corporum regularum* (Nuremburg, 1568), that Galileo might also have seen ***(Fig. 6).***[11] To be sure, Galileo could hardly have remained unaware of this kind of perspective literature, coming as he did from Florence. Still other examples probably known to him were the woodcuts of irregular spheres and polyhedrons published in Luca Pacioli's *Divina proportione* (Venice, 1509), ***(Fig. 7),*** the original drawings for which were traditionally attributed to Leonardo.[12]

Let us for a moment take leave of Galileo's Florence to look in briefly on Jacobean London, where we find Galileo's contemporary Thomas Harriot also engaged in the study of mathematics and astronomy. Harriot (1560–1621), who had mapped Virginia for Sir Walter Raleigh in 1585–86, turned his attention in 1609 upon the moon. In fact, he observed it with a telescope, anticipating Galileo by about six months. He managed to procure one of the new Flemish instruments (called "perspective tubes" in seventeenth-century English) of about six-power. After focusing it on the evening sky and seeing the moon magnified for the first recorded time, he made a drawing, with no comment save the date and time: "1609, July 26, hor. 9.p.m. . . . First quarter, 5 days."[13] His crude sketch ***(Fig. 8)*** shows little new about the moon, but it does reveal a critical difference in the manner of studying astronomy in London and in Florence during the early seventeenth century.

Following Aristotle, Europeans of the Middle Ages and the Rennaissance believed that the moon was a perfect sphere, the prototypical shape not only of the visible planets and stars but of the entire universe.[14] Christians added to this symbolism by seeing the moon as the sign of the Immaculate Conception; "pure as the moon" became a common simile. Christian sentiment had always held that the universe was incorruptible, that God would not have created the moon or any heavenly body in any form other than that of a perfect sphere. Renaissance artists, especially in the Catholic countries, frequently depicted the Virgin Mary standing on the moon that was represented as a translucent, alabasterlike ball.[15] In England also, the absolute sphericity of the lunar body was taken for granted. The problem, thus, was not to determine its shape, which all accepted, but to explain the mottled appearance of its surface, that "strange spottednesse," as Harriot called it. Some ancient authorities had explained the spots by arguing that the lunar surface was like a gigantic mirror reflecting the lands and seas of the earth. Others had claimed that the moon was composed of transparent substance with some internal denser matter giving off varying amounts of light.[16]

In England, the anti-Aristotelian Francis Bacon had concluded that the moon was not a solid body at all but composed of "vapour."[17] Thomas Harriot's own initial inference remains unknown, since he never published anything about his first lunar observation. We have only his rough sketch from which to extrapolate what he believed he saw through his telescope ***(see Fig. 8).*** That drawing shows the terminator (the division between illuminated and unilluminated portions of the moon) drawn with short, ragged strokes, indicating that he did not see it as a straight line, as it would have looked if on a smooth sphere. Within the upper illuminated area of the moon, Harriot noticed the darker configurations of what we now

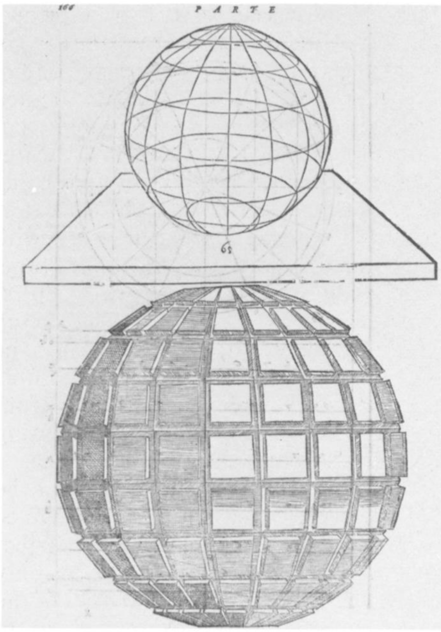

Fig. 4 Projection of a planisphere with raised protuberances. Daniel Barbaro, *La pratica della prospettiva,* Venice, 1568/9, p. 166.

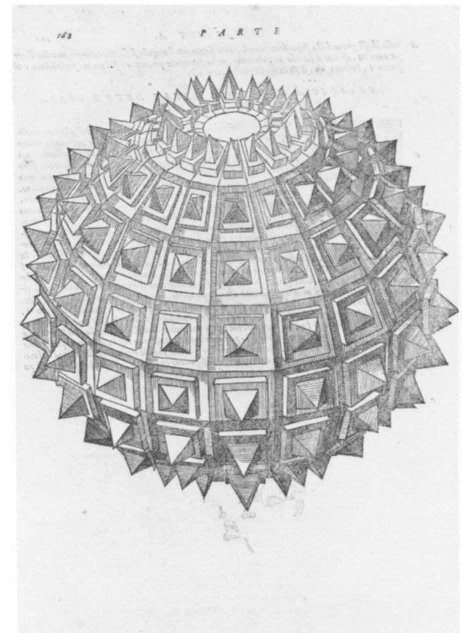

Fig. 5 Sphere with raised protuberances. Daniel Barbaro, *La pratica della prospettiva,* Venice 1568/9, p. 162.

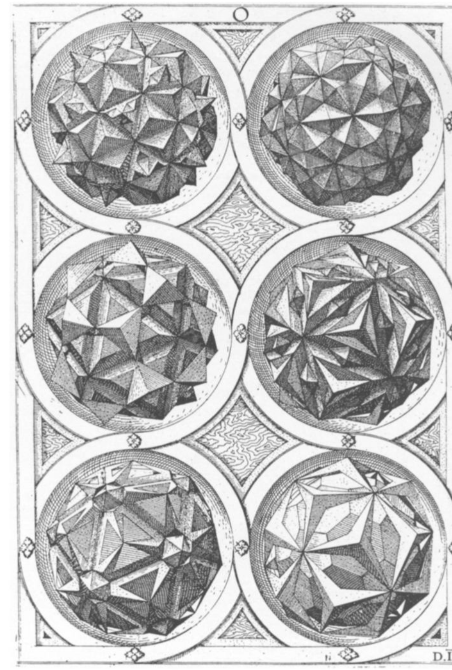

Fig. 6 Irregular hemispheres. Wentzel Jamnitzer, *Perspectiva corporum regularum,* Nuremburg, 1568.

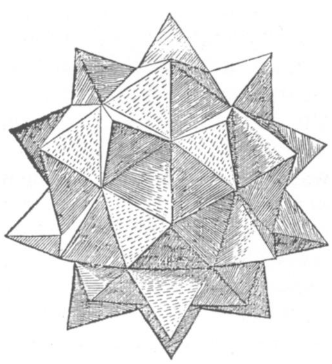

Fig. 7 Dodecahedron. Luca Pacioli, *De divina proportione,* Venice, 1509.

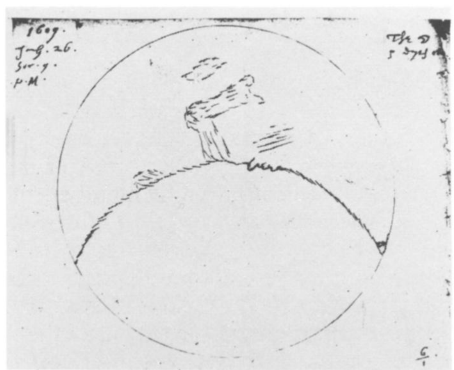

Fig. 8 Harriot's first lunar drawing. Petworth mss., Leconfield HMC 241/ix, f. 26.

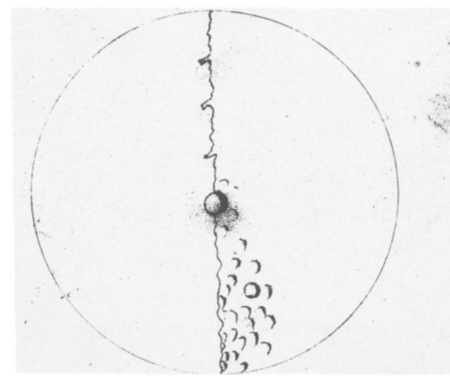

Fig. 9 Harriot's second lunar drawing. Petworth mss., Leconfield HMC 241/ix, f. 20.

know as the concave maria. Clearly, he saw these as finite surface markings rather than as amorphous "densities" within some diaphanous "vapour," and, thus, recognized that the moon's surface is solid and opaque. But he still did not know why the terminator appeared irregular, or what caused those darkened spots.

Why did Harriot miss what Galileo would see so precisely just a few months later? Was it only because his telescope was less powerful? We do not know exactly how the instruments of the two observers differed from each other, but it would surely be unfair to put the blame solely on Harriot's lenses. The fact is that no sooner had Galileo's discovery been announced in England, within weeks after its publication in Italy, than Englishmen recognized instantly what they had not seen before. As Marjorie Nicolson has exhaustively shown, poets as well as astronomers were now able to observe those heretofore unseen "mountains and umbrageous dales" through any kind of telescope.[18] Even Harriot "saw" shaded craters once he was aware of the Florentine's observations. In July of 1610, he made his second dated lunar drawing ***(Fig. 9),*** but, like his first, with no further written comment. We note here how the Englishman tried to sketch the moon's concavities by pen-stroke circles and half-circles as if trying to imitate Galileo's own renderings. One modern scholar, Terrie Bloom, has even argued that Harriot simply copied from Galileo.[19]

Bloom argues further that the reason Harriot had been unable in the first instance to "see" correctly the lunar surface was that he had had no "theoretical framework" in which to fit the strange revelations of his telescope. Bloom does not go on to identify just what "framework" had inspired Galileo, but I believe that she has put her finger on the truth.

Galileo did indeed have the right theoretical framework for solving the riddle of the moon's "strange spottednesse." Unlike Harriot, he brought to his telescope a special "beholder's share" (as E.H. Gombrich would say); that is, an eyesight educated to "see" the unsmooth sphere of the moon illuminated by the sun's raking light. His first telescopic image must have recalled those shaded-sphere problems in Barbaro's and Guidobaldo del Monte's perspective treatises.

Before examining Galileo's artistic response to the lunar landscape, we should bear in mind that in 1609 Italian Renaissance art, especially its theoretical side, had only just begun to chal-

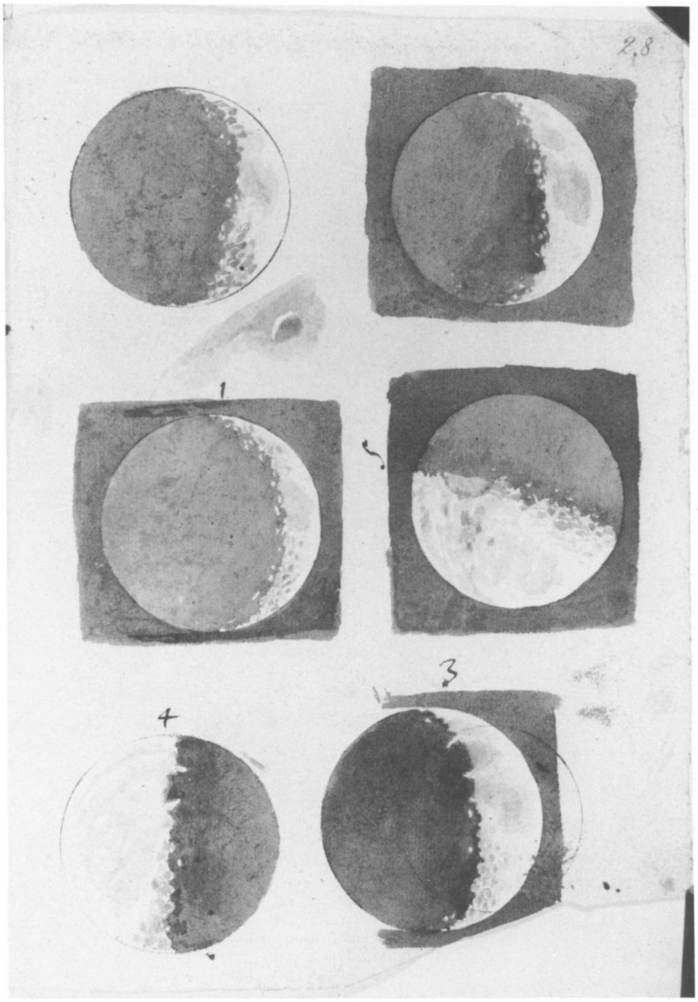

Fig. 10 Galileo's moon drawings. Bibl. Naz., Florence, Gal. 48, f. 28r.

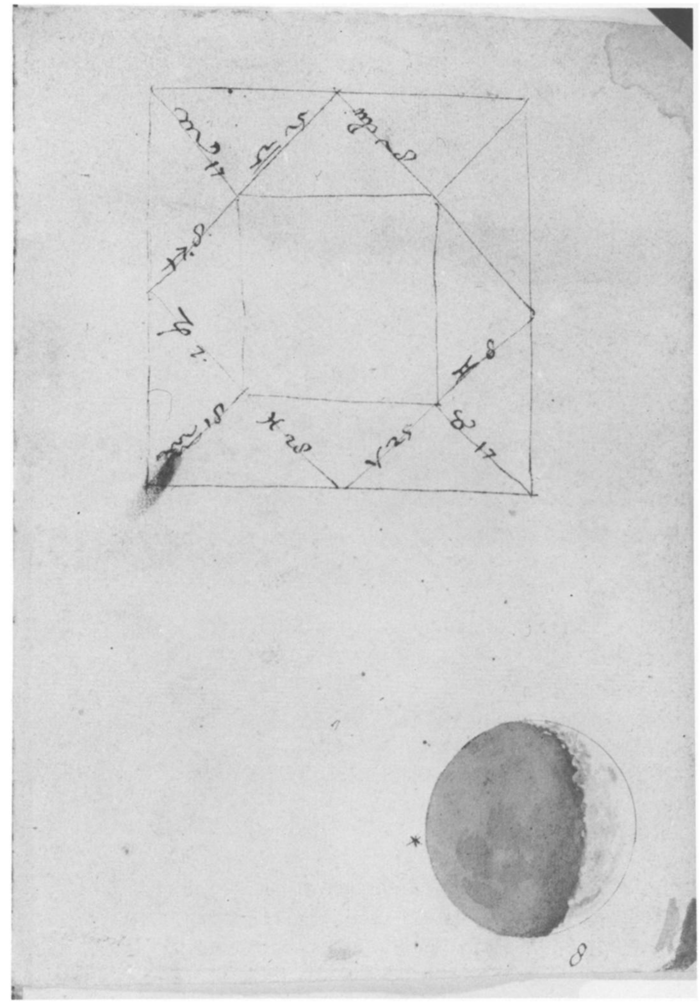

Fig. 11 Galileo's moon drawing. Bibl. Naz., Florence, Gal. 48, f. 28v. (This drawing contains an unrelated horoscopic diagram.)

lenge England's insular mentality. While literature flourished in Britain, the visual arts there still languished in a sort of retardataire Gothic survival. Inigo Jones, the first Englishman to have talent for Italian *disegno,* was barely on the scene, and linear perspective was not yet a serious subject of study even for artists. Although Harriot could certainly have read any of the continental perspective treatises in their Latin editions, the fact is that the demand in England for books on that subject was so slight that no native publication appeared until 1670 when Joseph Moxon printed a very modest and eclectic manual called *Practical Perspective.*[20] Jacobean London, for all its literary brilliance, offered Harriot no *visual* conceptual framework to compare to that which Florence provided Galileo by 1609.[21] It is a curious fact, if only a coincidence, that in 1611, hardly a year after England heard Galileo's stunning announcement, Inigo Jones was appointed Surveyor to the Prince of Wales, and Sebastiano Serlio's *Treatise on Architecture,* including Book Two on linear perspective, was translated into English. Both events—following immediately upon the news of Galileo's discovery—signaled the arrival finally of the Italian Renaissance to the British Isles.

In Venice meanwhile, Galileo knew nothing of Harriot's lunar observations. In fact, he learned much later than did Harriot about the Flemish invention of the telescope. Nevertheless, with remarkable ability, he taught himself the optical technology and, very much in Leonardo's spirit, managed to build several telescopes himself, improving the instrument eventually to some thirty-power. It is not certain just when or with what telescopic power he first looked upon the moon, but it was probably in November or December of 1609.[22] It is likely, however, that his primitive tube allowed him to see not the whole moon at once but only one section of it at a time. In any event, Galileo understood immediately what he was seeing. If he made first-hand sketches of these lunar sections directly from the telescope, they have not survived. But we do have seven small sepia drawings, each of a phase of the whole moon, which are still preserved on two sides of a single sheet of artists' water-color paper in a special collection of the Biblioteca Nazionale in Florence ***(Figs. 10 and 11).***[23] These sketches were clearly done by someone well practiced in the manipulation of ink washes, especially in the rendering of tone for chiaroscuro effect. They are by an experienced artist, and there is no reason to believe by anyone but Galileo himself. The astronomer no doubt prepared these drawings, perhaps as composites of earlier *ad hoc* sketches, to be reproduced as engravings in his book *Sidereus nuncius* ("The Starry Messenger") published in March 1610, barely five months after his first telescopic observation of the moon. Neither his own excitement nor his anticipation of the stupendous impression these words would make upon an unsuspecting world is revealed in his matter-of-fact description:

> I have been led to the opinion and conviction that the surface of the moon is not smooth, uniform, and precisely spherical as a great number of philosophers believe it (and

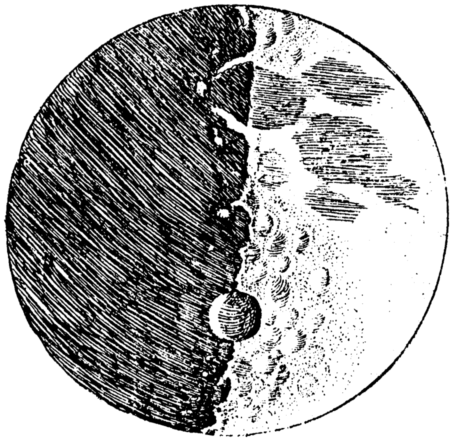

Fig. 12 Engraving of the moon. Galileo, *Sidereus nuncius,* Venice, 1610.

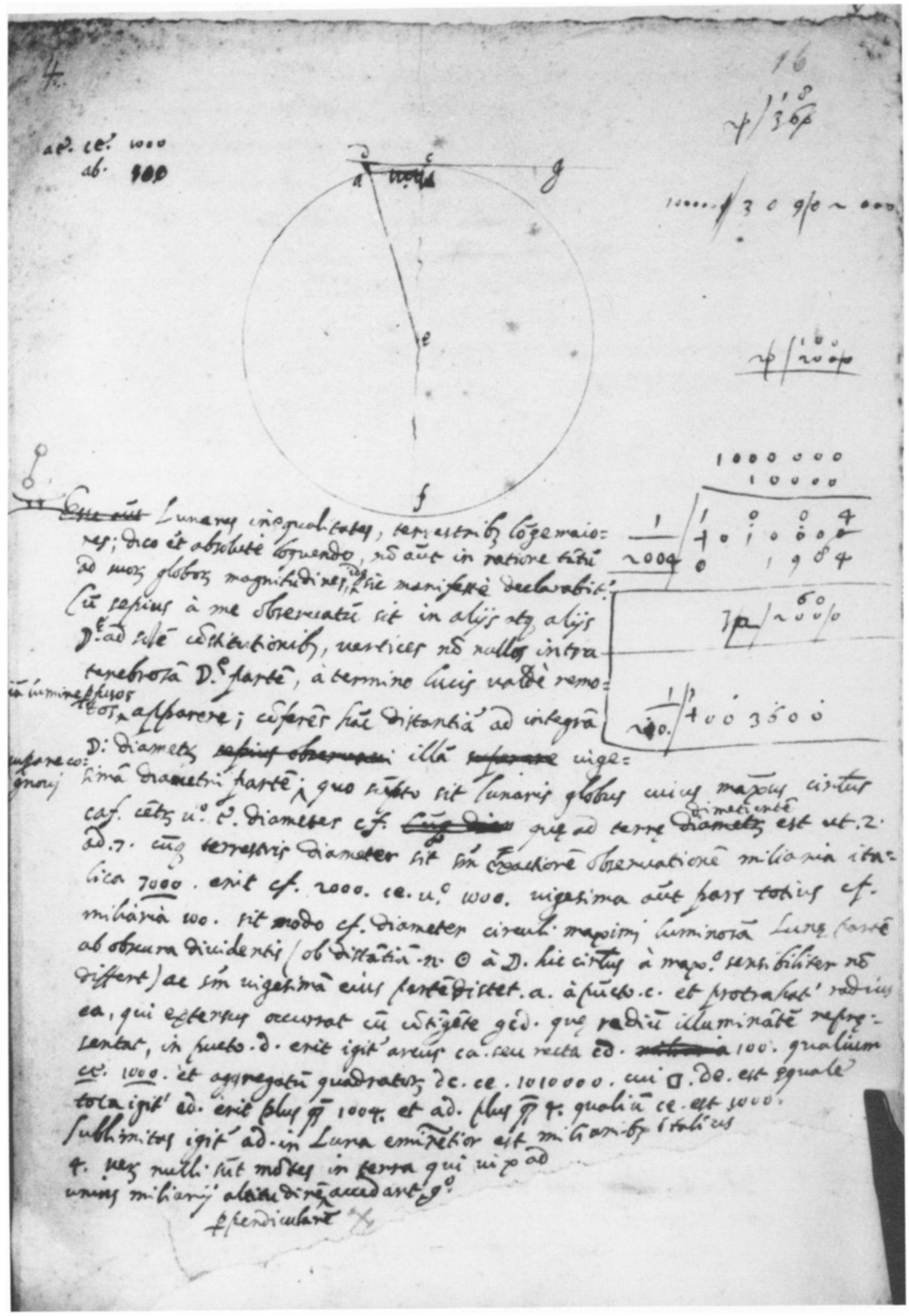

Fig. 13 Galileo's diagram for determining the lunar mountain heights. Bibl. Naz., Florence, Gal. 48, f. 16r.

the other heavenly bodies) to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the earth, relieved by chains of mountains and deep valleys.[24]

One of the published engravings, that of the moon waxing in its first quarter ***(Fig. 12),*** is, like the other four illustrations, not an exact copy of any of the seven wash drawings. In fact, it would seem that Galileo furnished the drawings only as guides to the engraver, intending that the published illustrations depict just the general features of the moon. It was certainly not his purpose to make an accurate moon map. Indeed, he permitted his engraver to exaggerate the crater lying on the lower portion of the terminator. This may be Albategnius, which is located near this place, although it is hardly as large as shown. In none of the wash drawings does Galileo show it so oversized, although in his text he mentions wanting to illustrate the crater correctly. Its appearance certainly captured his imagination, however, and he even likened it to the region of Bohemia on earth, also surrounded by high mountains.[25] He must have decided in any case to communicate his experience of this crater as a kind of kinesthetic expression rather than as a cartographic fact, and so bade his engraver draw it larger as a dramatic indication of how the moon is covered all over with such concavities. We should also bear in mind that Galileo's engraver probably had little opportunity to check his images firsthand with the telescope. He had to depend on Galileo's originals, and, more particularly, on the astronomer's excited verbal descriptions.

Galileo's seven wash drawings reveal a much more "painterly" moon than do the published engravings. In fact, most historians of science have studied only the engravings, which by virtue of their hard and linear technique tend to make Galileo's moon look like the arid and lifeless body modern science now knows it to be. In contrast, Galileo's wash renderings show that he still regarded it in the medieval "watery" spirit. With the deft brushstrokes of a practiced watercolorist, Galileo laid on at least a half-dozen different grades of washes, imparting to his images an attractive soft and luminescent quality. Remarkable indeed was his command of the Baroque painter's conventions for contrasting lighted surfaces and his ability to manipulate darks and lights in order to increase their mutual intensities. In the upper left of the sheet of sepia drawings ***(see Fig. 10),*** Galileo set down a small practice patch of two different washes and a white area, probably to help his engraver realize the form of a moon crater as it took shape in the waxing light. With artistic economy worthy of Tiepolo, Galileo indicated the concave hollow with a single stroke of dark, leaving a sliver of exposed white paper to represent the crater's glowing brim.

Is it preposterous to claim that these simple yet highly professional drawings belong as much to the history of art as they do to science? Unfortunately, no other comparable art work exists that is attributable to Galileo's hand. We have only the verbal testimony of his contemporaries concerning his great skill as a draftsman. In the true spirit of the *Accademia,* however, Galileo seems not to have engaged in art for the sake of self-expression but rather in drawing for the sake of visual discipline. *Disegno* for him was a tool to train his eye and hand and not merely a means to making a pretty picture. And yet I believe that Galileo has truly if unintentionally anticipated the development of the independent landscape in the history of art. His impressionistic technique for rendering fleeting light effects reminds one of Constable and Turner and perhaps even Monet. One need only read Galileo's commentary in *Sidereus nuncius* to appreciate his wonder as well as his rational understanding upon first gazing at the transient lunar topography:

> Let us note . . . that the said small spots always agree in having their blackened parts directed toward the sun, while on the side opposite the sun they are crowned with bright contours like shining summits. There is a similar sight on earth about sunrise, when we behold the valleys not yet flooded with light though the mountains surrounding them are already ablaze with glowing splendor on the side opposite the sun. And just as the shadows in the hollows on earth diminish in size as the sun rises higher, so these spots on the moon lose their blackness as the illuminated region grows larger and larger. Again, not only are the boundaries of shadow and light in the moon seen to be uneven and wavy, but still more astonishingly many bright points appear within the darkened portion of the moon, completely divided and separated from the illuminated light part and at a considerable distance from it. After a time these gradually increase in size and brightness, and an hour or two later they become joined with the rest of the lighted part which has now increased in size. Meanwhile, more and more peaks shoot up as if sprouting now here, now there, lighting up within the shadowed portion; these become larger, and finally they too are united with that same luminous surface. . . . And on the earth, before the rising of the sun, are not the highest peaks of mountains illuminated by the sun's rays while the plains remain in shadow? Does not the light go on spreading while the larger central parts of those mountains are becoming illuminated? And when the sun has finally risen, does not the illumination of plains and hills finally become one?[26]

Did ever a Seicento artist better express the new spirit of Baroque landscape painting? But after having thus marveled at the picturesque lunar terrain, Galileo quickly reverted to his more scientific self and made another stunning, perspective-inspired discovery. He had noticed that some of the lunar peaks were tipped with light within the shadow side even as the terminator boundary lay a long way off. At the same time he was able to convert this phenomenon into a geometric diagram for solving a shadow-casting problem, such as he may have recalled from Guidobaldo del Monte. On another manuscript page prepared for his *Sidereus nuncius* ***(Fig. 13),*** Galileo drew a circle representing the moon, divided by the terminator *cef.*[27] The sun's shadow-casting light rays he indicated by the tangent line *dcg.* With particular ingenuity, considering that his telescope had no cross-hair sighting device, he was able to estimate the real distance from the lighted lunar mountain peak to the terminator—represented in his diagram by line *dc,* which is more or less comparable to line *DK* in Guidobaldo del Monte's cone-shadow diagram ***(see Fig. 2)***—at about one-twentieth of the moon's diameter. Having established this relationship, he was able to triangulate the mountain's height. Since the moon's diameter was known to be two-sevenths of the earth's, or about two thousand miles, Galileo's triangle *ced,* with *ce* equaling one thousand miles and *cd* one hundred, revealed by Pythagorean calculation that *da,* the mountain's height on center from its base, reached more than four miles into the lunar sky! By applying a problem well known to Renaissance perspective students, Galileo added to his already wondrous revelations the fact that the mountains on the moon were even more spectacular than the Alps.

Galileo's telescopic discoveries opened the eyes of Europeans everywhere. If the visual arts in Harriot's England still lingered in the Middle Ages, Galileo's *Sidereus nuncius* suddenly offered that sceptered isle a crash course in Italian Renaissance ways of seeing. All the great English poets responded with imagination and gusto. The landscaped moon and "perspective glass" became frequent metaphors in the writings of Dryden, Donne, Samuel Butler, Milton, and many more.[28] In Italy, there were some recalcitrant souls who could not be persuaded that the moon was so "corrupt," and refused even to look through Galileo's telescope. The Holy Mother Church, however, was quick to co-opt the new revelation. In 1612, Galileo's friend Cigoli was commissioned to fresco the domed ceiling of the Pauline Chapel in the Basilica of Santa Maria Maggiore in Rome. The painter was permitted to depict there the Virgin Mary standing on a crater-pocked moon, no doubt inspired by one of Galileo's drawings.[29] To this day the image is officially and prudently called the *Assumption of the Virgin* rather than the *Immaculate Conception;* but, nonetheless, by admitting it to such a sacred place, the Church tacitly acknowledged Galileo's roughened moon—whether or not the Madonna in heaven appreciated the association.

In England, John Donne, with tongue in cheek, suspected that Galileo's discovery was all a plot anyway. In 1611, he announced:

> I will write the Bishop of Rome: he shall call Galilaeo the Florentine to him; who by this time hath thoroughly instructed himselfe of all the hills, woods, and Cities in the new world, the Moone. And since he effected so much with his first Glasses, that he saw the Moone, in so neere a distance, that hee gave himselfe satisfaction of all, and . . . when now being growne to more perfection in his Art, he shall have made new Glasses, and they received a hallowing from the Pope, he may draw the Moone, like a boate floating upon the water, as neere the earth as he will. And thither (because they ever claime that those imployments of discovery belong to them) shall the Jesuites be transferred, and easily unite and reconcile the Lunatique Church to the Roman Church; without doubt, after the Jesuites have been there a little while, there will soon grow naturally a Hell in that world also: over which you Ignatius [Loyola] shall have dominion, and establish your kingdome and dwelling there. And with the same ease as you passe from the earth to the Moone, you may pass from the Moone to the other starrs, which are also thought to be worlds.[30]

Twenty-two years later, Galileo would have reason to take this gibe more as a prophecy than as Protestant propaganda. Nevertheless, although the

Church considered him in disgrace, Galileo's detractors had to admit, thanks to the spreading power of Florentine *disegno,* that what he had seen through his telescope, and what that implied about God's universe, was just as "real" as a sculpted miracle by that good friend of the Jesuits, Gianlorenzo Bernini. In 1642, the year of Galileo's death, Filippo Baldinucci recorded a touching tribute to Galileo's influence, not only on seventeenth-century scientific knowledge of the moon but even on Baroque painting of it! It seems that Grand Duke Ferdinand II proposed a contest to a group of "spirited painters" in Florence, to find out who among them could best depict "those marvelous spots" on the moon after looking through Galileo's telescope. One of those artists was Baccio del Bianco, pupil of a pupil of Cigoli. Baldinucci so admired Baccio that he included a long biography of him in the same volume with Nicolas Poussin.[31]

With this anecdote, our story comes full circle. We began with a case of art influencing science, and end with that same science returning the favor.

Notes

The ideas in this paper were first inspired by conversations with Bert S. Hall and Thomas B. Settle, to whom I owe many thanks.

1 *Treatise on Painting by Leonardo da Vinci,* trans. Philip McMahon, Princeton, N.J., 1956, Vol. 1, p. 41.

2 Kenneth D. Keele, *Leonardo da Vinci's Elements of the Science of Man,* New York and London, 1983.

3 See: Ibid., particularly Chap. 5, "Leonardo's Scientific Method and the Mathematics of the Pyramidal Law."

4 Karen-edis Barzman, "The Florentine 'Accademia del Disegno': Institutionalizing Albertian Principles of Education," unpublished talk given at the 72nd Annual Meeting of the College Art Association of America, Toronto, February 24, 1984. See also: Ted Reynolds, "The Accademia del Disegno in Florence: Its Formation and Early Years," unpublished Ph.D. dissertation, Columbia University, 1974, Xerox University Microfilms, Ann Arbor, Mich., pp. 84–91. Concerning Galileo's own education relative to his science, see: Thomas B. Settle, "Ostilio Ricci, a Bridge between Alberti and Galileo," in the *Actes: XII. Congrès International d'Histoire des Sciences,* Paris, 1971, Vol. 3B; and I. Bernard Cohen, "The Influence of Theoretical Perspective on the Interpretation of Sense Data: Tycho Brahe and the New Star of 1572, and Galileo and the Mountains of the Moon," *Annali dell' Istituto e Museo di Storia della Scienza di Firenze,* 6.1, 1982, pp. 3–13.

5 Erwin Panofsky, *Galileo as Critic of the Arts: Aesthetic Attitude and Scientific Thought,* The Hague, 1954, pp. 3–15. An abridged but updated version was published in *Isis,* 47 (1956), pp. 182–85.

6 See the reminiscence of Galileo's pupil Vincenzo Viviani (1622–1703), published in *Le opere del Galileo,* ed. Antonio Favaro and Isodoro del Lungo, Florence, 1890–1909, Vol. 19, p. 602:

[Galileo] trattenevasi ancora con gran diletto e con mirabil profitto nel disegnare; in che ebbe così gran genio e talento, ch'egli medesimo poi dir soleva agl'amici, che se in quell'età fosse stato in poter suo l'eleggersi professione, averebbe assolutamente fatto elezione della pittura. Ed in vero fu di poi in lui così naturale e propria l'inclinazione al disegno, et acquistovvi col tempo tale esquisitezza di gusto, che'l giudizio ch'ei dava delle pitture e disegni veniva preferito a quello de' primi professori da'professori medesimi, come dal Cigoli, del Bronzino dal Passignano e dall'Empoli, e da altri famosi pittori de'suoi tempi, amicissimi suoi, i quali bene spesso lo richiedevano del parer suo nell'ordinazione dell'istorie, nella disposizione delle figure, nelle prospettive, nel colorito et in ogn'altra parte concorrente alla perfezione della pittura, riconoscendo nel Galileo intorno a si nobil arte un gusto così perfetto e grazia sopranaturale, quale in alcun altro, benchè professore non seppero mai ritrovare a gran segno; onde'l famosissimo Cigoli, reputato dal Galileo il primo pittore de'suoi tempi, attribuiva in gran parte quanto operava di buono alli ottimi documenti del medesimo Galileo, e particolarmente pregiavasi di poter dire che nelle prospettive agli solo gli era stato il maestro.

7 Miles Chappell, "Cigoli, Galileo, and *Invidia,*" *Art Bulletin,* 62 (1975), p. 91, n. 4.

8 Stephen Straker, "The Eye Made 'Other': Dürer, Kepler, and the Mechanisation of Light and Vision," *Science, Technology, and Culture in Historical Perspective,* The University of Calgary Studies in History, No. 1, 1976.

9 For an annotated list of perspective books published in the sixteenth and seventeenth centuries, see: Luigi Vagnetti, *De naturali et artificiali perspectiva,* published as a special edition of *Studi e documenti de architettura,* Cattedra di composizione architettonica della facoltà di architettura de università di Firenze, 1979, nn. 9–10 (concerning Guidobaldo del Monte's treatise, see pp. 345–47). See, also: Thomas Da Costa Kaufmann, "The Perspective of Shadows: the History of the Theory of Shadow Projection," *Journal of the Warburg and Courtauld Institutes,* 38 (1975), p. 277; and *I sei libri della prospettiva di Guidobaldo dei Marchesi del Monte dal latino tradotti interpretati e commentati. . . ,* ed. and trans. Rocco Sinisgalli, Rome, 1984.

10 Vagnetti (cited n. 9), pp. 334–35; Kaufmann (cited n. 9), pp. 276–77.

11 Vagnetti (cited n. 9), pp. 335–37.

12 Ibid., pp. 266–68.

13 I am indebted to John W. Shirley for his generous assistance concerning the scientific career of Thomas Harriot. See, especially: his "Thomas Harriot's Lunar Observations," in *Science and History: Studies in Honor of Edward Rosen,* Studia Copernicana 16, Wro-

claw, 1978, pp. 283–308; also his *Thomas Harriot: A Biography,* New York, 1983 (reviewed by Alan Shapiro in *Science,* 223 [1984], pp. 1070–71). See, also: Terrie F. Bloom, "Borrowed Perceptions: Harriot's Maps of the Moon," *Journal for the History of Astronomy,* 9 (1978), pp. 117–22.

14 See Marjorie Nicolson, *A World on the Moon: A Study of Changing Attitudes Toward the Moon in the Seventeenth and Eighteenth Centuries,* Smith College Studies in Modern Languages, Northhampton, Mass., 1936, Vol. 17, no. 2.; also: Willy Hartner, "Terrestrial Interpretation of Lunar Spots," in *Reason, Experiment, and Mysticism,* ed. M.L. Righini-Bonelli and William R. Shea, New York, 1976, pp. 89–95.

15 See especially the depictions of this subject by Bartolomé Esteban Murillo. His examples now in the Louvre and the Walters Gallery, Baltimore, clearly show such an "alabaster" moon (illustrated in Diego Angulo Iñiguez, *Murillo,* Madrid, 1981, Vol. 3).

16 The moon presented such a puzzle to medieval philosophers that Dante Alighieri even stopped to digress on the subject in the midst of his climb to Paradise with Beatrice. Dante has Beatrice explain, with the aid of an experiment with mirrors, that the moon's spots are not really physical at all. Rather, the reason has to do with God wanting to signal mankind that while the heavens remain incorruptible, each heavenly part must exert a different influence on the earth; hence, the variations in lunar light (see: *Paradisio,* Canto 2).

17 *Novum organum,* Book 2, Aphorism 36; see: Nicolson (cited n. 14), p. 12.

18 Marjorie Nicolson, *Science and Imagination,* Ithaca, N.Y., 1956.

19 Bloom (cited n. 13).

20 Vagnetti (cited n. 9), p. 412.

21 I am grateful to Roland Frye for allowing me to read his unpublished paper, "Ways of Seeing, or Epistemology in the Arts: Unities and Disunities in Shakespearian Drama and Elizabethan Painting," which examines the slow assimilation of Italian perspective theory in English art.

22 For arguments concerning the date and time of Galileo's first moon observations, see: Guglielmo Righini, "New Light on Galileo's Lunar Observations," in Righini-Bonelli and Shea (cited n. 14), pp. 59–77; Owen Gingerich, "Dissertatio cum Professore Righini et Sidereo Nuncio," ibid., pp. 77–89; Stillman Drake, "Galileo's First Telescopic Operations," *Journal for the History of Astronomy,* 7 (1976), pp. 153–68; and finally and conclusively, Ewen A. Whitaker, "Galileo's Lunar Observations and the Dating of the Composition of *Sidereus Nuncius,*" *Journal for the History of Astronomy,* 9 (1978), pp. 155–69.

23 See the worthwhile discussion of these drawings by Owen Gingerich (cited n. 22), the only scholar in the controversy concerning their date (see n. 22) to have examined them with something like an art historian's eye. There is no way that Galileo could have made these careful pen-and-wash studies during his exciting first moments at the telescope, as other historians of science have assumed. Like any seventeenth-century "landscape," Galileo's finished depictions were composed not in *plein air* but in the "studio."

24 *Sidereus nuncius,* Venice, 1610. Galileo discussed not only the moon's surface in this epochal book but also his discoveries of the four satellites of Jupiter, which he named, for his patrons, the "Medician Stars." The above translation from Galileo's Latin is published in Stillman Drake, *Discoveries and Opinions of Galileo,* New York, 1957, p. 31.

25 Drake, *Discoveries* (cited n. 24), p. 36.

26 Ibid., pp. 32–33.

27 Ibid., pp. 40–41. The same diagram and letter code is reproduced in *Sidereus nuncius.*

28 Nicolson, *World in the Moon* (cited n. 14); and idem, *Science and Imagination* (cited n. 18).

29 On this painting, see: Anna Matteoli, *Lodovico Cardi–Cigoli pittore e architetto,* Pisa, 1980, pp. 246–49. It has been reproduced recently in Chappell (cited n. 7), figs. 6 and 7; also in Panofsky (cited n. 5), where it is mistakenly captioned as being in the Church of Santa Maria del Popolo.

30 Nicolson, *World in the Moon* (cited n. 14), pp. 39–40; originally published by Donne in his *Ignatius His Conclave,* London, 1611.

31 Filippo Baldinucci, *Delle notizie de'professori del disegno da Cimabue in qua,* Florence, 1773, Vol. 16 (Dec. IV, Par. I, Sec. V), p. 152:

> Circa all'anno 1642 volle lo stesso serenissimo Granduca far ritrarre al naturale coll'aiuto di un grande e perfetto occhiale del Galileo, il gran Pianeta della Luna: e diedene l'incumbenza ad alcuni spiritosi pittori: e non dovea l'uno vedere l'operazione dell'altro: non so io per qual fine dell'alto intelletto di quel gran principe, se non fosse stato in parte per vedere, come ciascheduno di loro in proporzione grande avesse intese quelle maravigliose macchie, per maggiore illustrazione e conferma delle veritadi, scoperte per mezzo di quel nobile strumento. Uno di costoro fu Baccio del Bianco, che si portò bene; ed io mi abbattei alcuna volta in compagnia di amici a vedervelo sopra operare.

My thanks to Karen-edis Barzman for pointing out this provocative and apropos reference. Unfortunately, I only learned of Roger Ariew's excellent paper, "Galileo's Lunar Observations in the Context of Medieval Lunar Theory," *Studies in the History and Philosophy of Science,* 15.3 (1984), pp. 213–27, just as my own article was going to press. I am pleased, however, that Ariew's philosophical argument also takes note of Galileo's unique geometrical training.

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