
# Galileo's Telescopic Discoveries: Thinking Visually in the History of Science

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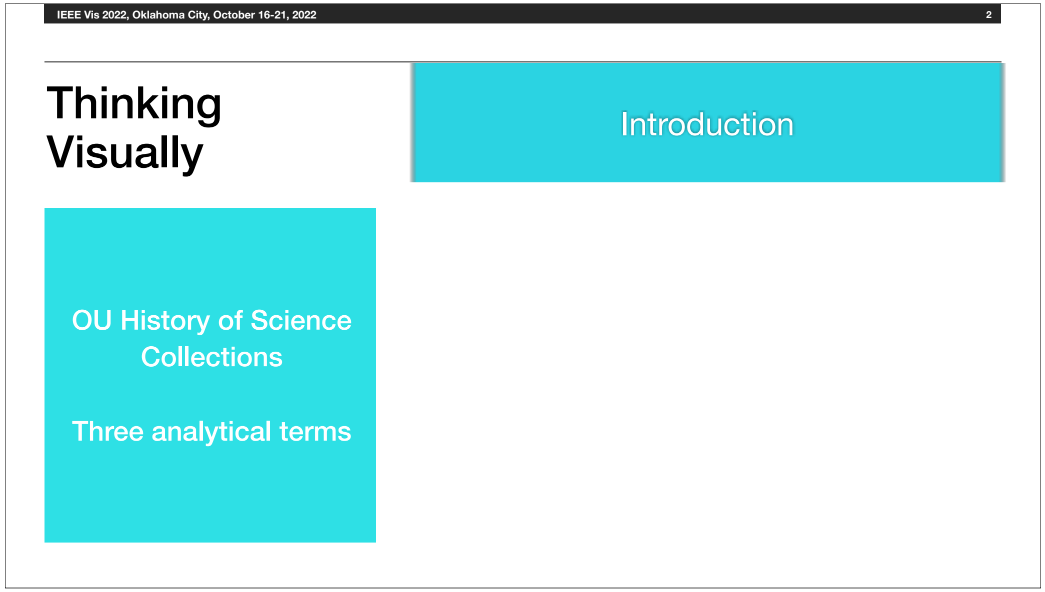
Galileo Galilei, *Sidereus nuncius* (Venice, 1610)

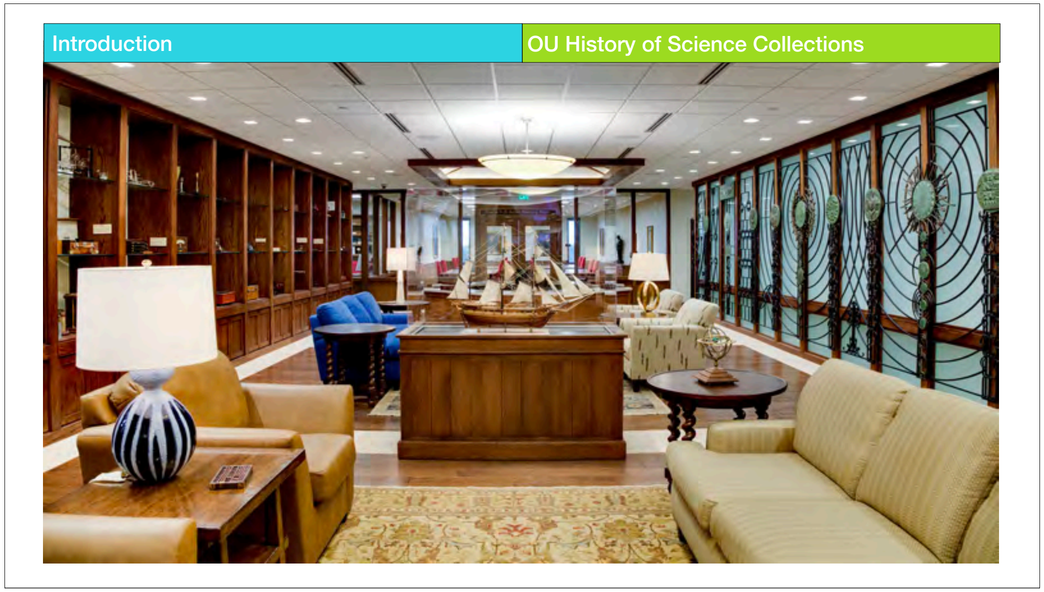
OU

My thanks to the organizers, David, Hendrik and Danielle. It is a joy and a privilege to present this capstone on Galileo's Telescopic Discoveries as an example of thinking visually in the history of science. Thank you all very much for coming to a talk by a historian of science. I've chosen to focus on one particular case study in greater depth than would be possible with a more general survey. Settle back and use your imagination as you listen to this story — perhaps you will come up with some meta-reflections connecting Galileo's world to your own work and to your experience this week.




To begin, I’ll say a brief word about the OU History of Science Collections, and define three analytical terms.


Research universities are often best known for their athletic programs.  But among historians of science,




the University of Oklahoma is known for the History of Science Collections.

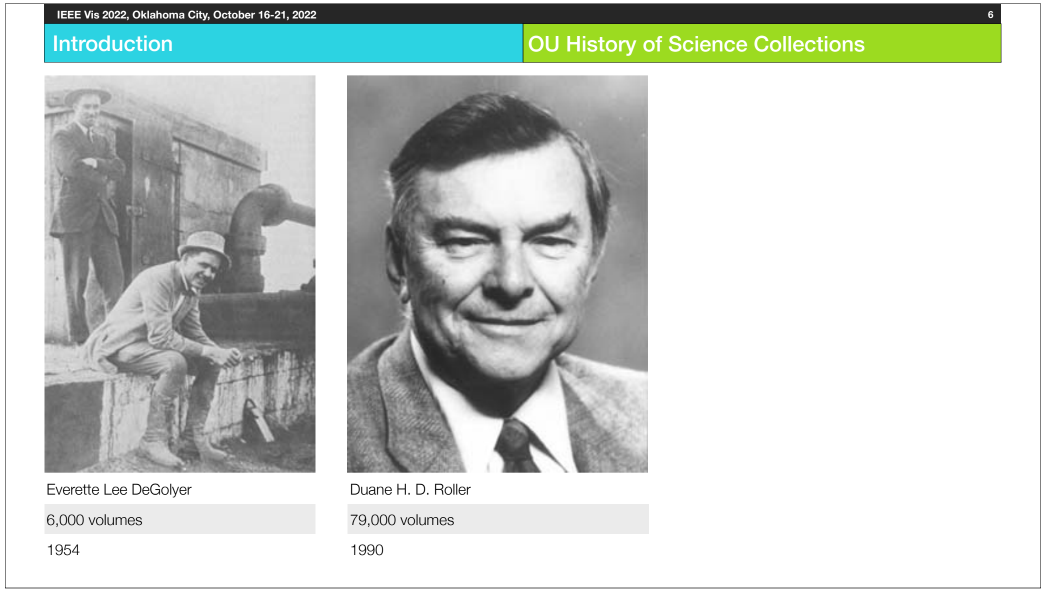
Introduction | OU History of Science Collections

Everette Lee DeGolyer

6,000 volumes

1954

The Collections began in the late 1950s with a gift of 6,000 rare books by Everette Lee DeGolyer, an alumnus of the OU geology school.




Duane Roller, son of a physicist, became the first curator and professor of the history of science. When he retired in 1990, a separate Department for the History of Science had been created. There are now 11 faculty in the history of science program, and we offer graduate and undergraduate degrees in the history of science.

Introduction | OU History of Science Collections

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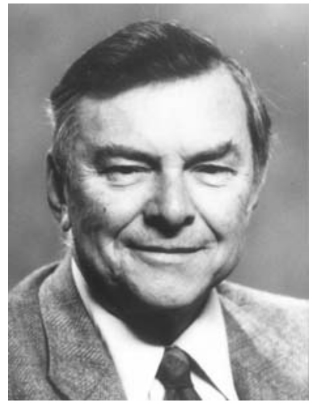


Duane H. D. Roller

79,000 volumes

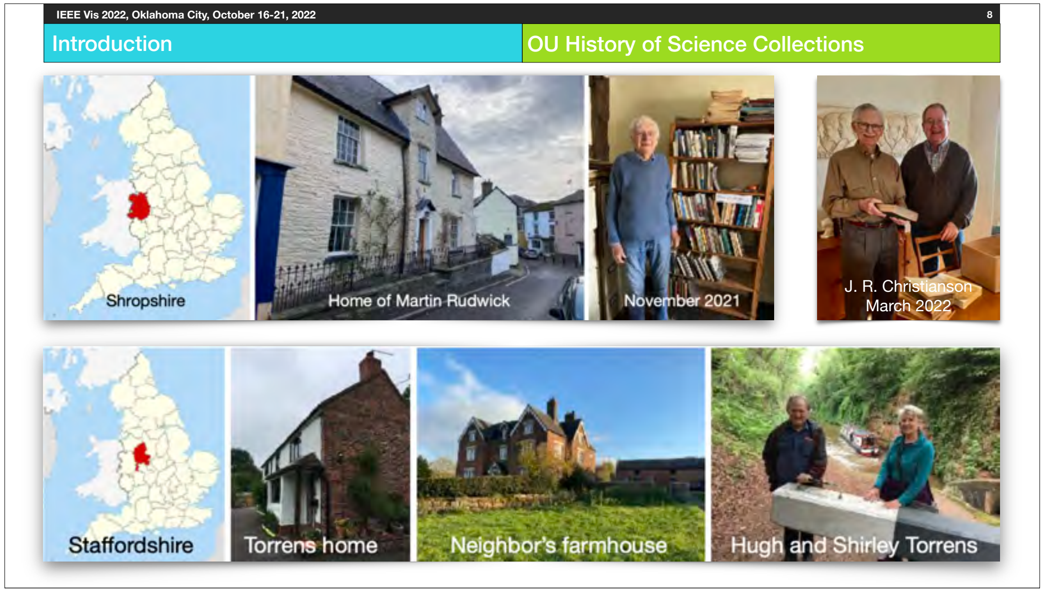
1990

Marilyn B. Ogilvie

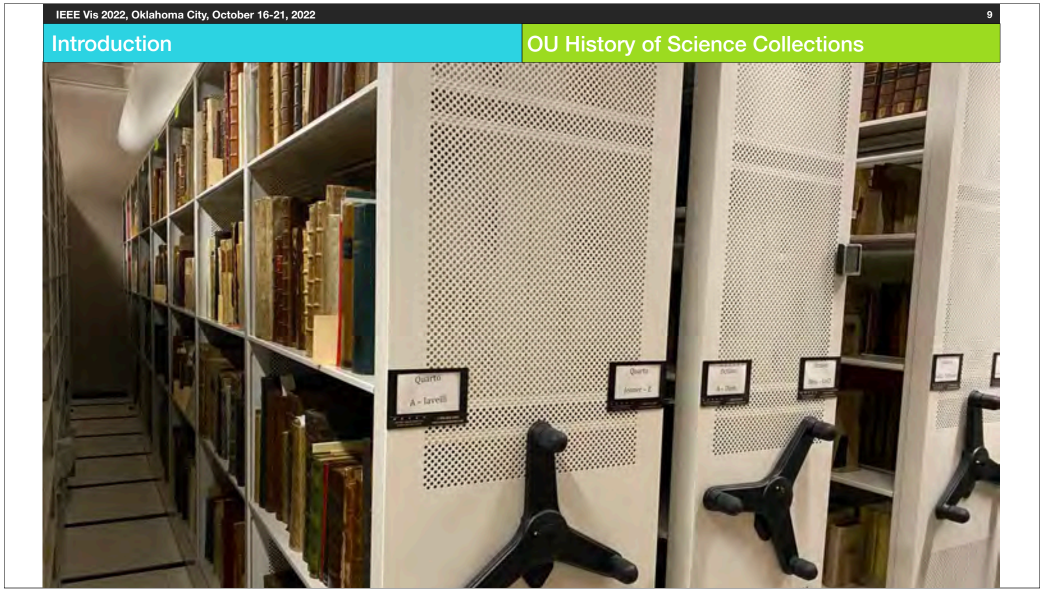
94,000 volumes

2008

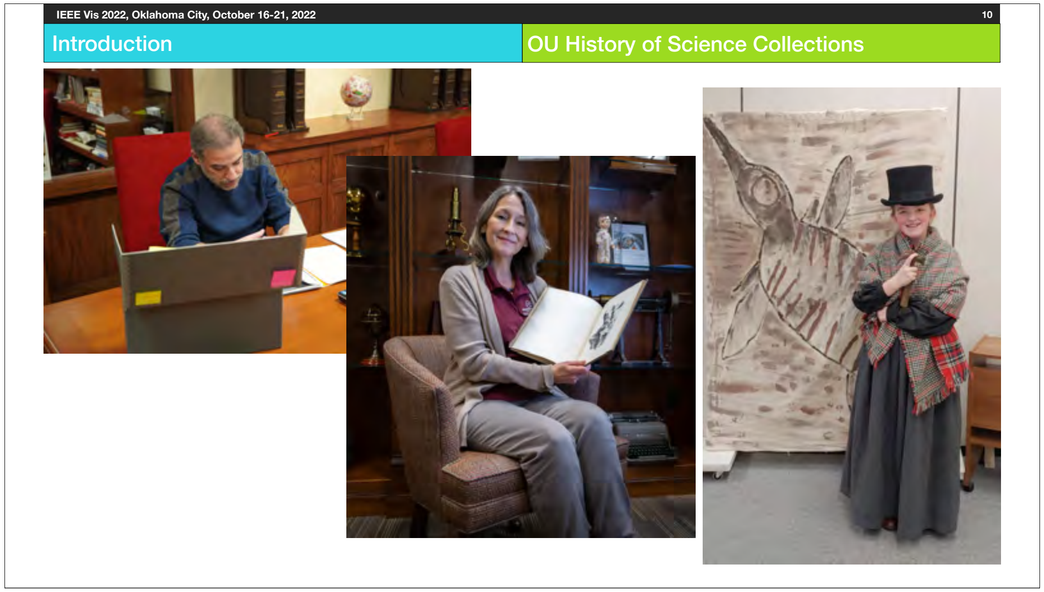
Marilyn Ogilvie, a specialist on women in science, became curator in 1991. Under her direction the Collections grew to 94,000 volumes before her retirement in 2008. I became curator in 2009 and we are now at 100,000 volumes.



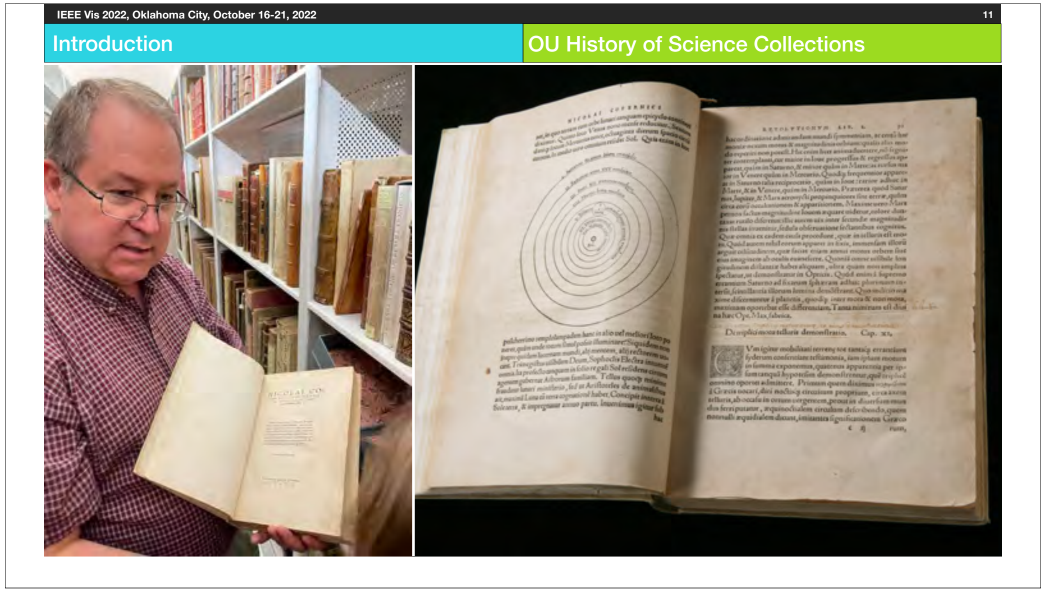

After we collect the books, from donors or other sources…



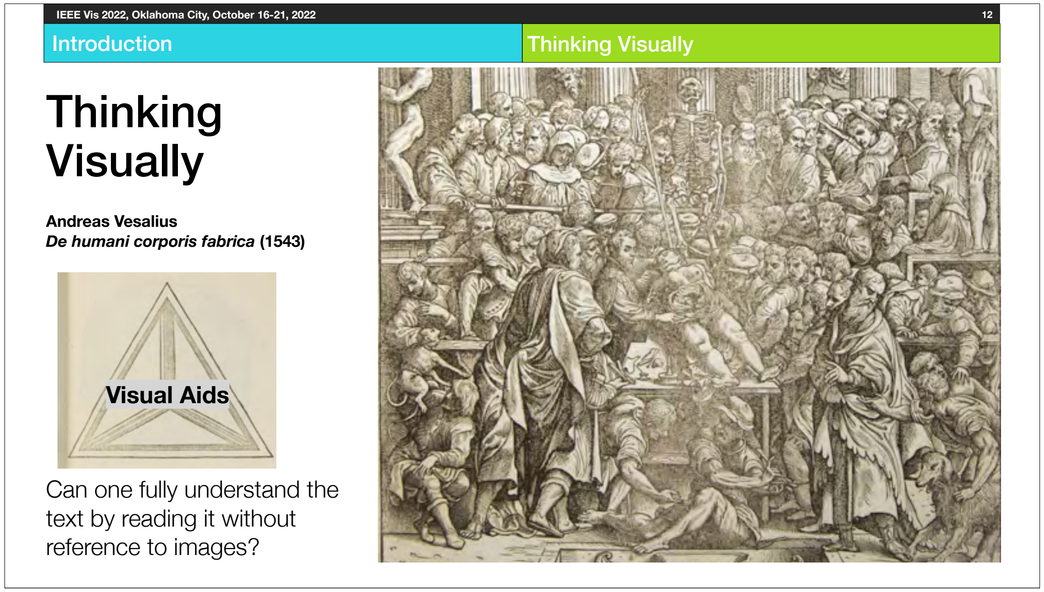

we preserve them in climate-controlled vaults.




Then we make them available to students and scholars for teaching and research.

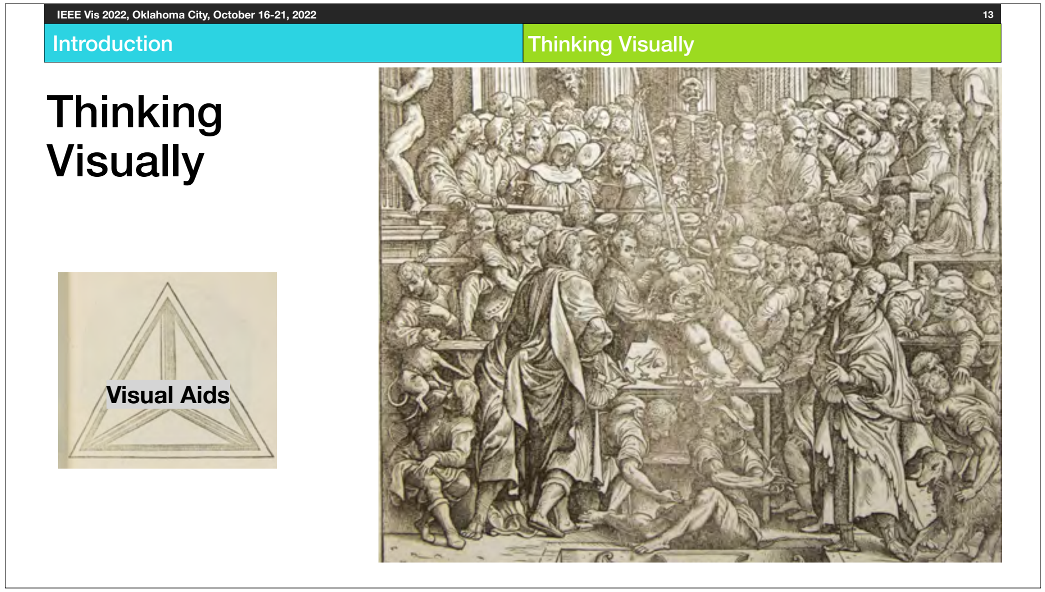



Imagine now that we are together in our most secure vault, and the aroma of old books surrounds you. We shall browse the shelves and select some of treasures to explore together. (pause)

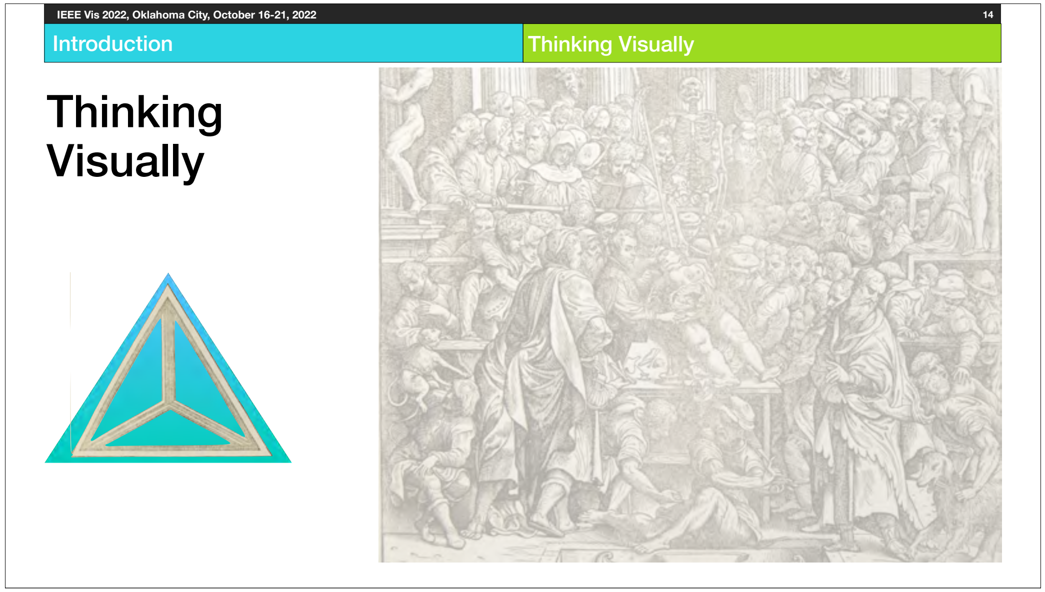



Let's take a moment to analyze what we're looking for… First, what I do NOT mean by "thinking visually" is the use of visual aids that supplement a text, as in this detail from the frontispiece of Vesalius, On the fabric of the human body. The test for a visual aid in this sense is this:

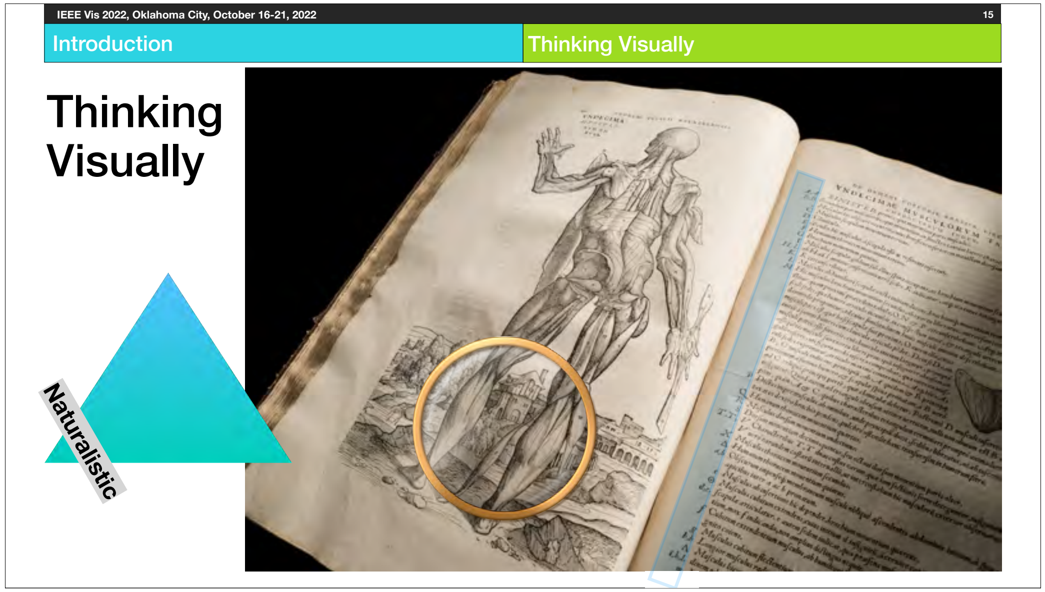
- Can one fully understand the text by reading it without any reference to images? If so, then the images are supplemental visual aids which ornament the text. Ornamental images like this are certainly fascinating and worthy of study for their visual rhetoric, but we will set them aside for our purposes this morning in order
- to focus instead only upon using images to think visually. In other words, I want to focus on examples when *both* the text and the visual representations are necessary, when neither stands alone, when neither is sufficient or complete in itself, but when text and image must be read together in combination.




If we think about the functions of visual representations, let visual aids be one vertex of a tetrahedron. (This tetradhedron was drawn by Leonardo, btw.)

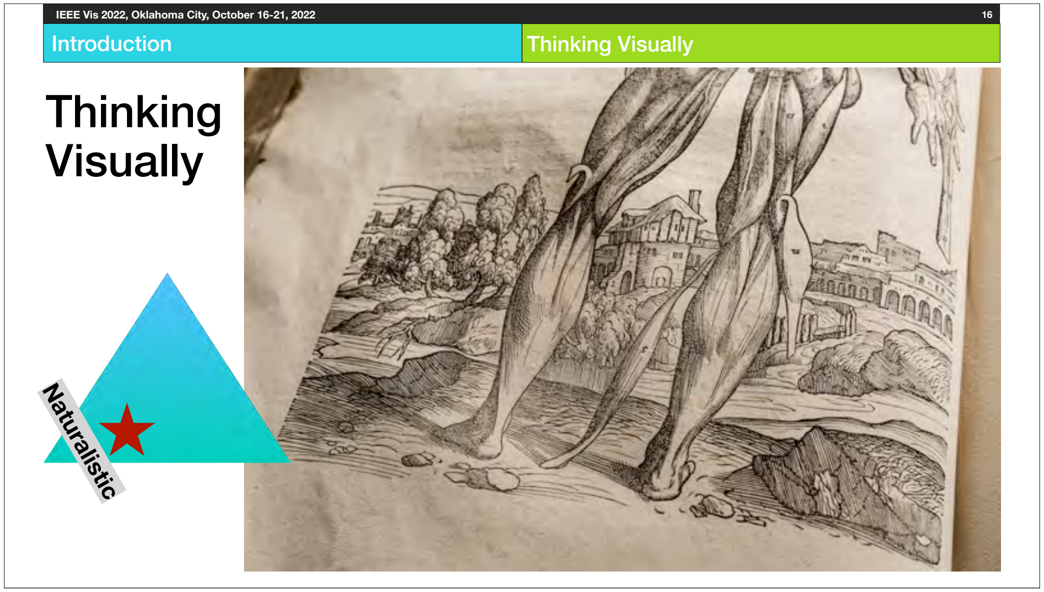



Setting that function aside, let's take this triangle as the base of the tetrahedron, and see if we might plot three different ways of thinking visually, on a continuum between the three corners:




First, in this image, also from Vesalius, the illustration contains letters to designate different parts of the body. These letters in the illustration are keyed to

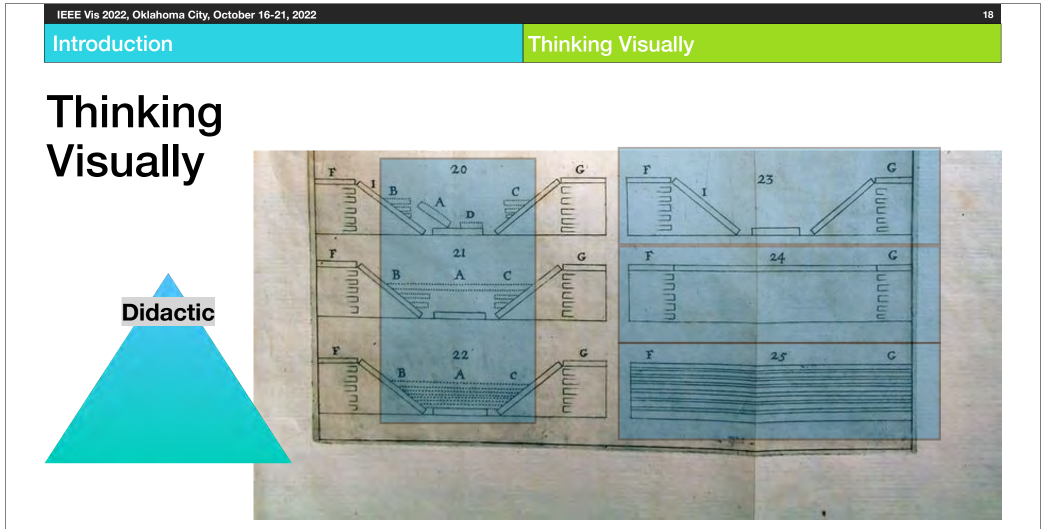
- corresponding letters in the text, where each structure is described and explained. Therefore the text and the visual representation are interlaced, and are read together in a coordinated manner. In this case the image is not simply ornamental. It is not a mere visual aid.
- Yet there's more going on here: notice that the muscles are contracted in an aesthetically stunning way that gives an impression of naturalism. A naturalistic representation aims to provide an illustration that evokes the appearance of the original.




Muscles do not appear like this on the dissecting table. When the anatomist examines muscles they are lifeless.  These muscles are shown contracting as in life. This illustration goes well beyond the need for accuracy, so this is a naturalistic form of visual representation.


Second, an anatomy work published at the same time as Vesalius but without the same artistic proficiency was Charles Estienne, On the Dissection of the Parts of the Human Body. It turns out that Estienne's anatomy was just as accurate as Vesalius, but the illustrations do not have the same degree of naturalism.

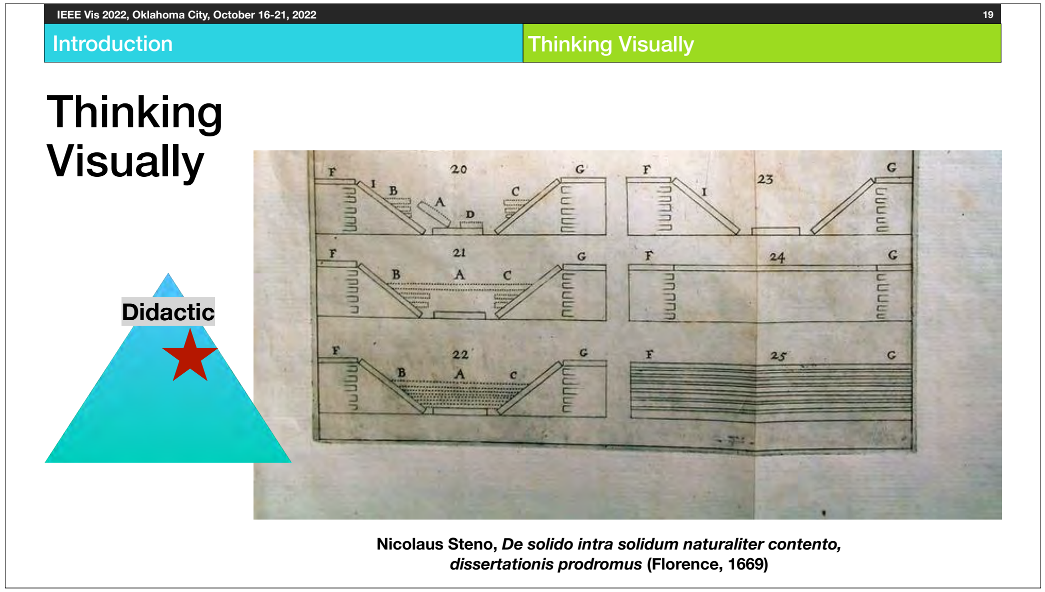
- There is even a cutout in the woodblock to illustrate the portion of the body under discussion.
- So the Estienne illustrations move closer to the Evidential corner compared with Vesalius. An evidential presentation aims to draw attention to particular aspects of the object, highlighting or explaining evidence in a visual manner, regardless of the degree of naturalism.



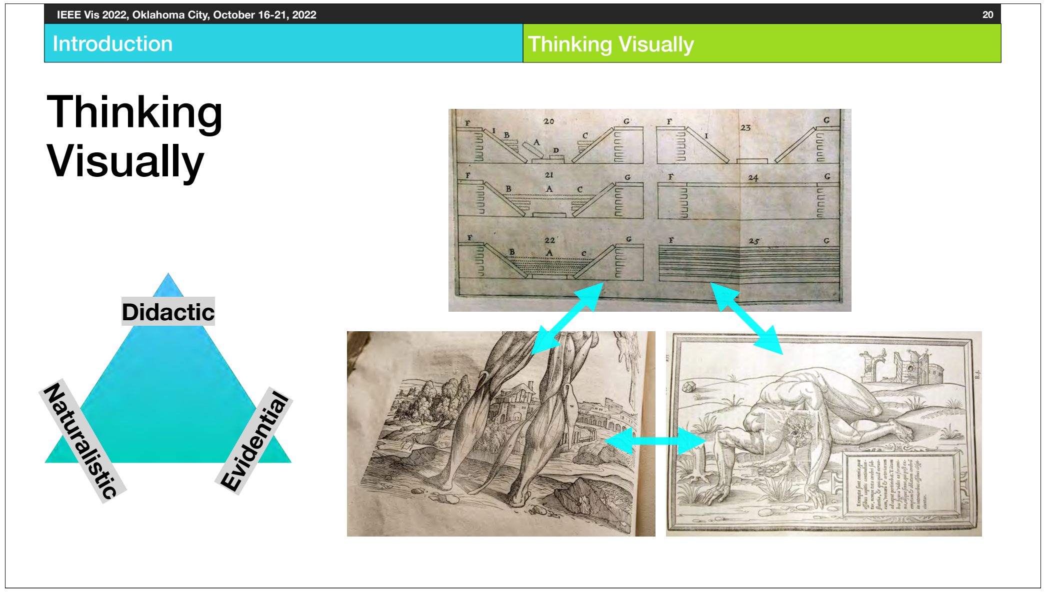

Nicolaus Steno, ***De solido intra solidum naturaliter contento, dissertationis prodromus*** **(Florence, 1669)**

Third, some illustrations are didactic in nature. Steno was a renowned anatomist who performed an anatomy of the Earth in the hills around Tuscany. He created this diagram to help readers think through how to dissect the rock formations they might find around them. Steno's schematic diagram explains the origin of the rock formations in Tuscany in two cycles, of three steps each:

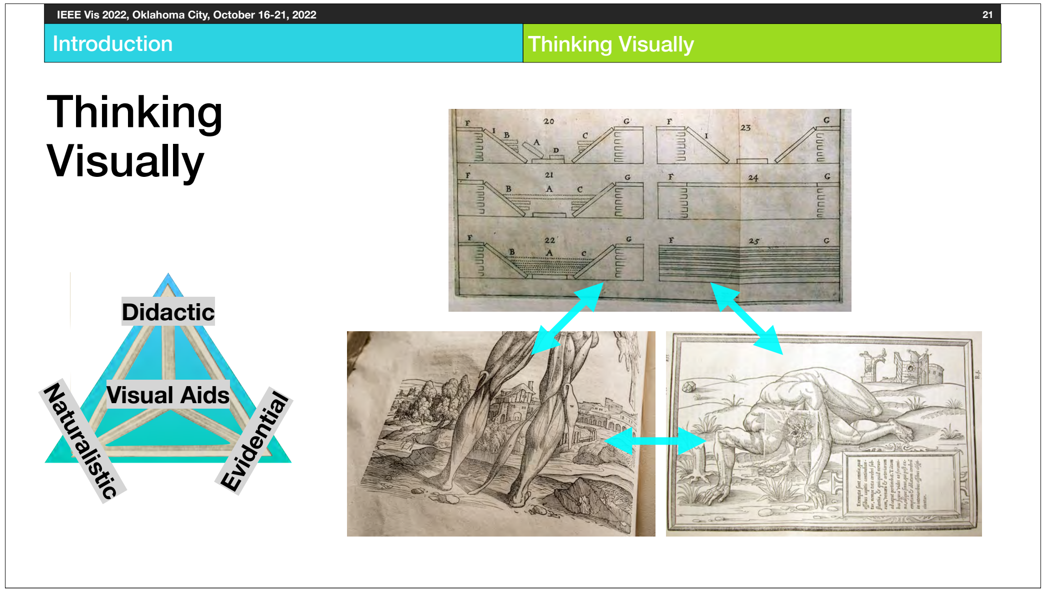
- First, deposition, of strata in originally horizontal layers.
- then subterranean excavation, the formation of caverns.
- then crustal collapse. Then
- repeat the same three-step cycle again, on a smaller scale.
- The question Steno posed is whether the geohistory of other regions of the world might be reconstructed using a similar kind of visual logic. Now this diagram is not at all naturalistic; it is abstract, even geometrical. It is based upon evidence, but its aim is much more than to present evidence:




it is didactic, a tool for thinking through the origin of the rocks. It is a tool for thinking through how one might reconstruct a history of the Earth. So, didactic images are visual tools for thinking. More than a visual aid that symbolizes or summarizes an independent verbal argument, didactic images are heuristic, leading us to discovery before the conclusion is known, leading us cognitively but non-verbally to new ideas…. Thinking aids, not visual aids.



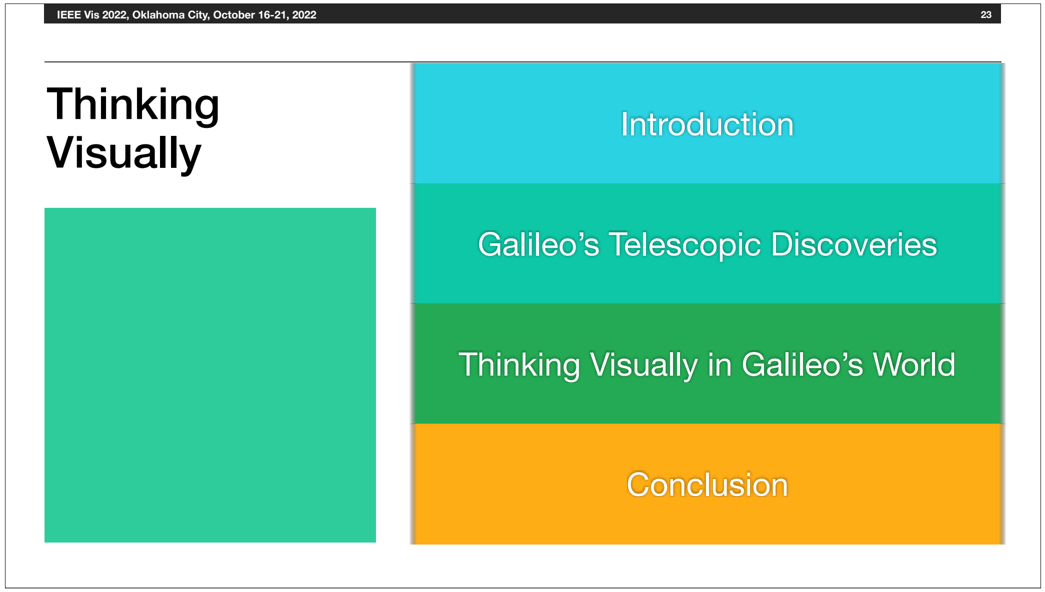

So naturalistic, evidential, and didactic endeavors involve three dimensions of thinking visually. In my work as a historian of science, I've found that these analytical terms help me to better understand what is going on with visual representations in historical texts. Many images, of course, are a mix of these,



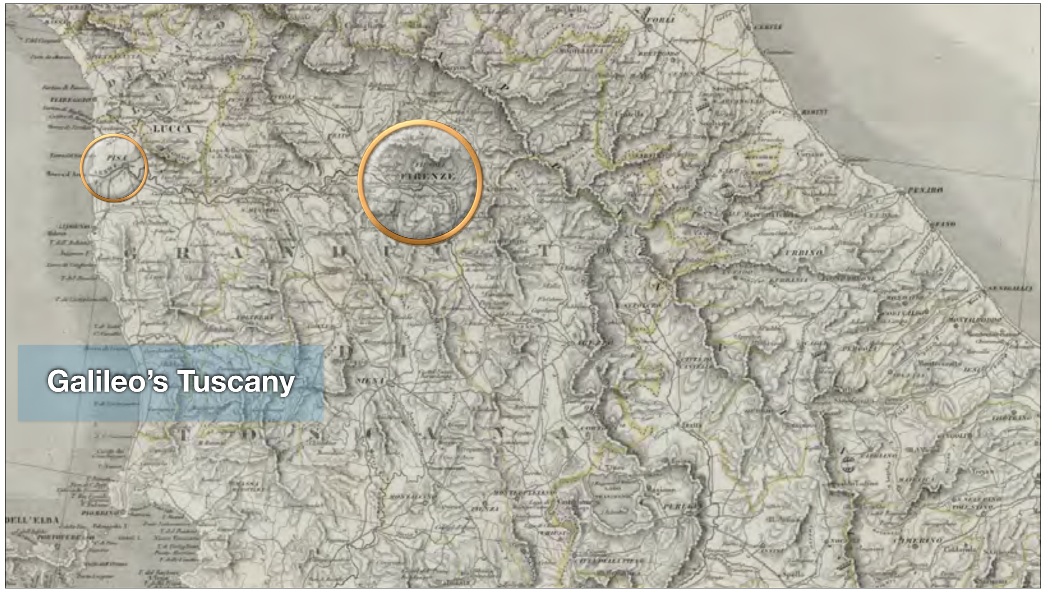

or even a mix of all four, so we might plot them relative to other images at any point within the tetrahedron.


Let’s test the thinking visually terms with an example from Galileo. With his telescope, Galileo discovered four satellites revolving around Jupiter, printing more than 60 observations of their positions as they changed from night to night. The first point is that the observations are presented as a combination of text and illustrations, intended to be read in combination.

- Second, these diagrams are definitely not naturalistic. We can cross that out. They were printed using an upper case “O” rotated sideways for Jupiter, and asterisks for the satellites themselves.
- To some degree they might be considered didactic, because the sequence provides a helpful way to think through how satellites might shift their positions over time.
- But the representations are primarily evidential, in that this is exactly how the satellites did in fact appear over a period of months. So do these terms make sense? In theory, we might map any visual representation along these dimensions. As we proceed, I invite you to consider whether these terms might be applicable in some way to your own work.

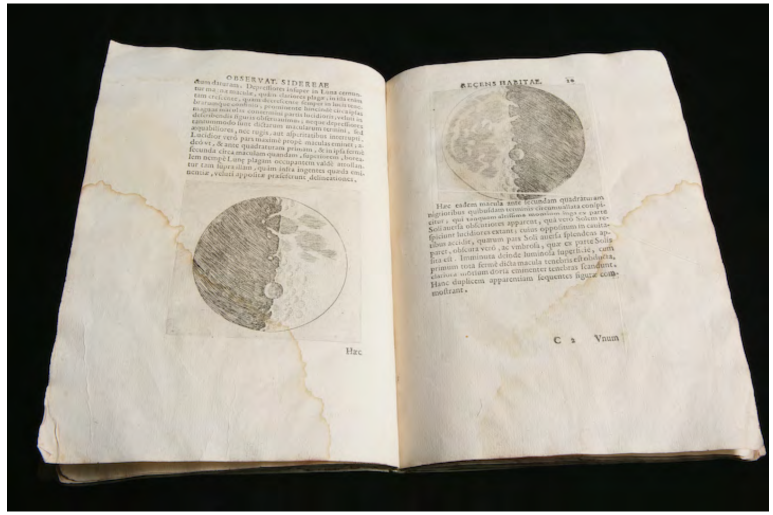



So that's the introduction. Now let's get started with the main story, Galileo's telescopic discoveries.



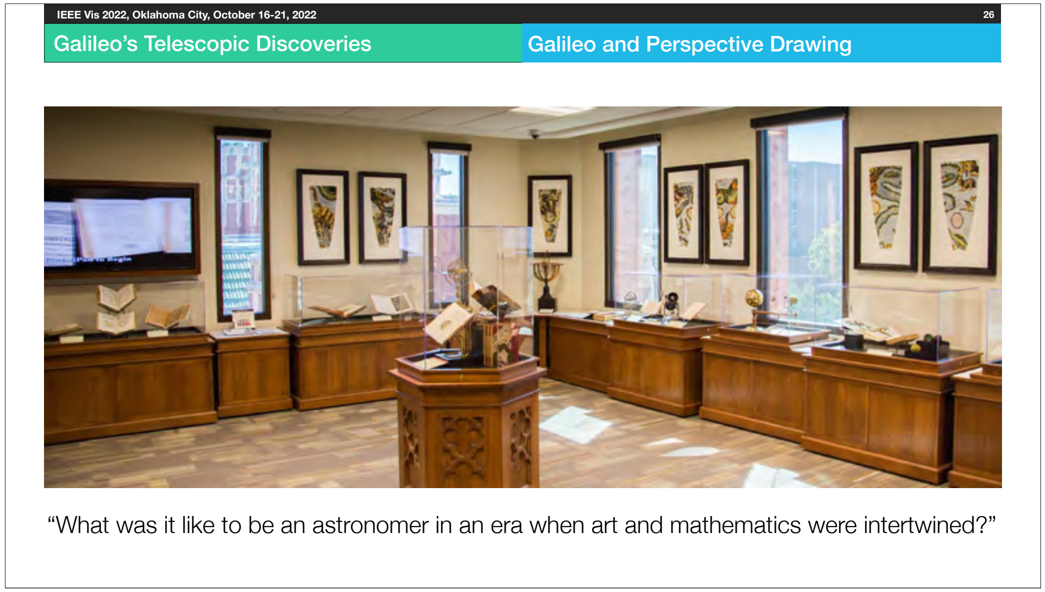

Let’s go back more than 400 years, to a world long before your own work could be imagined. Yet perhaps upon meta-reflection, you might find some connections with your own scientific culture. At this time, Firenze or Florence is the capital of Tuscany.
• To the west, on the delta of the Arno river, is Pisa.  This was a special place and time, where science was affected by the surrounding culture in a way that sparked creativity. That special spark arose from deep and natural interdisciplinary connections, which are evident in Galileo’s science. What was the secret sauce that made these difficult interdisciplinary connections creative and effective in Galileo’s Tuscany? One key aspect is related to thinking visually.

## Galileo's Telescopic Discoveries



**Galileo**
***Sidereus nuncius***
**(Venice, 1610)**

This is Galileo's Sidereus nuncius or Starry Messenger, the first published report of observations made with a telescope. Its publication in 1610 caused a sensation. It catapulted Galileo almost overnight into the status of an international celebrity. Galileo discovered mountains on the Moon, in addition to the four satellites of Jupiter.

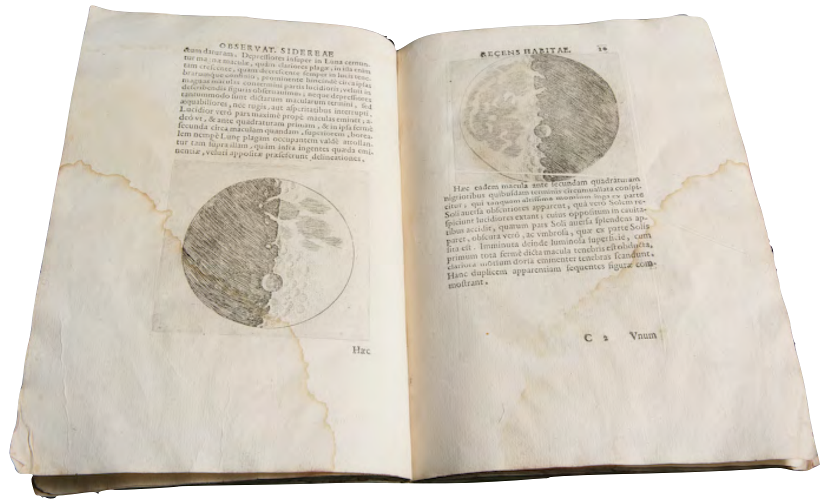



In 2015 we put on a Galileo’s World exhibit, in which one gallery was devoted to Galileo and Perspective Drawing.
• This gallery explored the question: “What was it like to be an astronomer in an era when art and mathematics were intertwined?” For the introduction to this gallery, I presented some bold theses:

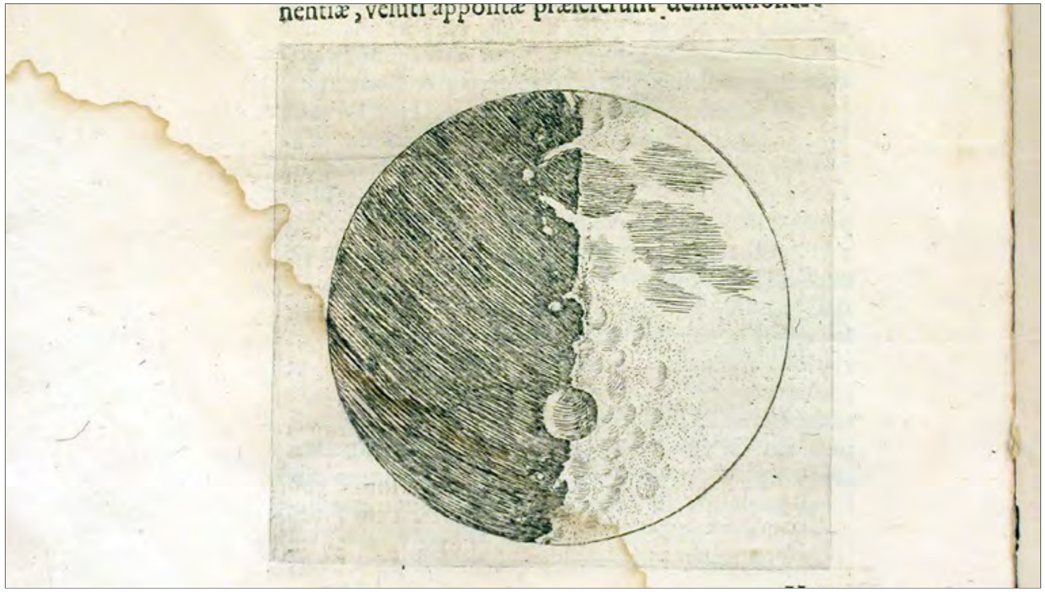
- "In the *Starry Messenger*, Galileo reported his discovery of four satellites of Jupiter and mountains on the Moon. These sensational telescopic discoveries were made possible by Galileo's training and experience in Renaissance art. Galileo's scientific discoveries occurred in the context of a specific artistic culture which possessed sophisticated mathematical techniques for drawing with linear perspective and handling light and shadow. When Galileo peered through his telescope and discovered mountains on the Moon, he did so because he was seeing with the eyes of an artist. Contemporaries without artistic training were not able to see what Galileo saw; they were able to look but not to see."

Quote: "In the Starry Messenger, Galileo reported his discovery of four satellites of Jupiter and mountains on the Moon. These sensational telescopic discoveries were made possible by Galileo's training and experience in Renaissance art. Galileo's scientific discoveries occurred in the context of a specific artistic culture which possessed sophisticated mathematical techniques for drawing with linear perspective and handling light and shadow. When Galileo peered through his telescope and discovered mountains on the Moon, he did so because he was seeing with the eyes of an artist. Contemporaries without artistic training were not able to see what Galileo saw; they were able to look but not to see." End quote.

## Galileo’s Telescopic Discoveries



Because lenses at that time were of such poor quality, Galileo’s discoveries were made not by optics but by the artistic training of his eyes.  Let’s explore why this was so.




First, were Galileo’s engravings of the Moon attempts to provide a naturalistic representation of the Moon? Quite simply, no.


Galileo was capable of drawing a naturalistic portrait of the Moon when he wanted to, as in a manuscript known as the Florence sheet, now held in the national library of Florence. This was drawn at the telescope.

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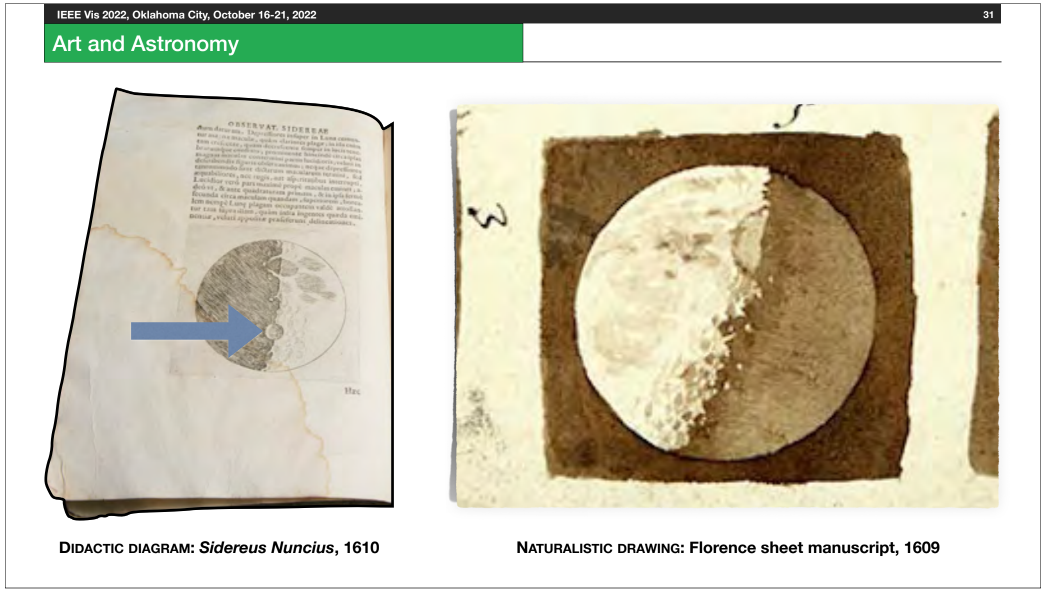
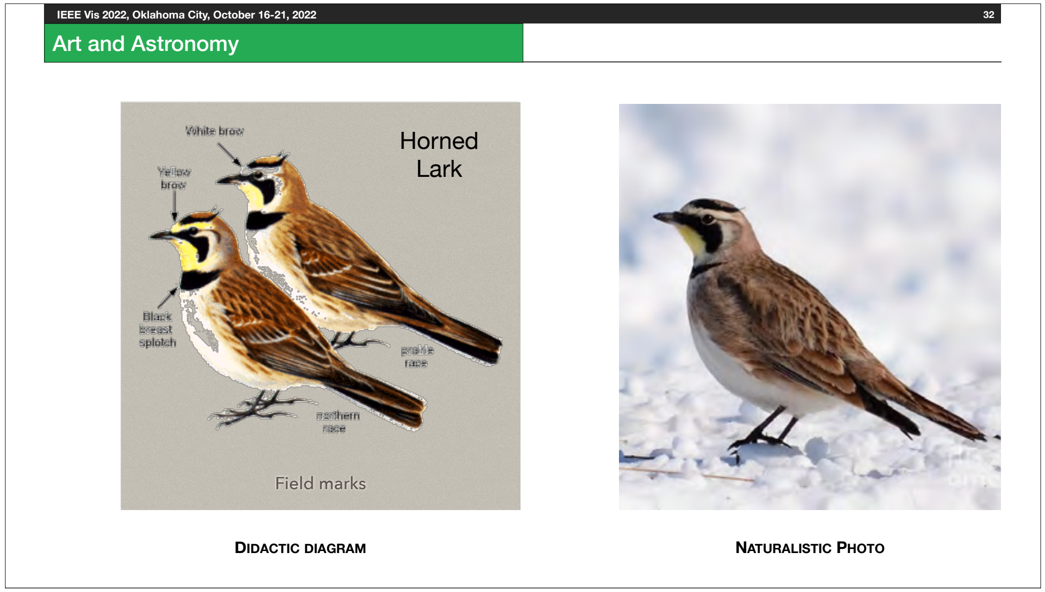
Florence, Biblioteca Nazionale Centrale, Ms. Gal. 48, f. 28r



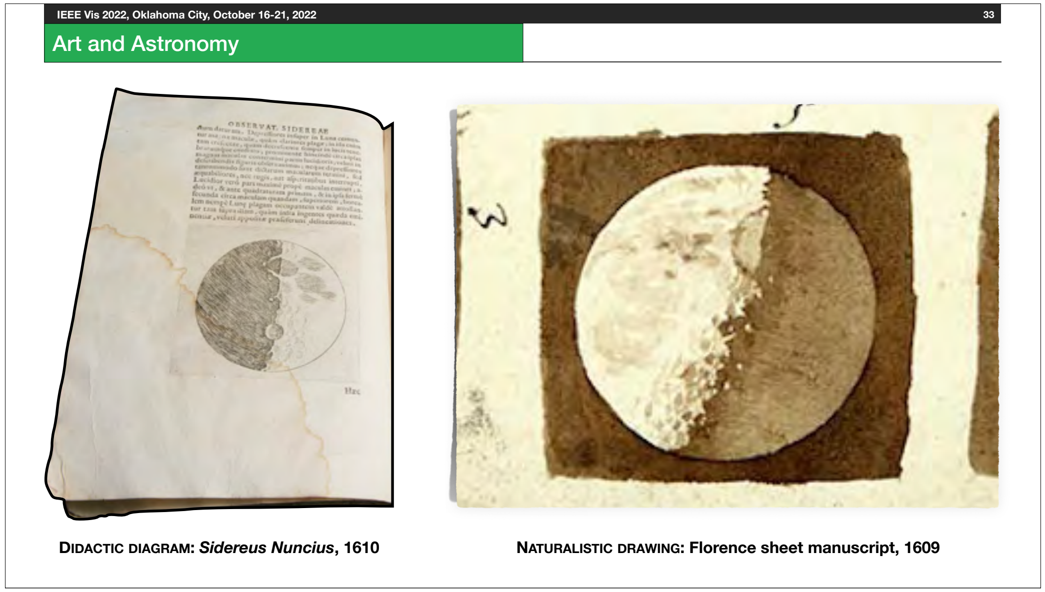

Contrast the first printed edition of Siderus nuncius. We might ask: Are the engravings in the Sidereus nuncius copied directly from the manuscript drawings? The answer is clearly no.

• In particular, notice the crater in the bottom center of the engraving. There is no counterpart to this crater in any of the Moons drawn on the Florence sheet. Why might this be so?

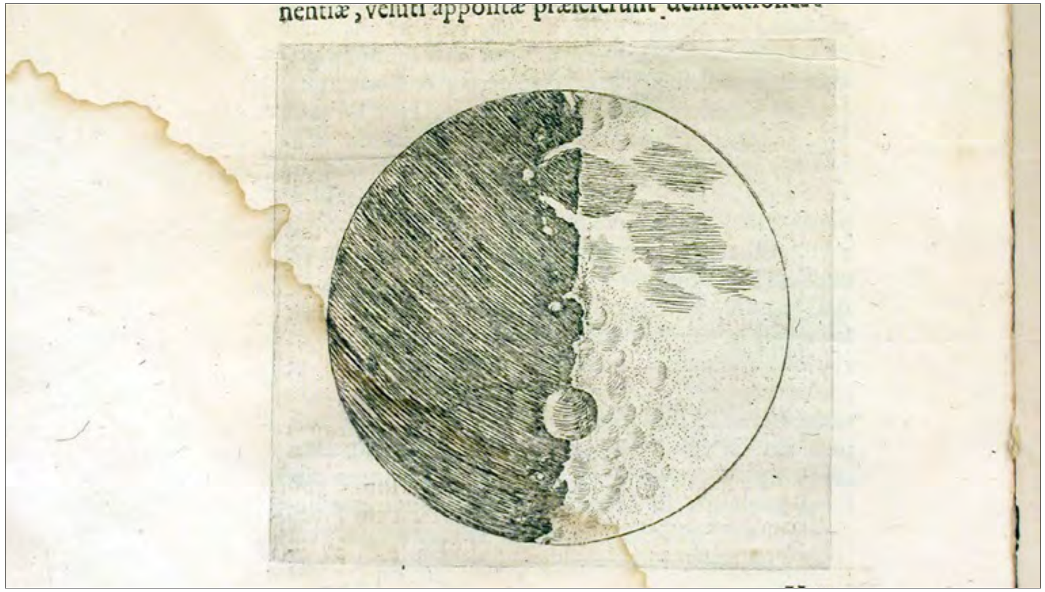



Think for a moment about a field guide. Field marks have a didactic purpose. Field marks simplify some features and exaggerate others

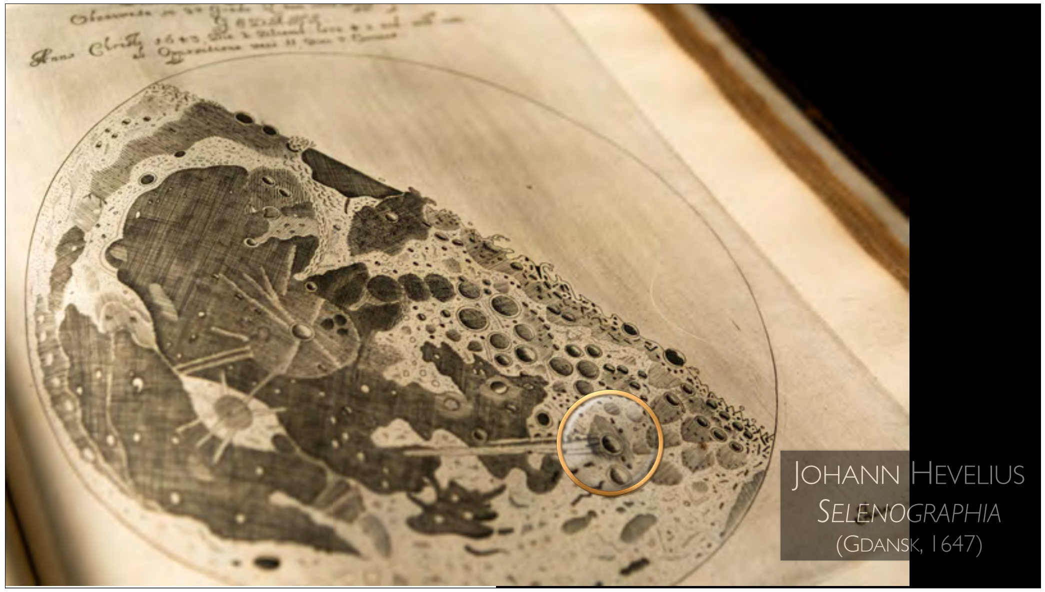
- compared to a photograph or an artistic portrait of the same bird.



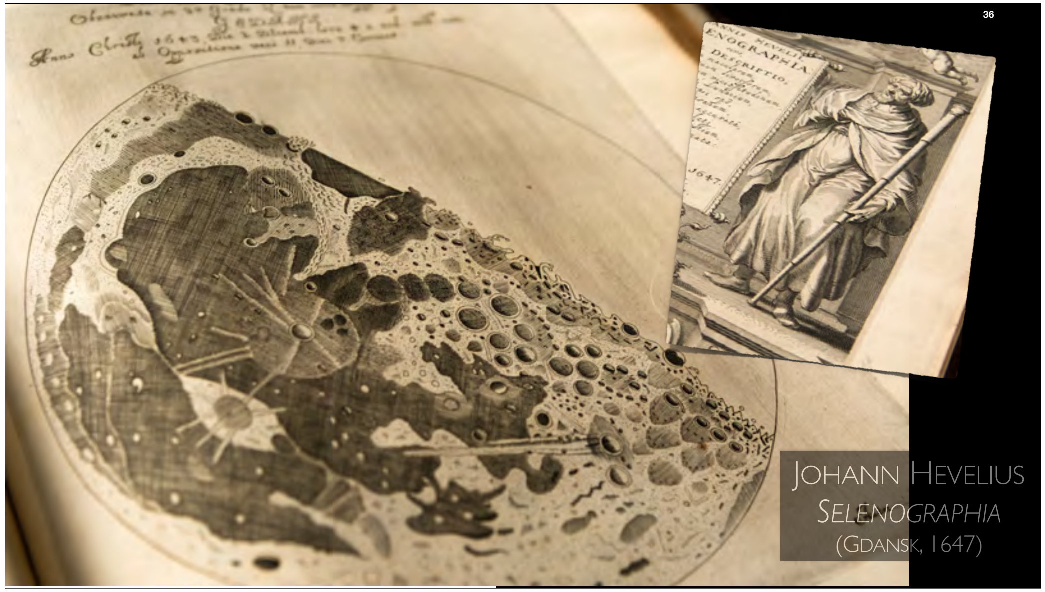

In the same way, Galileo's printed etchings of the Moon like the one on the left are like diagrams of field marks.  They serve a different purpose from the naturalistic sketches of the Florence sheet on the right.  In contrast to the naturalistic drawings, Galileo's printed etchings call attention to certain features and teach us how to interpret the observations. The printed etching on the left is didactic rather than naturalistic.




Well, then, were Galileo's engravings of the Moon attempts to map the surface of the Moon? Again, the answer is clearly no.

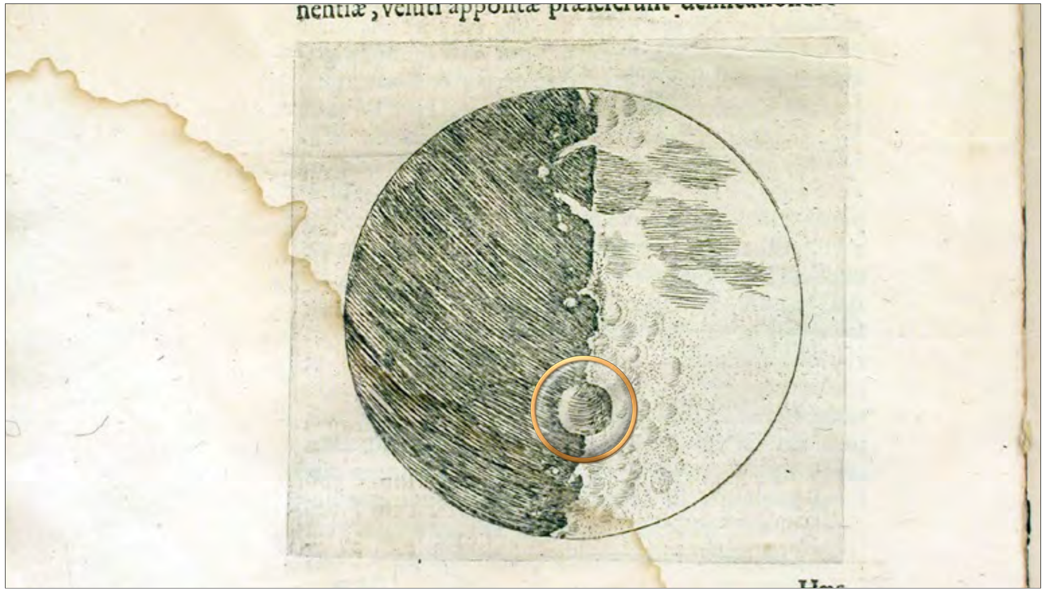



The size of the crater at the bottom center is accurately depicted here in the atlas of Hevelius. It is quite small.  One misinterprets Galileo to accuse him of exaggerating its size…

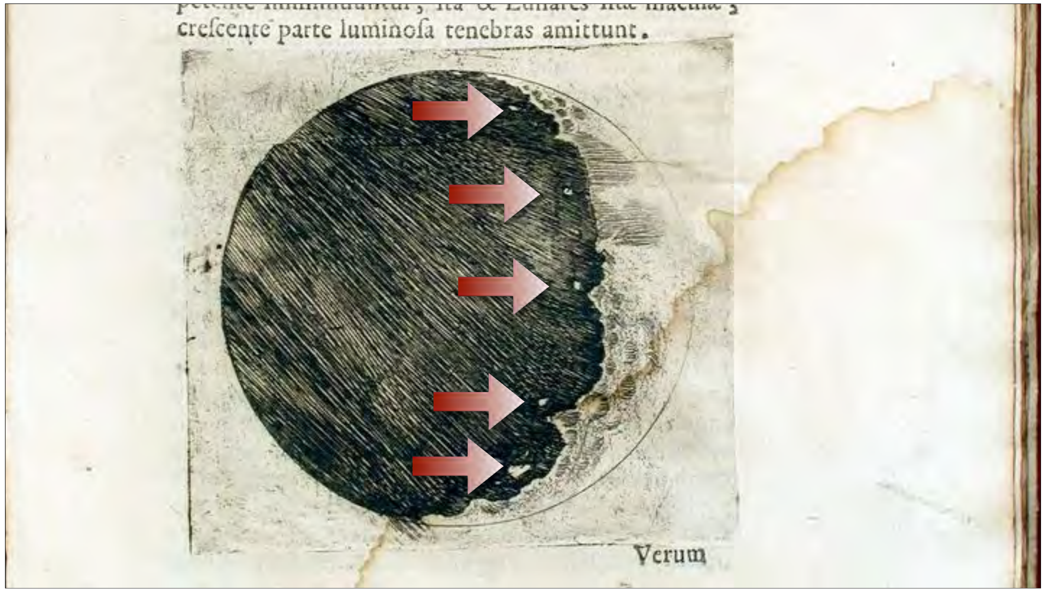



Galileo's book set off the 17th century race for the Moon.  Not a race to go there, but a race to map its surface.  It's astonishing that this task was accomplished by mid-century — in this comprehensive lunar atlas of Johann Hevelius, less than 40 years after Galileo's initial telescopic discoveries.

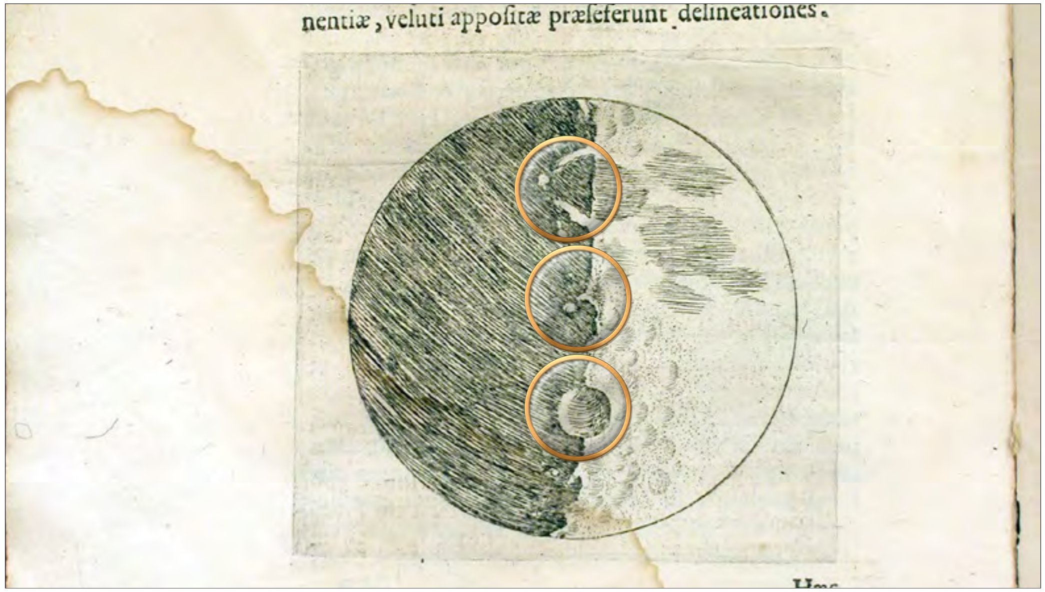
• Incidentally, for those who might hastily assume that Galileo marks a unique staring point for modern science, as something altogether new, the title page of this volume depicts Galileo in Middle Eastern dress as a tribute to the Islamicate optical tradition.



So Galileo was not exaggerating the size of the crater located here, because he was not trying to map the Moon, he was trying to help us think more clearly about the lunar surface generally.  In contrast to Hevelius, Galileo’s drawings are not evidential but didactic. • Before the Moon could be mapped, first someone had to demonstrate that there was something there, real surface topography, that could be mapped.  The assumption at the time, was that the shading of the Moon was internal, its surface as smooth as a marble. But Galileo showed that’s not so.

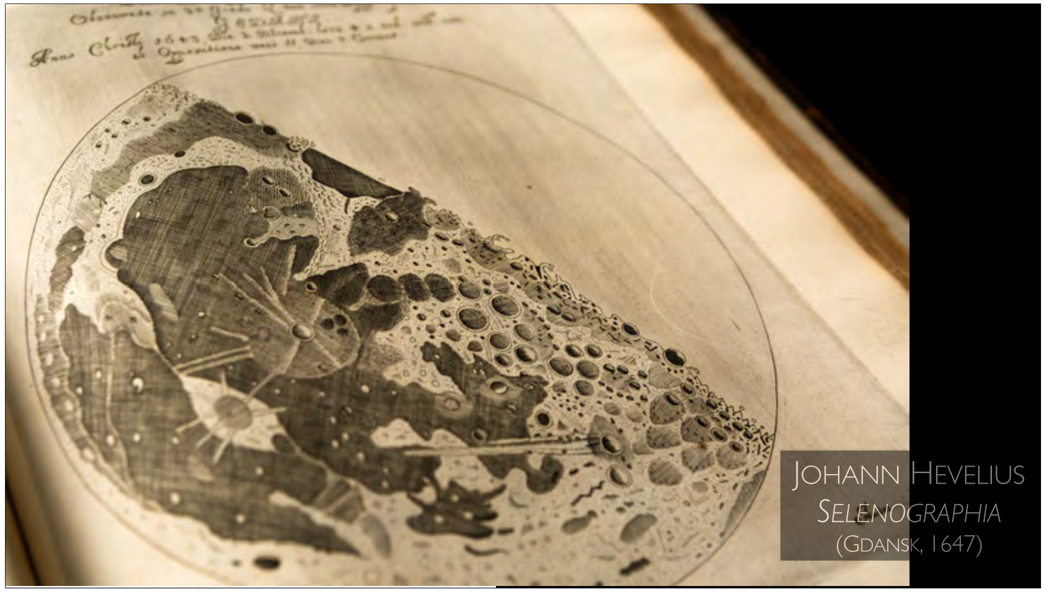



He countered arguments that the Moon's surface was smooth by teaching us how to see, how to observe the changing play of light and shadow. • The white dots to the left of the shadow line, or terminator, are mountain peaks, standing above the plains that are still in morning darkness.

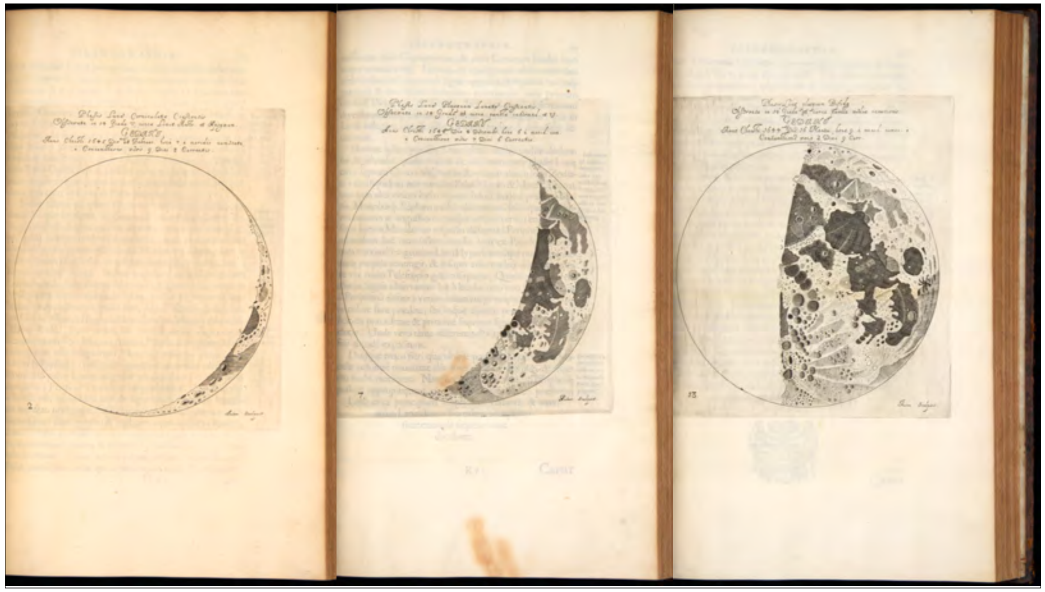



This lunar depiction leads us through a process of making three different observations over time. First, the small circle of light represents an isolated peak visible on a particular night, shining above the darkness of the surrounding plain. The light triangular region immediately to its right designates a foothill.

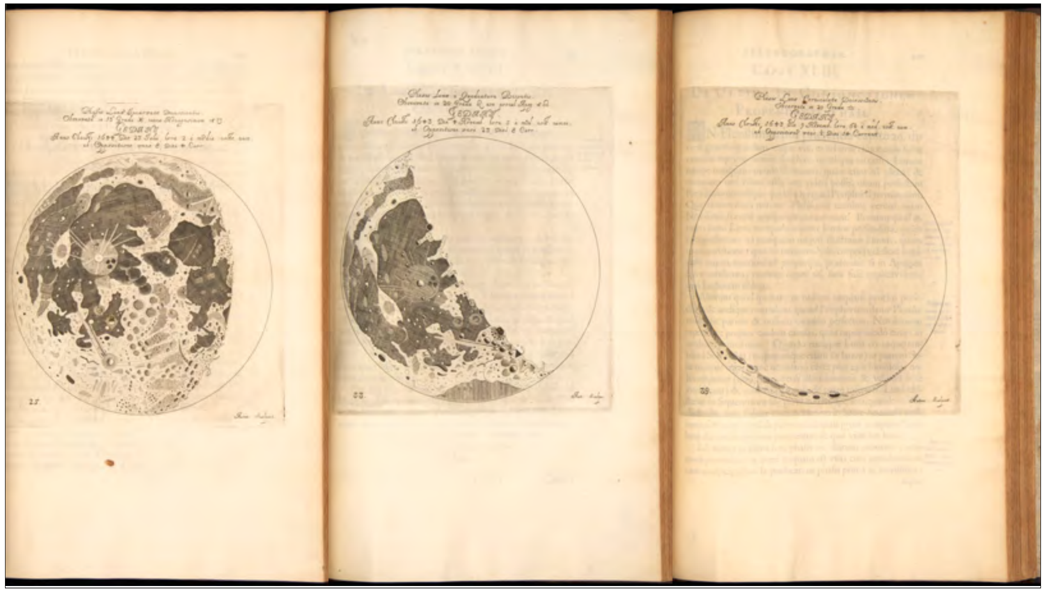
- On a subsequent night, that very peak will appear farther from the terminator, or main shadow line. And the foothill to its right has become elongated, now appearing like a mountain ridge, with another ridge appearing immediately below it.
- On some night after that, the ridges have converged and the whole area takes on a circular appearance. Galileo was not mapping the moon, nor implying that a crater of that size is present in that location, but instead teaching us to observe the changing appearances of a single location on the Moon over three successive nights. This diagram teaches us to interpret the changes of light and shadow on the surface of the Moon. Galileo was showing us how to detect real lunar topography, contrary to the Aristotelian physicists.
- This is a didactic image, leading us in a process of visual thinking. As a result, we now understand that a map of the Moon must emerge as a composite inference from the evidence of many nights' observations.




Today, amateur astronomers who love the Moon know that to stare directly at the Full Moon is blinding at night; surface detail is entirely washed out.

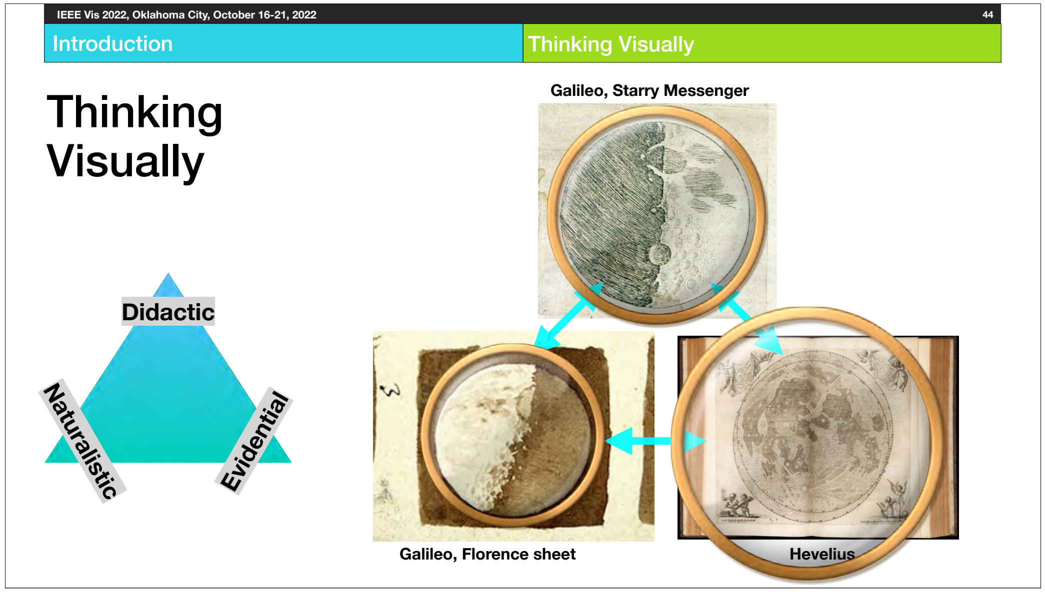


To map the Moon, one must examine the “shadow line” night after night as it passes across the face of the Moon. At the shadow line, light moves back and forth, first one way and then the other,



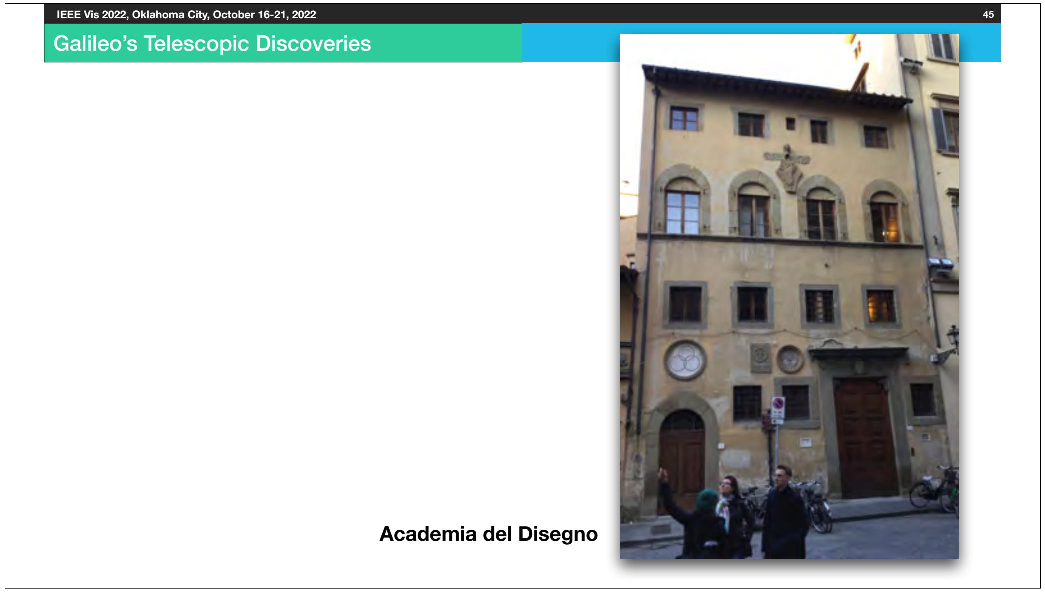
over the month-long lunar cycle, casting shadows in both directions at opposite phases. Some lunar features are visible only on one or two nights during the entire lunar cycle.


From these studies Hevelius assembled a definitive map of the lunar disk.

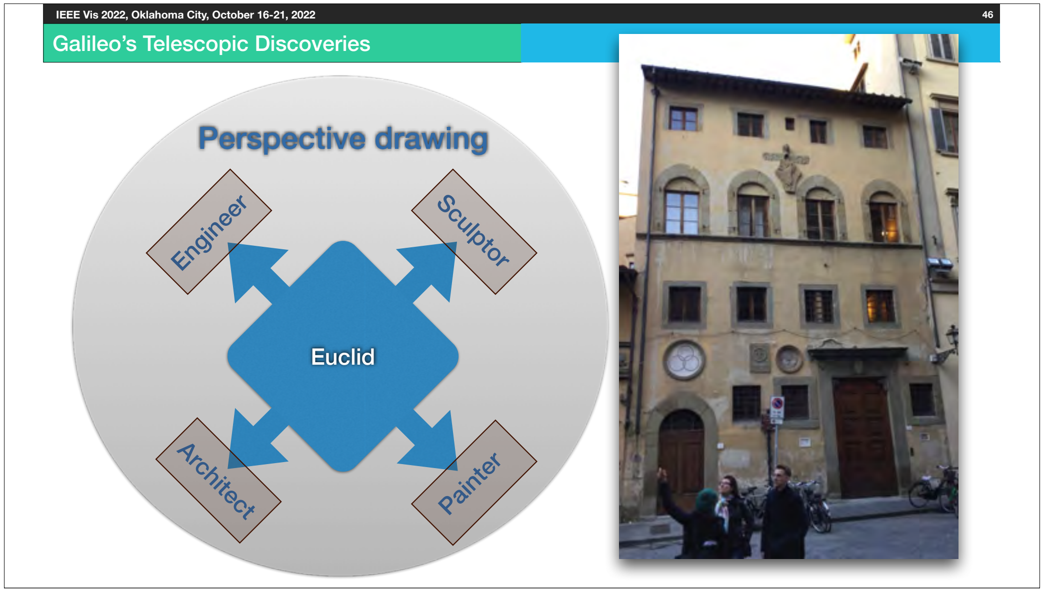



To recap:

- Galileo sketched on the Florence sheet in a naturalistic manner what he saw through the telescope.
- In the Starry Messenger, he used didactic images to teach us to think visually about how lunar topography would appear in multiple observations taken over time.
- Less than 4 decades later, Hevelius produced an accurate map of the Moon created as a composite of 40 individual portraits over a 5-year span. Hevelius' composite map is a visual construction; the Moon does not appear like the map on any single night of its cycle.



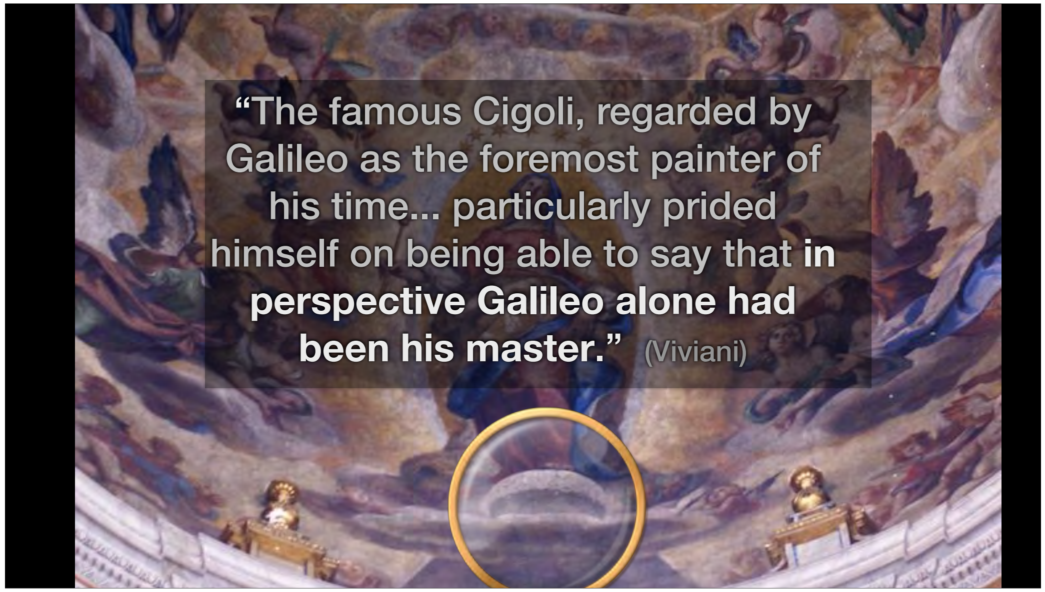

So Galileo was a superb visual thinker. How did Galileo learn to see the lunar surface artistically, before anyone else? How did he gain experience in the study of light and shadow? At that time in Tuscany, many young men enrolled in artisan workshops, such as the Academia del Disegno (or Academy of Drawing). In these artisan workshops they would study Euclidean geometry in a hands-on way by acquiring the techniques of perspective drawing. Later in life, Galileo was elected an honorary member of the Academia del Disegno.




For their capstone project, students in these artisanal workshops would apply their geometrical drawing skills to

- a project in art such as a painting or drawing, and go on to become artists.
- Or they might craft a sculpture, or make a blueprint, and go on to be sculptors or architects.
- Or they might create a design for a complex machine, and go into engineering, as did Galileo.
- In artisan workshops, future artists and engineers studied side by side. This was interdisciplinary education in action, manifesting natural and organic connections between subject areas. (pause) It is worth pondering: Compared to the role of perspective drawing in the artisan workshops, are your visualization principles and techniques of similar cross-disciplinary applicability? Pedagogically, what is your equivalent today of the artisan workshops of Tuscany?


As a young man, Galileo studied in the artisan workshop of Buontalenti, where lessons in geometry were given by Ostilio Ricci. Ricci's lectures there were also attended by Galileo's friend, the painter Cigoli.



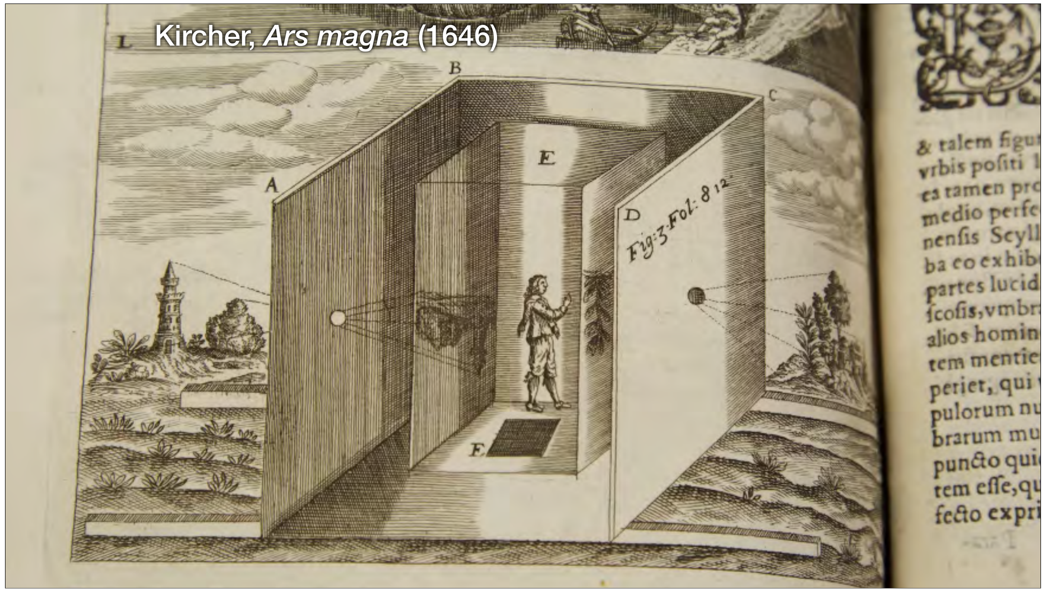

This is a painting by Cigoli in Rome, of the Virgin standing on the Moon.

- But the Moon shows craters, as it appeared through Galileo’s telescope.
- Galileo’s later secretary, Viviani, recorded that Cigoli stated that Galileo had been his teacher in the art of perspective drawing, writing, quote:  “in perspective, Galileo alone had been his master.”


This is the first English translation of Euclid's Elements of Geometry, printed in 1570. In the chapter on the geometrical solids, this copy retains the original pop-ups, which helped beginning students learn to think 3-dimensionally. Euclid, as studied in the Florentine artisan workshops, was the starting point for optics and perspective.

——————-

(Optics combined geometry, experiment, vision and art.)



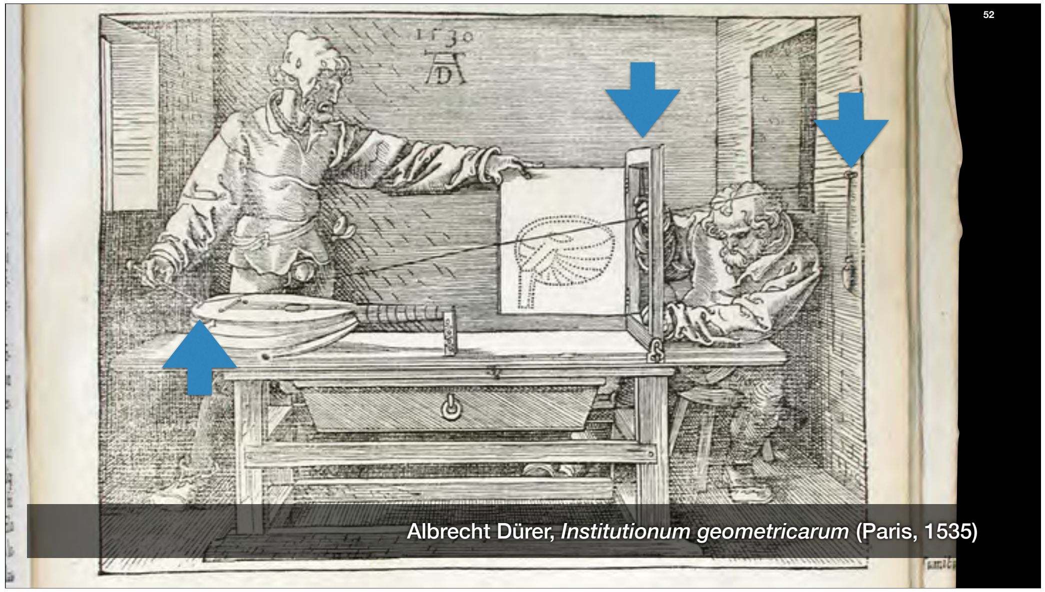

Kircher, *Ars magna* (1646)

Euclid worked out the principles of the “camera obscura.” Camera obscura literally means a “dark room.” It consists of a box or container in which light enters via a small hole and projects an image on an opposite wall. The image will be reversed and upside-down, but its proportions will be preserved and it can be traced to produce a realistic landscape. Renaissance artists had been familiar with the camera obscura for several hundred years, and it was well-known to astronomers like Kepler and Galileo.


Leonardo da Vinci, in Luca Pacioli, *Divina proportione* (1509)

The linear propagation of light in the camera obscura made it possible to draw with true perspective.  To aid in perspective drawing, many additional instruments, tools and techniques were developed.  This geometrical drawing demonstrates true perspective and a mastery of light and shadow.  You don’t get that by accident.

• This and other similar diagrams were drawn by Leonardo da Vinci.  They were the only materials ever put in print by Leonardo during his lifetime, appearing in a work on drawing by Leonardo’s friend Luca Pacioli.  Artists over the following century would practice the techniques and tools of perspective drawing by re-creating geometrical figures like Leonardo’s. They were thinking visually.




Albrecht Dürer, *Institutionum geometricarum* (Paris, 1535)

This explanation of perspective drawing comes from a work by Albrecht Dürer called the Institutes of Geometry. It was similar in scope to the Pacioli, yet published a generation later.  Dürer here shows a variation on the perspective drawing technique known as “Alberti’s window.” The artist is creating a drawing of a lute with true perspective by means of

- a string running from the object,
- through the canvas window,
- to the vanishing point on the wall.


Sirigatti, *La Pratica di Prospettiva* (1596)

This beautiful work by Sirigatti, published when Galileo was a young man, brings the tradition of perspective drawing up to Galileo’s time. Sirigatti was a member of the Accademia del Disegno, mentioned earlier.


The work contains 64 full-page engravings, each with an accompanying page of text, to train artists and engineers.  Here is the exercise for the lute, as we saw in Dürer.

Sirigatti, *La Pratica di Prospettiva* (1596)

Here are some exercises similar to the Leonardo drawings in Pacioli.  Galileo worked his way through Sirigatti, practicing the techniques of linear perspective by reproducing these and the other drawings.

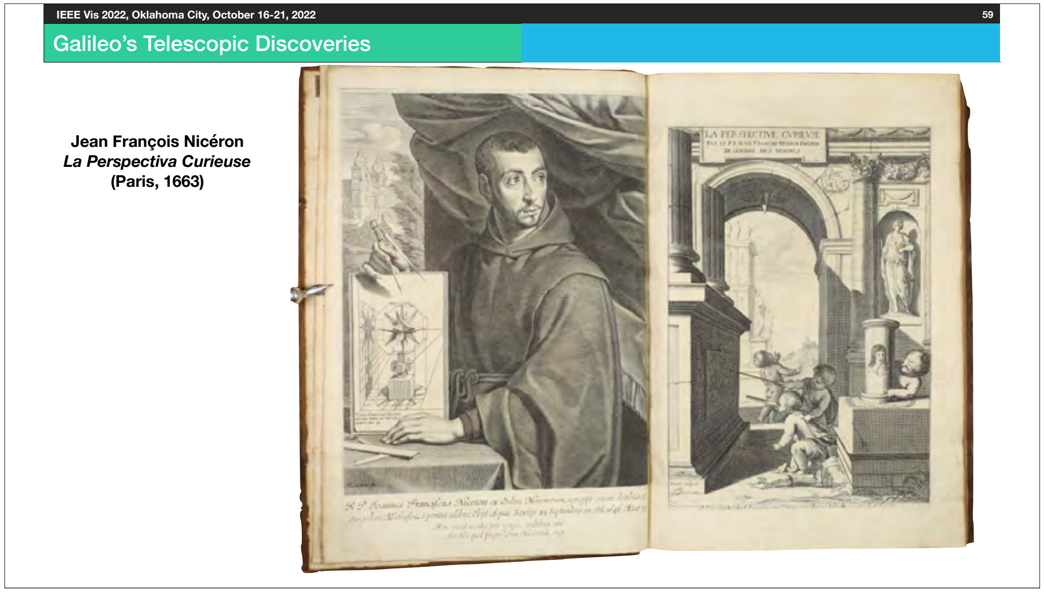

Any young artist or mathematician working his way through Sirigatti, like previous generations working through the exercises of Leonardo or Dürer, would master perspective and the handling of light and shadow.

Sirigatti, *La Pratica di Prospettiva* (1596)

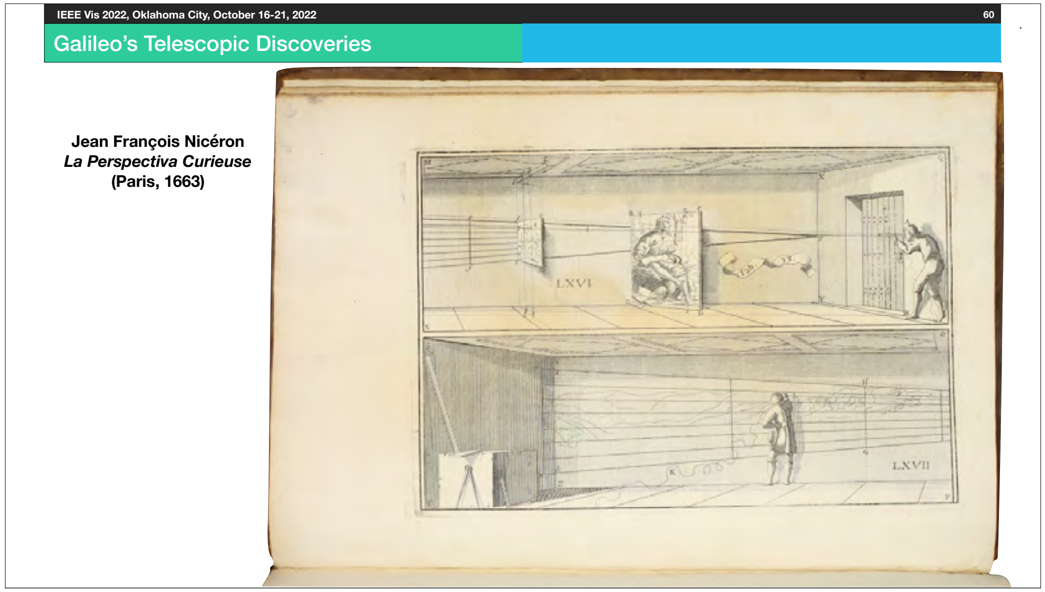
Careful study of the spikes on this ring by Sirigatti, and the shadows they cast, prepared Galileo's eyes to interpret the shadows cast on the Moon by mountains and other topographical features.

• Imagine that each spike is the same lunar mountain observed at different times under light from different angles. Remember that Galileo studied how to draw this diagram *before* he used the telescope.

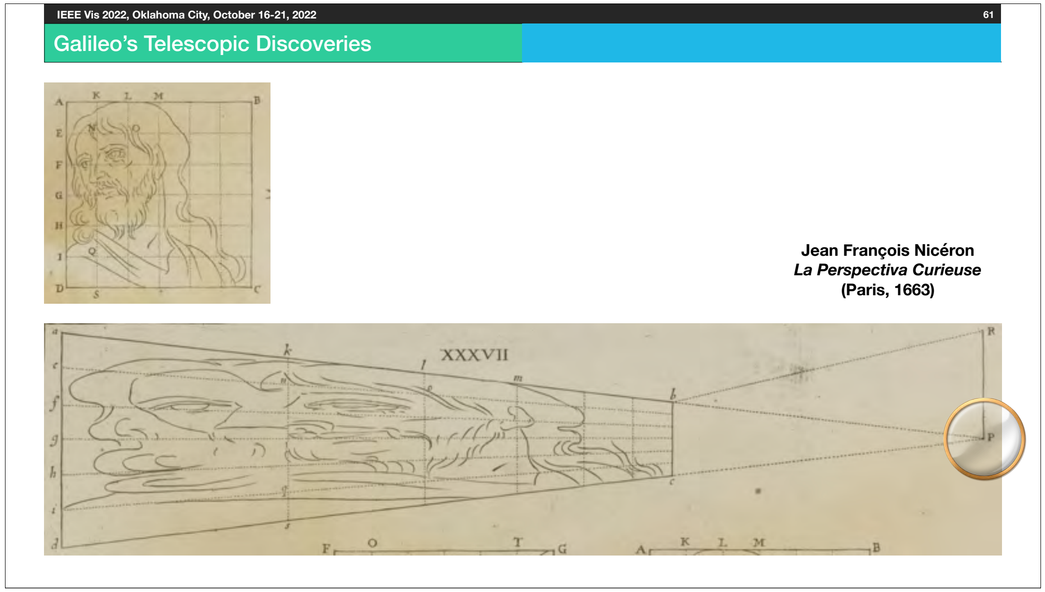

Thomas Harriot, one of the leading astronomers in England, was observing the Moon at this same time and conversing with his friends about what they called the “strange spottedness of the Moon.” Harriot and a friend concluded that the Moon looks like an Apple pie! Why did Harriot not discover the lunar mountains before Galileo? Harriot did not have the benefit of this tradition of artistic training in perspective drawing like Galileo; there was as yet no equivalent of Sirigatti in England to help him interpret the “strange spottedness” as shadows cast by mountains. Once Galileo published the Starry Messenger, Harriot quickly agreed, because Galileo taught him how to see.




During a visit to Florence, the French mathematician Jean François Nicéron met with Galileo's artist friend Cigoli.  Cigoli showed Nicéron a perspective drawing tool he himself had invented.  Nicéron later published Cigoli's technique in this book.




In Florence, Nicéron also viewed examples of anamorphic drawing techniques, such as Alberti perspective boxes.




Make your own Alberti box by taping this image inside the long side of a shoebox. Then cut a sighting hole in the small end of the box,

• so that the narrow point (“P”) is positioned at the sighting hole. Hold the box sideways up to your eye so that you can sight along the diagram with your eye at point P.

• What picture will you see? (pause) Florentine artistic culture, steeped in the techniques of visual thinking through perspective drawing, was the midwife at the birth of Galileo’s telescopic astronomy.

— — — — —

http://kerrymagruder.com/TH504/Alberti-box.pdf

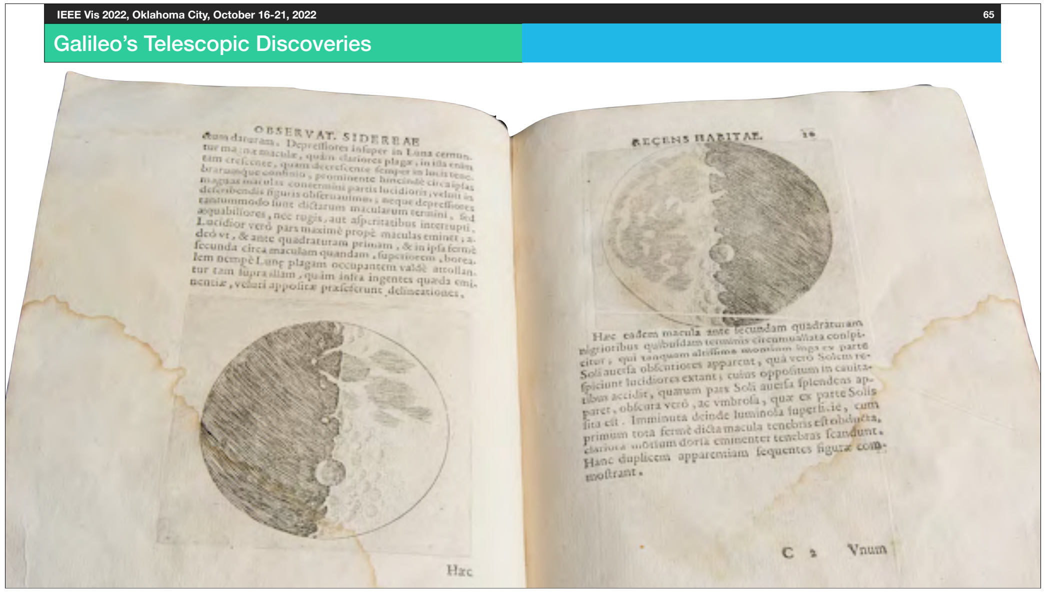
Galileo, *Sidereus nuncius* (1610)

This is the title page of the OU copy of the Sidereus nuncius.

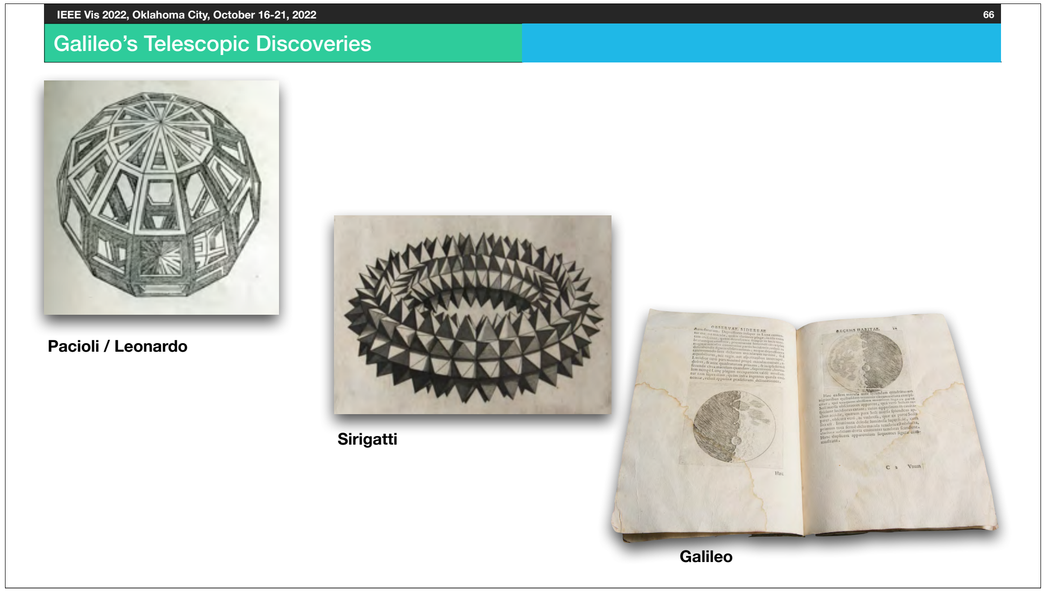
Galileo, *Sidereus nuncius* (1610)

Galileo’s signature appears in the lower right corner. He inscribed this copy as a gift to Gabriel Chiabrera, a poet in the Medici court.

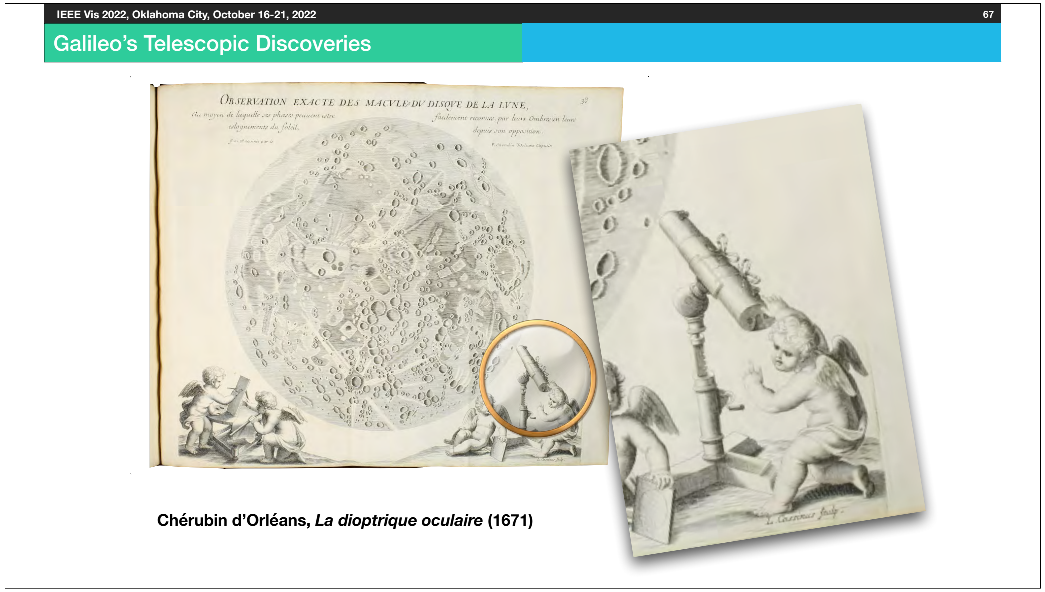

Within the title itself, Galileo refers to the telescope as a perspicilli, or “perspective tube.” Galileo regarded the telescope as another tool for perspective drawing.



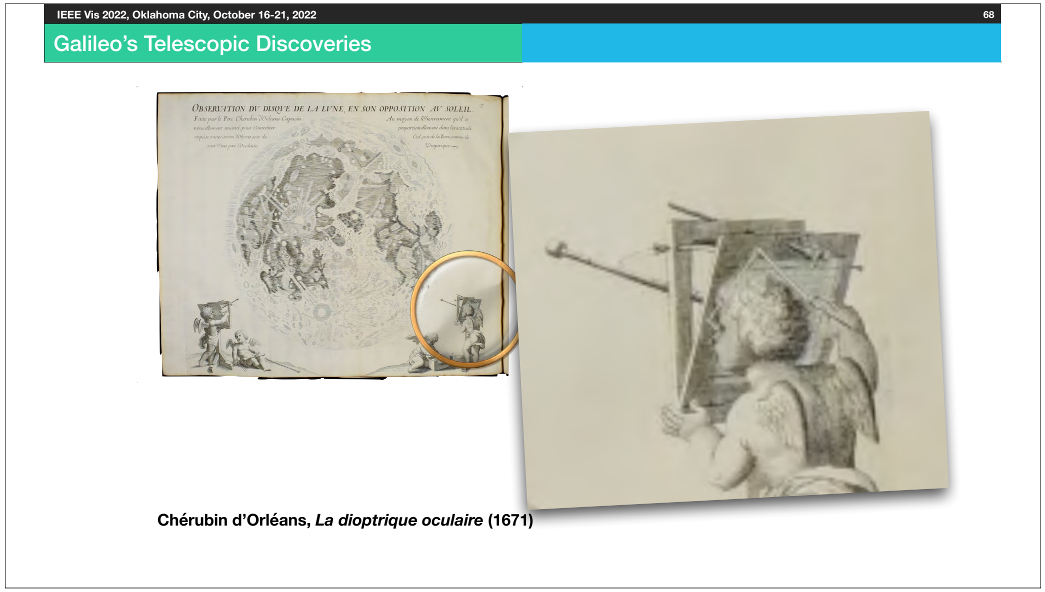

Galileo’s years of practice of the principles of light and shadow in perspective drawing, enabled him to interpret the markings appearing in his “perspective tube” as the shadows of mountains protruding up from the surface of the Moon, just like the spiked donut exercise from Sirigatti.




So the most revolutionary astronomical discoveries of Galileo grew out of modes of visual thinking initially developed in art for perspective drawing. This sequence – Leonardo, Sirigatti, Galileo – is the background for our story that, to repeat, when Galileo peered through his telescope and discovered mountains on the Moon, he did so only because he was seeing with the eyes of an artist. He made his telescopic discoveries as much through artistic training in visual thinking as through optics. He was thinking visually, as are those to whom you teach the principles and methods of visualization science.



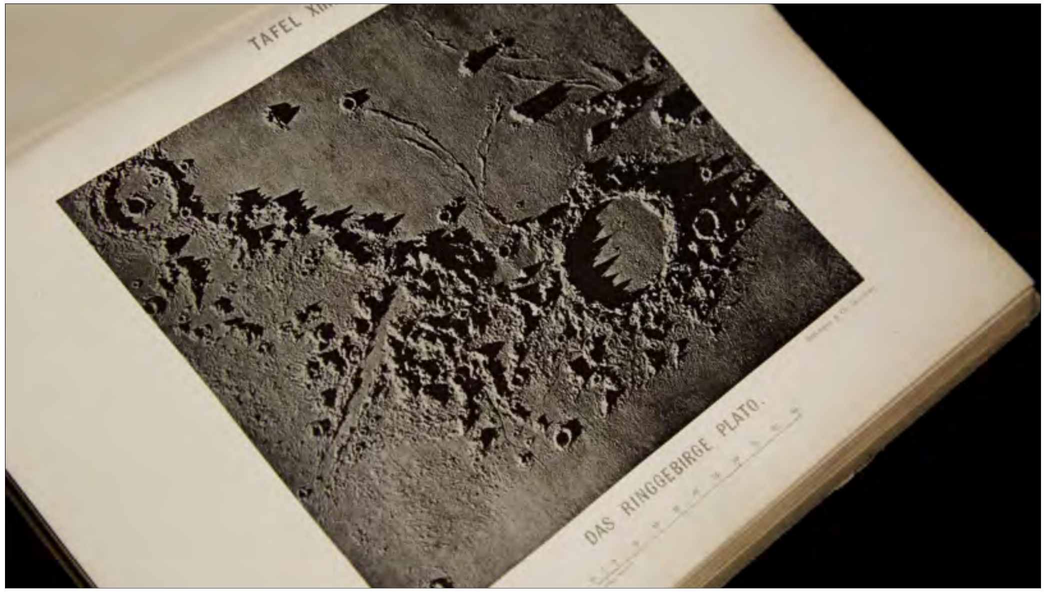

A generation after Galileo, Cherubin D'Orléans provided a comprehensive theoretical and practical discussion of perspective, vision and optics. d'Orléans adopted the lunar map of Hevelius, shown here, based on Hevelius' comprehensive telescopic observations. The putti are observing the Moon with telescopes.



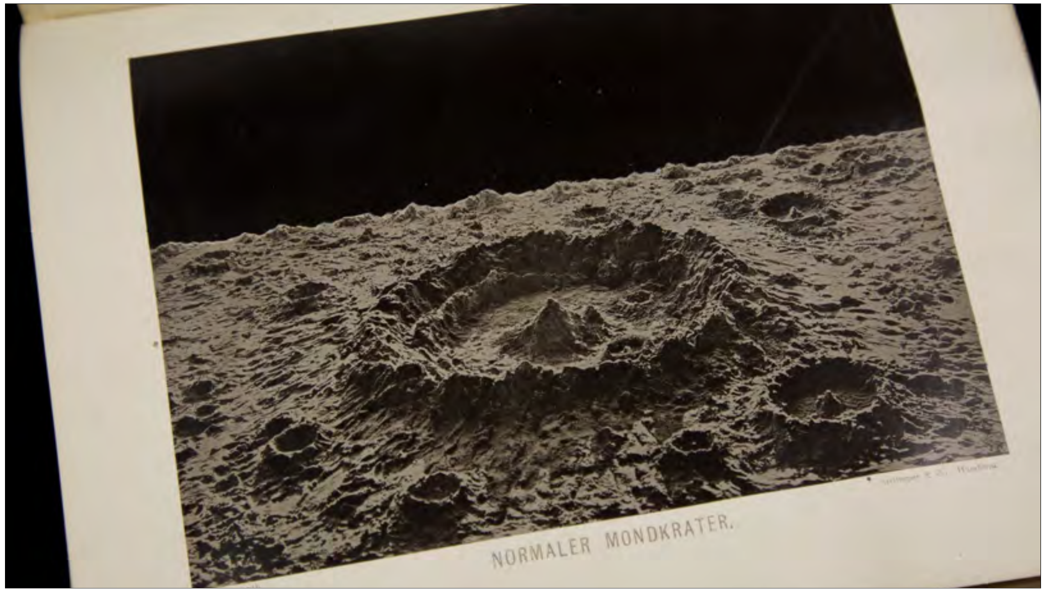

This is another page in the same work. Yet on this plate, the putti are observing the Moon not only with the telescope, but with the "pantograph," a perspectival tool devised by d'Orléans. The tradition of perspective that underlay Galileo's discoveries was not yet forgotten.

James Nasmyth and James Carpenter (1876)

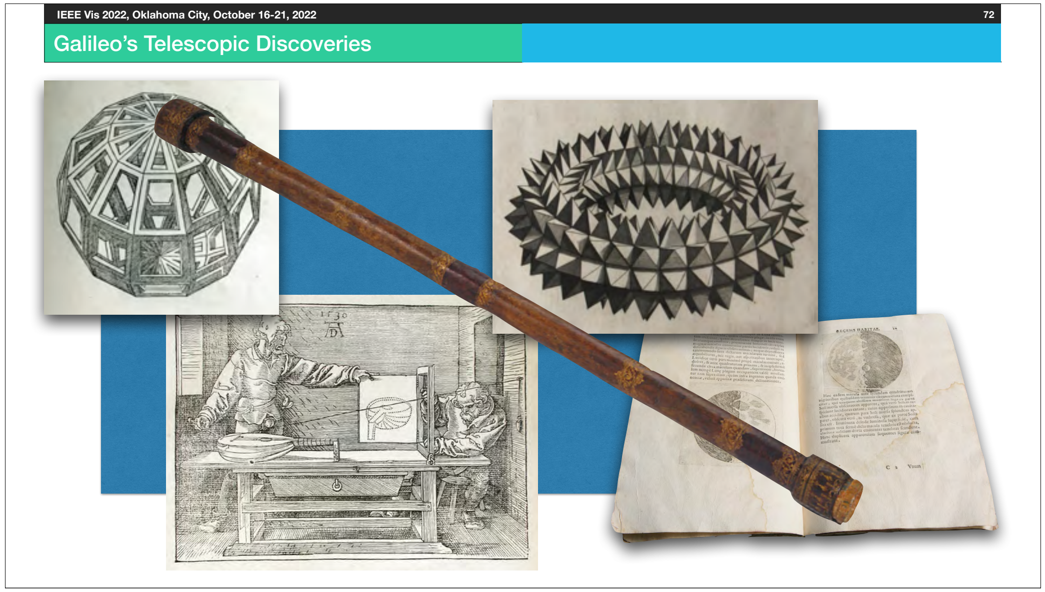
Let's move forward into the late 19th century.  This is not a photograph of the Moon!  No Earth-bound telescopes could then discern such detail. Nasmyth was a Scottish engineer best-known for inventing the steam hammer.  He combined avid interests in astronomy and photography. Carpenter was an astronomer at the Greenwich Observatory.  Together they constructed plaster models of the lunar surface. They photographed these plaster models using raking light, or light from the side.



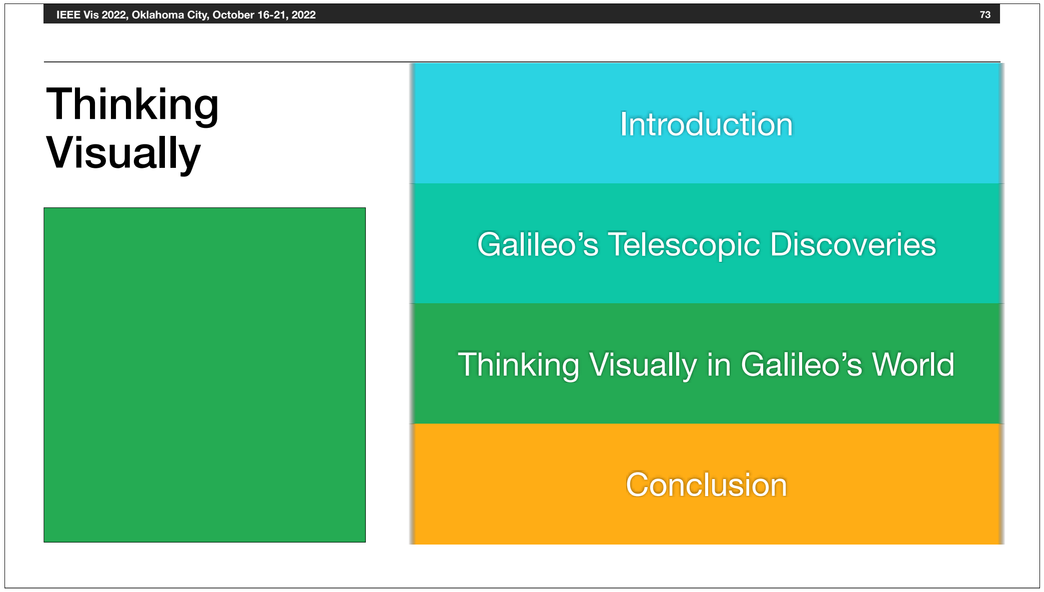

With light rays coming from oblique angles, they were able to simulate shadow effects on the surface of the Moon. In this British achievement in astronomy, we see that a productive connection between art and astronomy did not end with Galileo.




The shadows Galileo observed on the Moon revealed topographical relief. In the controlled conditions of their photographic laboratory, Nasmyth and Carpenter recreated the same effects in detail which Galileo originally taught us all to understand.  The tradition of thinking visually continued.

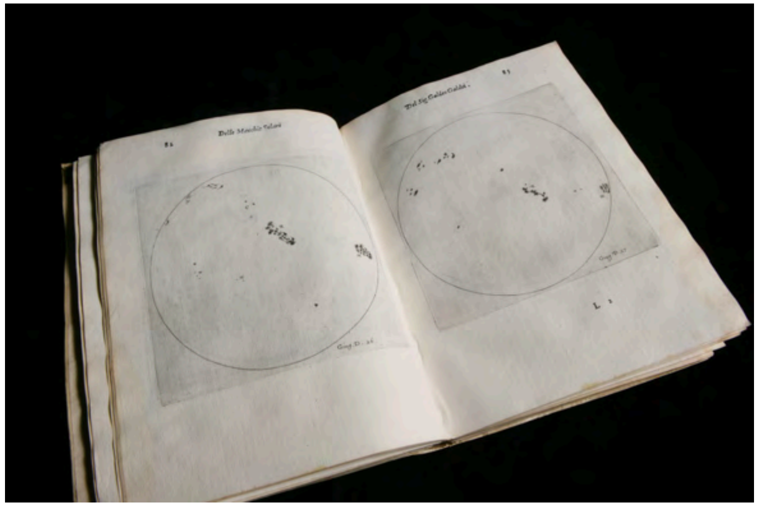



If Thomas Harriot, Nasmyth or Carpenter were to join the faculty at your university, do you think they would advise students from personal experience of the necessity of developing modes of visual thinking? But you don't need Leonardo or Dürer or Sirigatti or Galileo to tell you that your work in visualization science is critically important.




So that's Galileo's Telescopic Discoveries. Let's briefly glance at a few other examples of thinking visually in the world of Galileo.

Thinking Visually in Galileo's World | Letters on Sunspots



Galileo Galilei,
*Istoria e Dimostrazioni Intorno alle Macchie Solari*
(Rome, 1613)

"History and Demonstrations Concerning Sunspots"

Galileo published a description of sunspots in 1613 as they appeared through his telescope. Two years earlier, the Jesuit astronomer Christoph Scheiner argued that sunspots are little planets like Venus revolving around the Sun. Galileo rebutted Scheiner with Letters on Sunspots, shown here. Letters on Sunspots features a stunning sequence of full-page copper-plate engravings of the solar disc.

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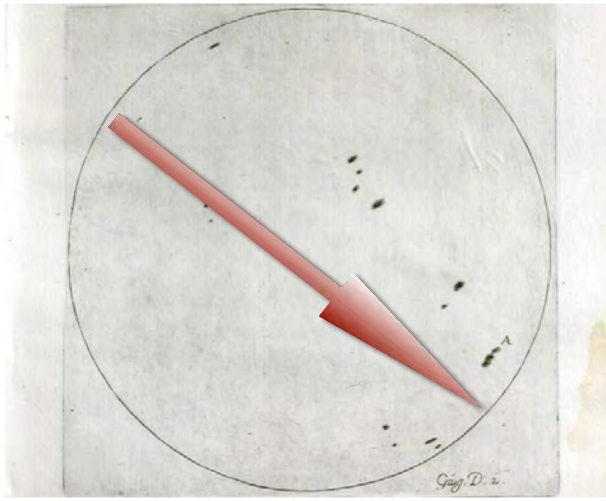
Thinking Visually in Galileo's World | Letters on Sunspots

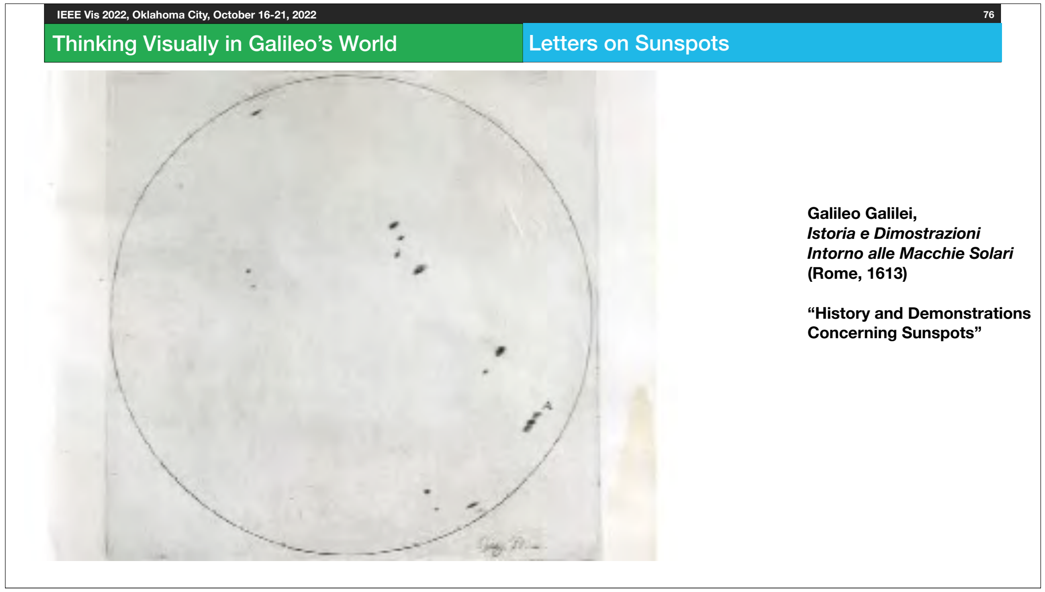


**Galileo Galilei,**
***Istoria e Dimostrazioni Intorno alle Macchie Solari***
**(Rome, 1613)**

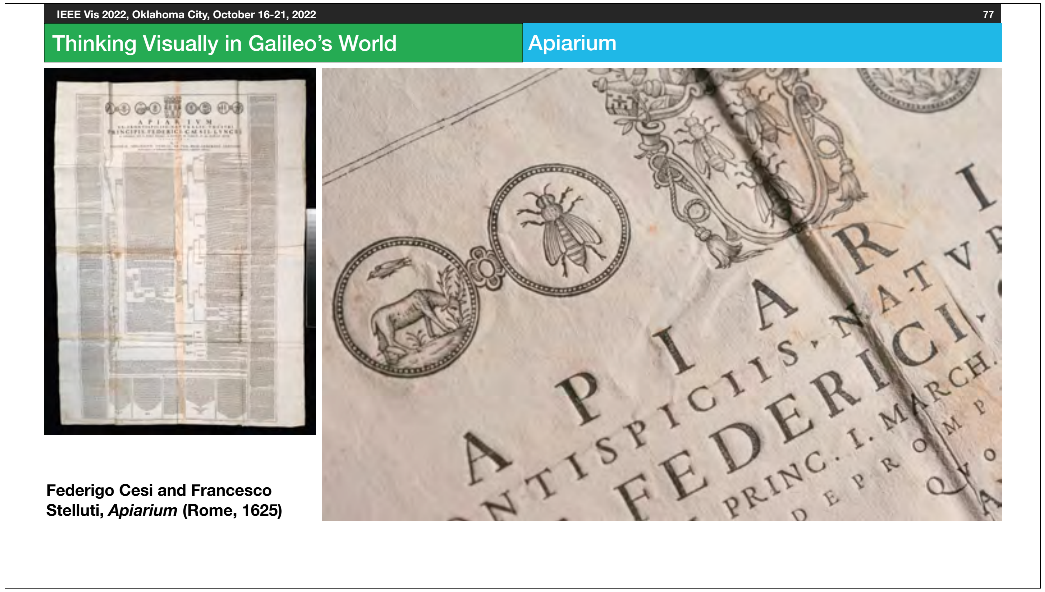
**"History and Demonstrations Concerning Sunspots"**

By tracking the motion of sunspots across the face of the Sun, Galileo proved that they were on the Sun's surface, and that they were not little planets circling around in orbits above. We will browse his observations for 28 days.

• (arrow) As we do, note how the spots move together across the Sun.

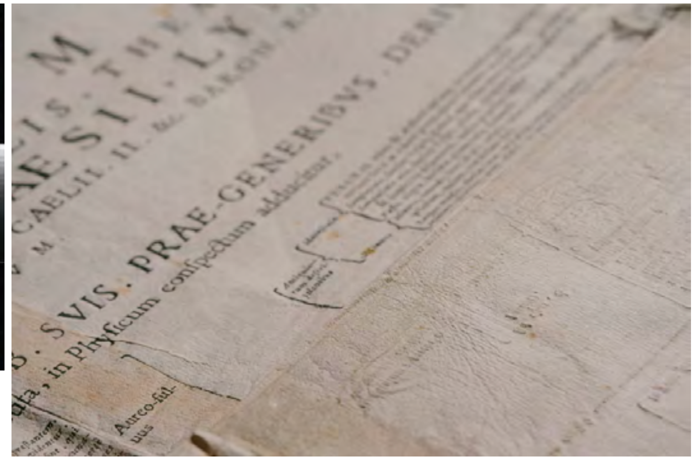



By *moving together*, and moving *slowly* (they take about a month to go all the way around), they cannot be planets. Note how irregular they are in *shape*, and how they form and disappear with irregular *timing*. That's not like planets either. Note the *foreshortening* of the spots as they approach the edge of the solar disk (lower right). That proves they're contiguous with the surface. [wait until animation is finished] Galileo's visual evidence was demonstrative and persuasive. Scheiner eventually published the definitive work of the 17th century on sunspots. He accepted Galileo's argument that sunspots "move like ships" on the surface of the Sun. Scheiner recognized that this conclusion suggested the Sun and the heavens are *corruptible*, a tenet contrary to Aristotle but already accepted by many theologians, including Cardinal Bellarmine, an eminent Jesuit whom Scheiner respected and with whom Galileo had a notable conversation.



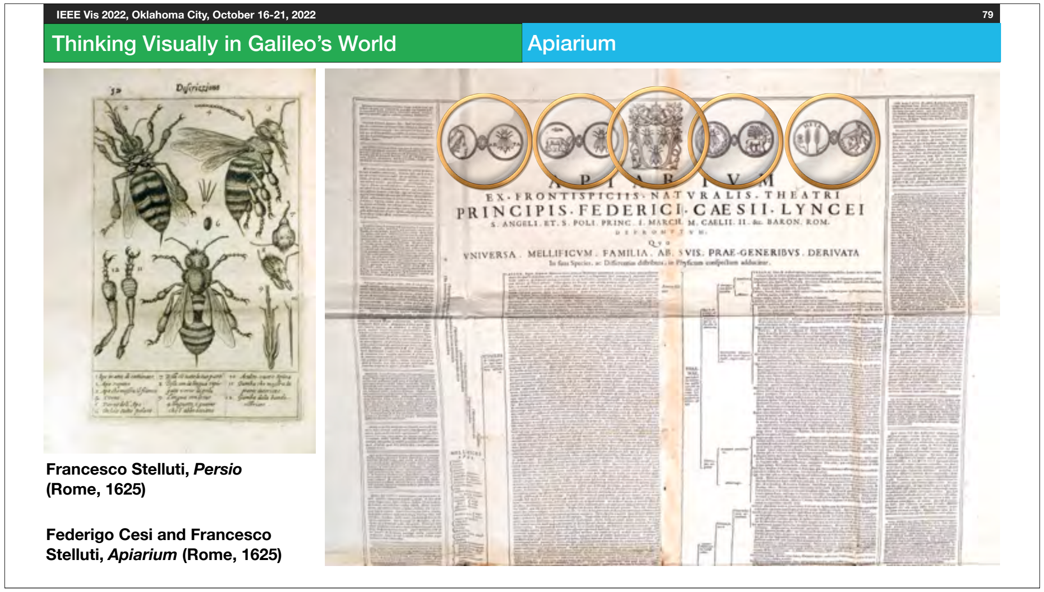

Another example of Galileo’s expansion of our visual world is the microscope. A generation before the well-known microscopic publications of Robert Hooke and Jan van Leeuwenhoek, Galileo adapted the telescope into a new instrument, which was named a microscope by one of his fellow members in the Academy of the Lynx. This poster-sized work is the first publication of observations made with a microscope. Two other Lynx members, Federigo Cesi and Francesco Stelluti, studied the anatomy of the bee as it appeared under the lenses of Galileo’s microscope.

Thinking Visually in Galileo's World | Apiarium



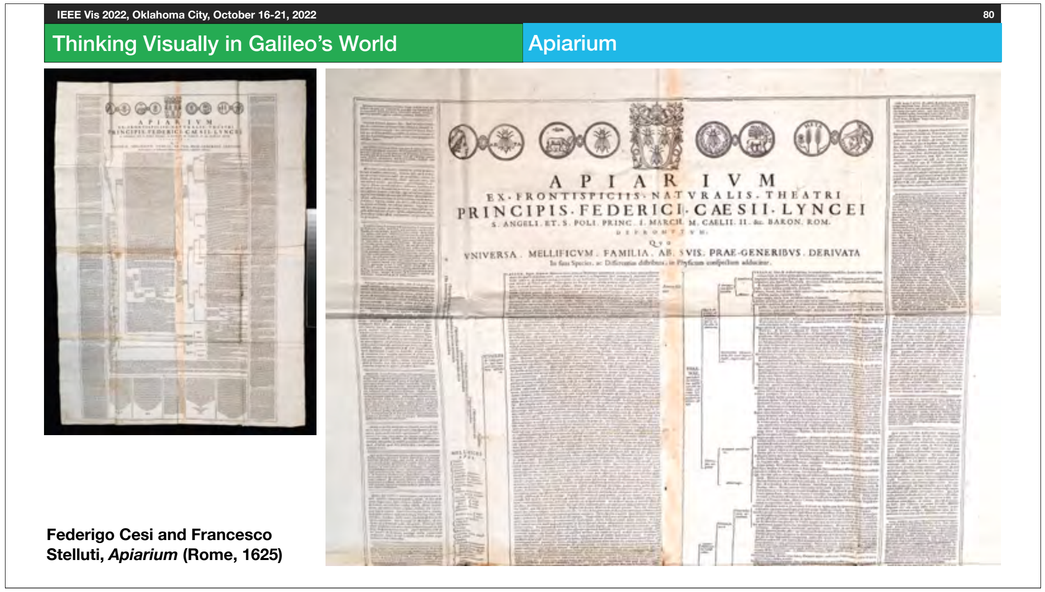
Federigo Cesi and Francesco Stelluti, *Apiarium* (Rome, 1625)

Because only a handful were printed, the type has bitten deeply into the paper. Only four printed copies survive.




Along the top are representations of four ancient coins depicting bees. The work celebrated the accession to the papacy of Galileo's friend Maffeo Barbarini.

- Not coincidentally, the Barbarini family crest displays three bees.
- In a work of the same time, Stelluti published drawings of the bee as seen under Galileo's microscope. Just as Galileo's telescope brought near the distant Moon and stars, so through Galileo's microscope the eyes of the Lynx could fathom the secrets of the small, portraying structures of the bee never seen before. If anyone wonders why three microscopic bees happen to appear in the same arrangement as on the Barbarini crest, well, who would ever think science and diplomacy should NOT be combined?




The text of the Apiarium includes classical references to bees as well as new knowledge, integrated in a tabular outline. The visual elements are the chunks of text, arranged at will. Rather than composing a discursive treatise with a linear argument in a logical progression, this text is designed with a layout that encourages multiple pathways through the document. The flow of reading is undetermined. The paragraphs are broken up into separate blocks. One might read it piecemeal, and digest it incompletely, or incrementally over time. And perhaps the visual arrangement might suggest new permutations and combinations, new connections and relations between the various chunks of content in the overall subject area. Let's compare this feature of the Apiarium with another publication of the Lynx.

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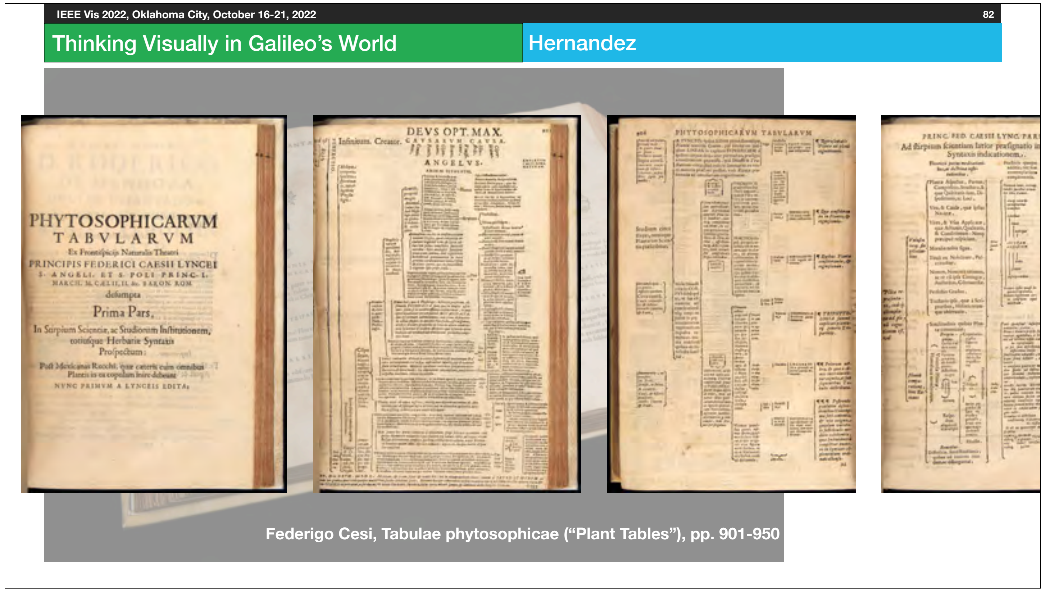
Thinking Visually in Galileo’s World | Hernandez

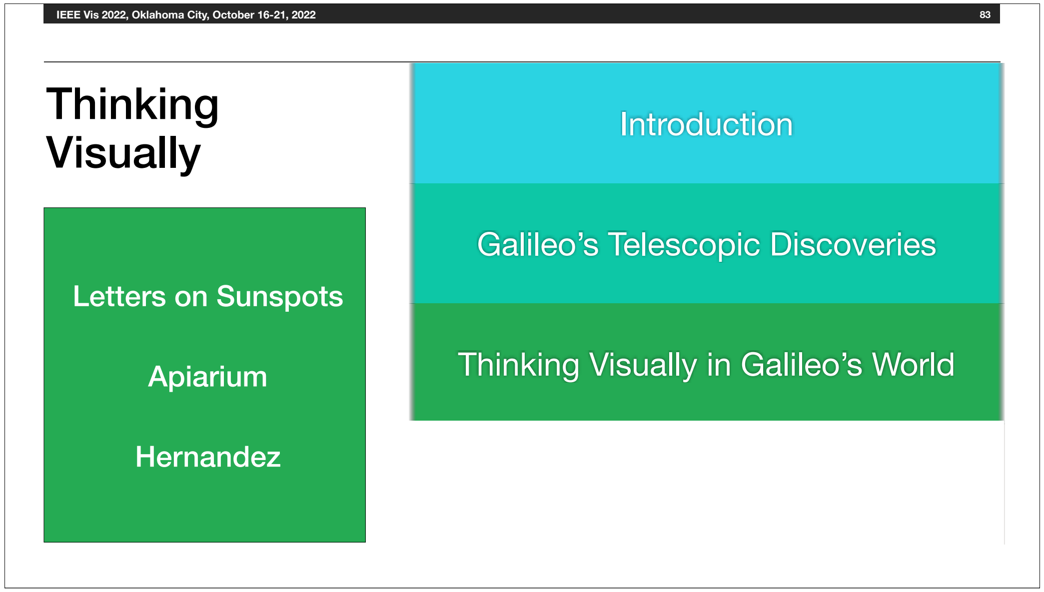
**Francisco Hernandez,**
***Nova plantarum, animalium et mineralium Mexicanorum historia***
**ed. Federigo Cesi, Francesco Stelluti, et al. (Rome, 1651)**

“A New Natural History of the Plants, Animals and Minerals of Mexico”

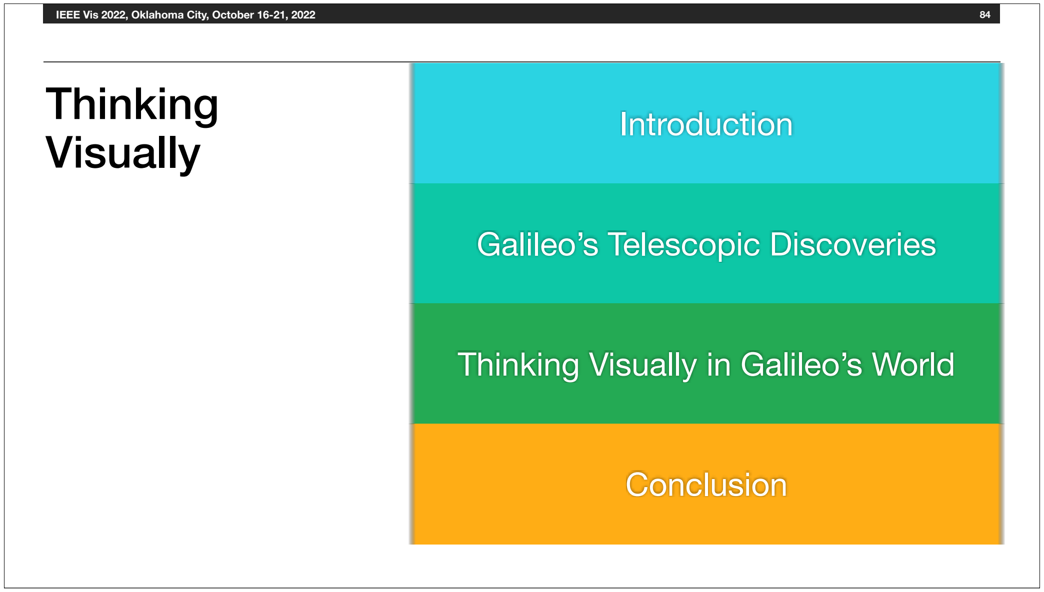
Francisco Hernandez compiled the most important early natural history of the Americas, shown here. After spending nearly a decade with the Aztecs in central Mexico in the 1680s, it was finally published in 1651, with clarifications and notes contributed by nearly all members of the Lynx, including Galileo. The descriptions include Aztec names and medicinal uses of Mexican plants.



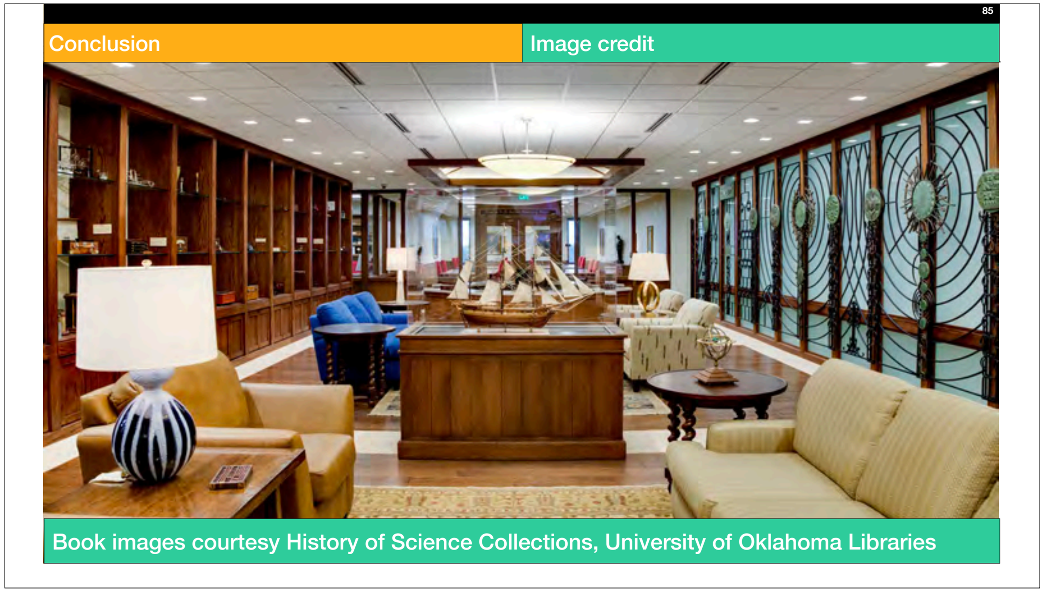

The last 50 pages of the volume are a tabular layout created by Cesi. Cesi's tables sought to discern the natural order by means of schematic diagrams similar to the layout features we encountered with the Apiarium. This goes on for 50 pages! A tabular method of visual thinking breaks up long discursive logical treatises into chunks that may be shifted around if necessary. Here the tabular method is applied to the ordering of plants and animals long before the explosion of taxonomy in the classical works of Linnaeaus and others in the 18th and 19th centuries. Did the tabular layout itself have a didactic effect on taxonomic method in this case? Not enough scholarship has been done on this question.



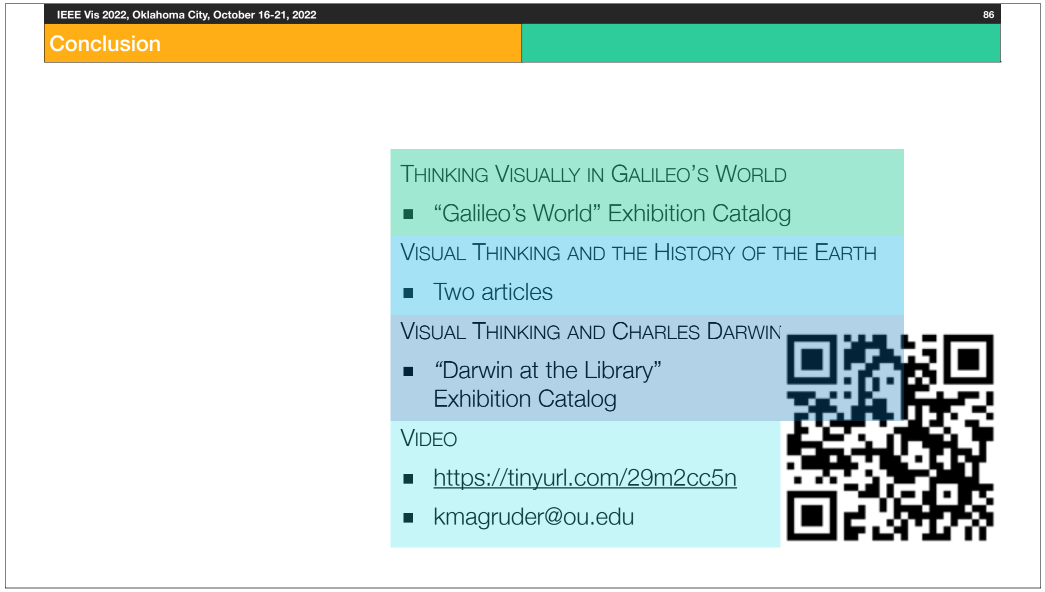

So Galileo’s Letters on Sunspots, the Apiarium, and the Hernandez tables are just a few additional examples of thinking visually in Galileo’s world.




Now, to conclude,

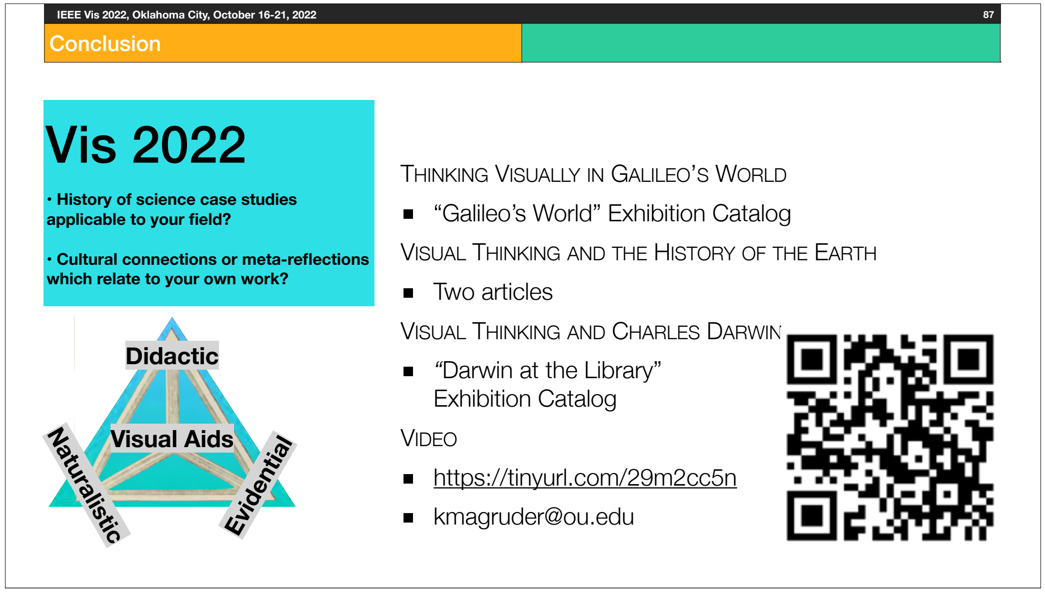



With the single exception of the Florence sheet manuscript, all rare book images in this presentation are courtesy of the History of Science Collections, University of Oklahoma Libraries. The books used in this talk were among those set out to view during last night's open house.




Peruse these sources if you want more along these lines.

- First, a Galileo's World exhibition catalog, particularly the gallery on perspective drawing. In case you have a long flight home, I've added two new episodes:
- the role of visual thinking in reconstructing the history of the Earth, and
- the significance of visual thinking in the work of Charles Darwin. I have two short published articles on the former, and another exhibition catalog for Darwin.
- Links to all of these are found on the Vimeo page where I've uploaded an advance recording of this talk, so the video link or QR code is the only one you need. Or feel free to email me, although I'm notorious for not responding quickly, and as I'll be traveling out of the country for the next few weeks; if you don't get a reply, please keep trying.




I have tried to show that the analysis of visual thinking in terms of naturalistic, evidential, and didactic modes makes sense of what we see in the case of Galileo and his world. These modes of visual thinking have proven helpful to me with regard to other episodes in the history of science, including thinking about the history of the Earth, and Darwin's investigations into the nature of life, just for starters.

- But more importantly for today, think about what you have seen and heard this week during the conference, and consider your own work.
- Are case studies like this one from the history of science applicable in any way to your field?
- Are there any cultural connections or meta-reflections that have occurred to you while listening to this story of Galileo's telescopic discoveries, which relate to your own work? I welcome hearing your thoughts along any of these lines. Thank you.

https://vimeo.com/groups/750547/videos/760681165