Galileo in Padua.

Eighteen fundamental years in perspective

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2. The cultural context
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   - The two chief world systems
3. Galileo: new instruments for the New Science
   - 1604: astronomical observations and local motions
   - Parabolic trajectory of projectiles
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But to understand the research activity of Galileo in Padua we have to spend a few words on the cultural context of the time.

Cultural context: liberal versus mechanical arts

The definition of liberal arts (classical *trivium* - grammar, rhetoric, and dialectic - and the *quadrivium* - arithmetic, geometry, astronomy, and music) can be dated back to Plato and Aristotle writings. They are considered as the only arts that can produce knowledge, and it's not a coincidence that they are performed by free men.

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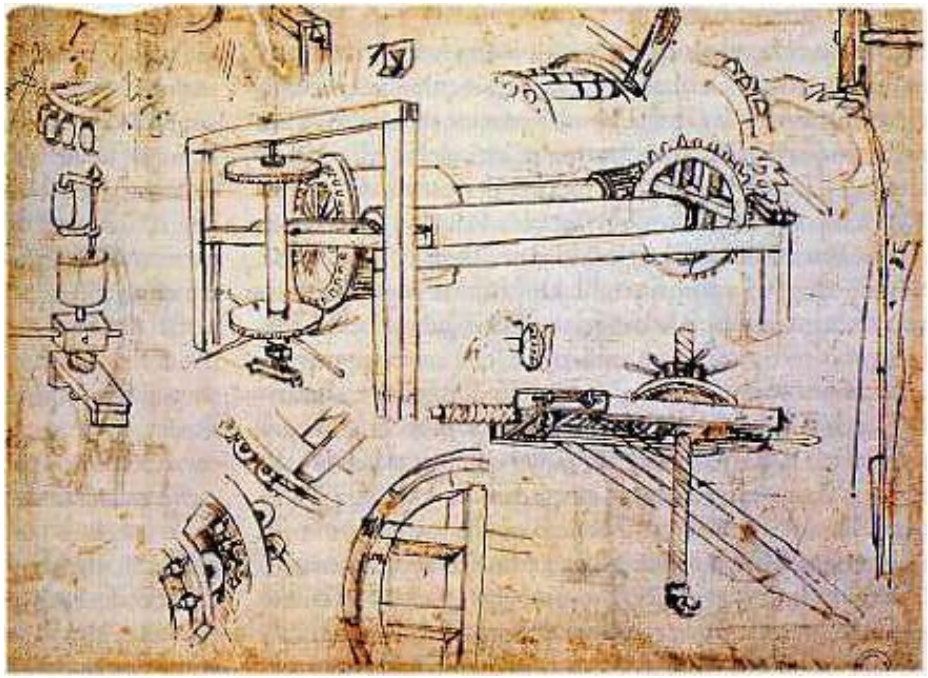
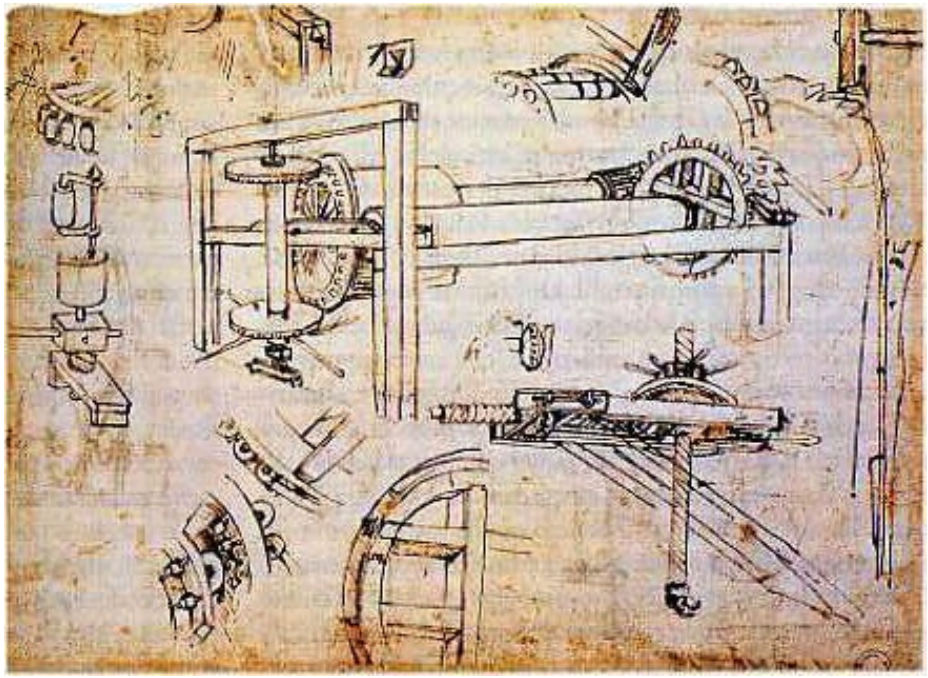
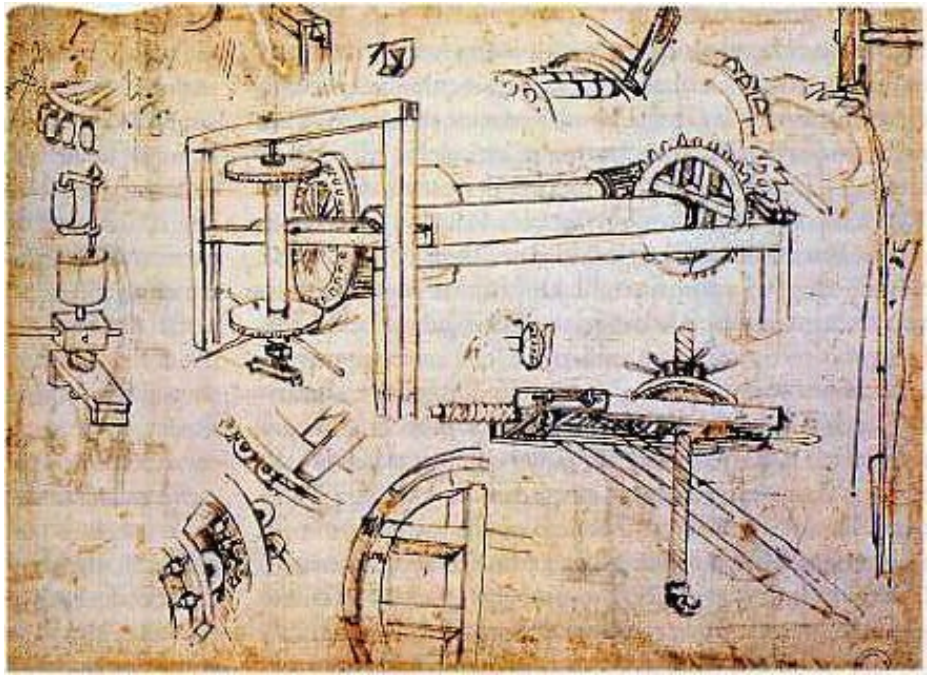
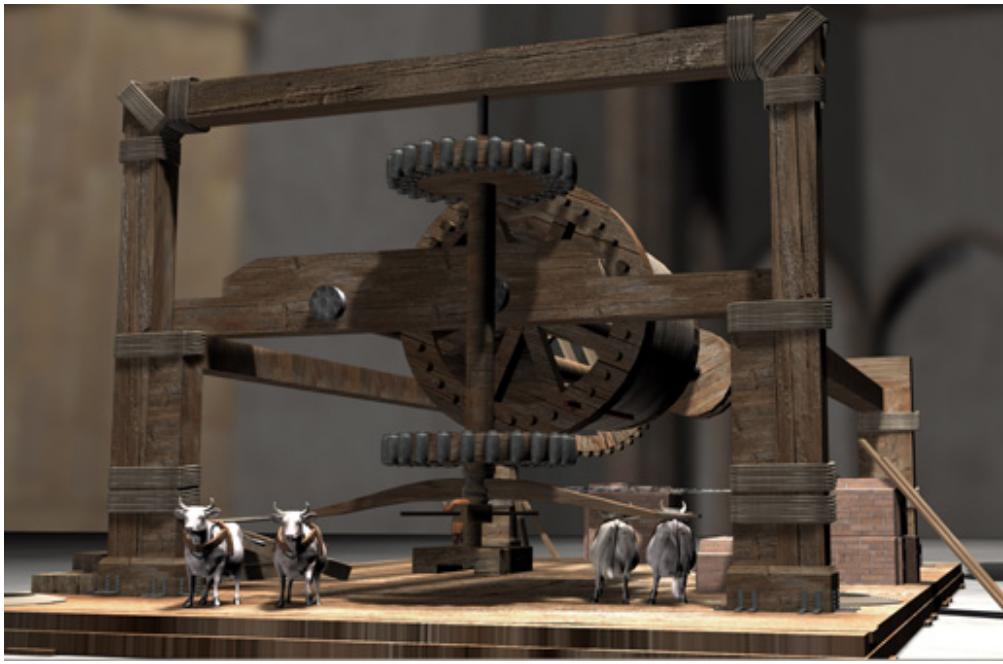
During the XVth and the XVIth century, starting from Italy but suddenly expanding in the whole Europe, the above distinction was overcome. It was becoming clear for many learned men in contact with craftsmen that there was a lot of knowledge produced in the artisan workshops.





Central winch of Brunelleschi's building yard (ca.1420) for the dome of Florence's cathedral (it has three velocities and reversal of rotation to work at continuous cycle). Drawing of Leonardo da Vinci, Codice Atlantico.





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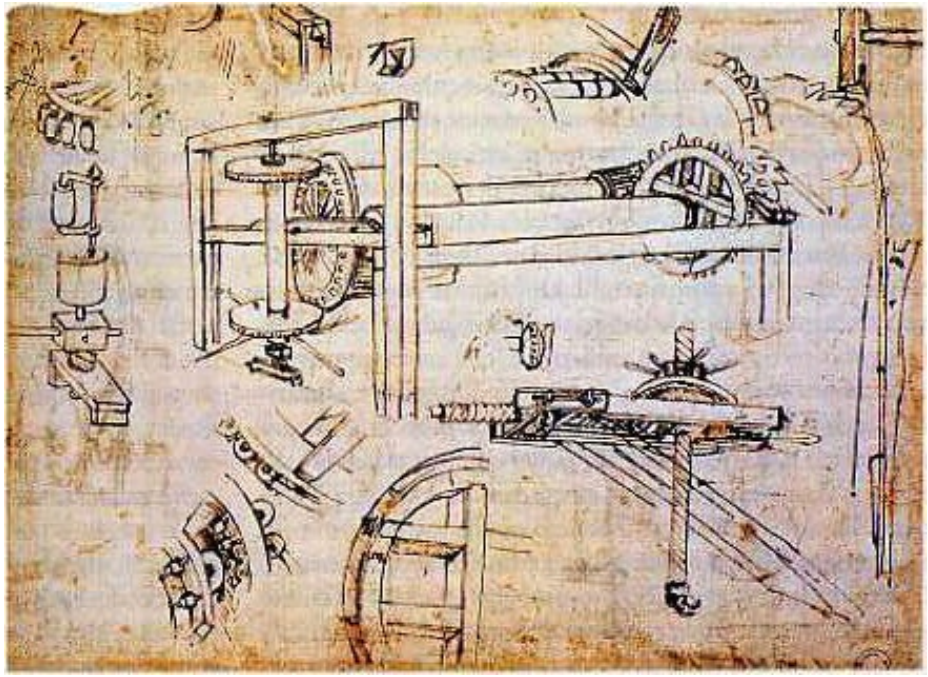

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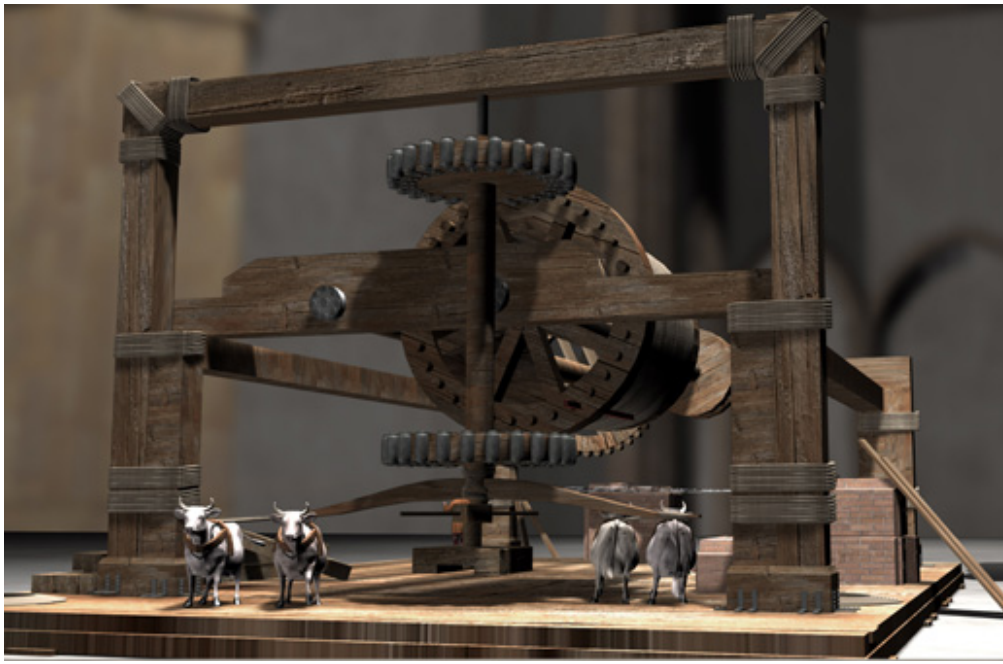

To project and realize this kind of machine a lot of knowledge is necessary: statics, dynamics, strenght of materials.

From these contacts between learned men and craftsmen a new image of “scientist” was born, with a first new evaluation of the instruments. Instruments started to be seen not only as products of knowledge present in manual arts but also as producers of knowledge. In such a welding between contemplative science and experimental science, we can identify one of the distinctive characters of modern natural science.

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When Galileo uses his telescope as a scientific instrument, he has well understood the importance of mechanical arts for the development of knowledge. He has faith in an instrument coming from artisan workshops, functional not to distort but to develop eyesight, source of new knowledge, in contrast with the exclusivity of “natural” sight by human eyes of the received view. This is the true revolution that Galileo starts off and emblematically represents, a revolution that is one of the fundamental consequences of the age of Humanism and Renaissance.

Cultural context: the two chief world systems

The two chief world systems were the so called Aristotelian-Ptolemaic system and Copernican system. The first had its physics, whereas the latter lacked a physics of its own.

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On the contrary, the sublunar region, including the atmosphere and the Earth, was the scene of change, of life and death, of generation and corruption, and it hosted bodies made of the mixture of the four elements (earth, water, air and fire).

The physics supporting Aristotelian-Ptolemaic system

The terrestrial (and sublunar) bodies, according to the proportion of their constituting elements, had their "natural" place at a given height or distance from the centre of the Earth: if they were in a different position, they moved (a "natural" motion) along a straight line, to go back to their natural place.

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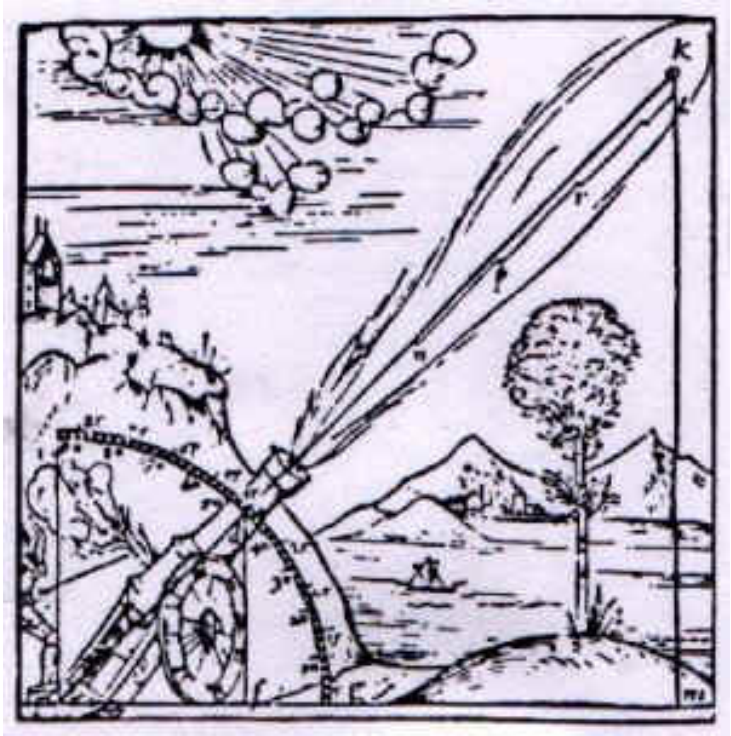

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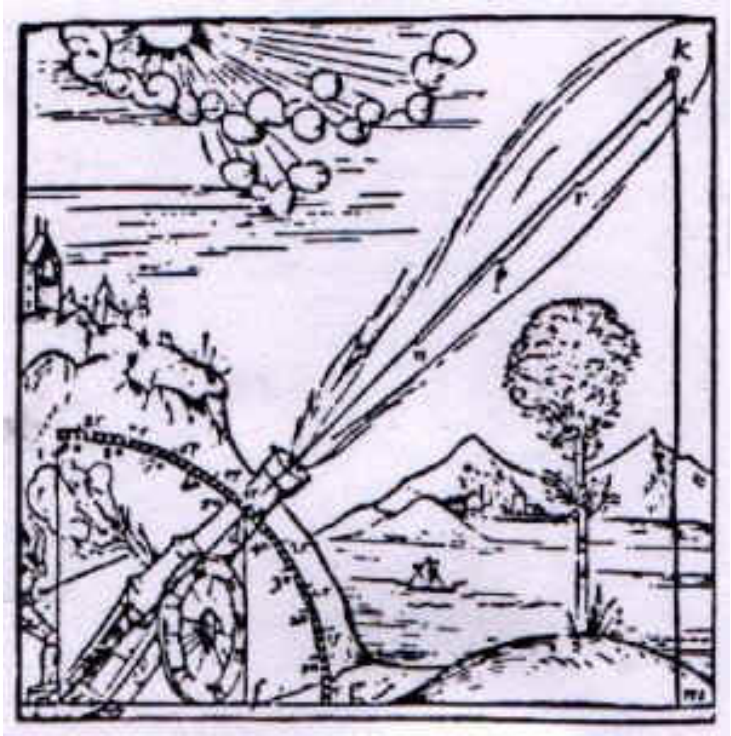

The motion of projectiles was interpreted as the sequence of two distinct motions: first a violent motion, and then a “natural” one.

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- why does the Moon revolve around the Earth while both revolve around the Sun in one year?

“Enter Galileo”: a new physics

It is not clear when Galileo adhered to Copernicanism. It is quite likely that he became Copernican in Padua (one of the first evidences of his adherence to Copernicanism lies in a letter to Kepler written on 4th August 1597, in which he wrote: “I adopted Copernicus’ opinion many [?] years ago”).

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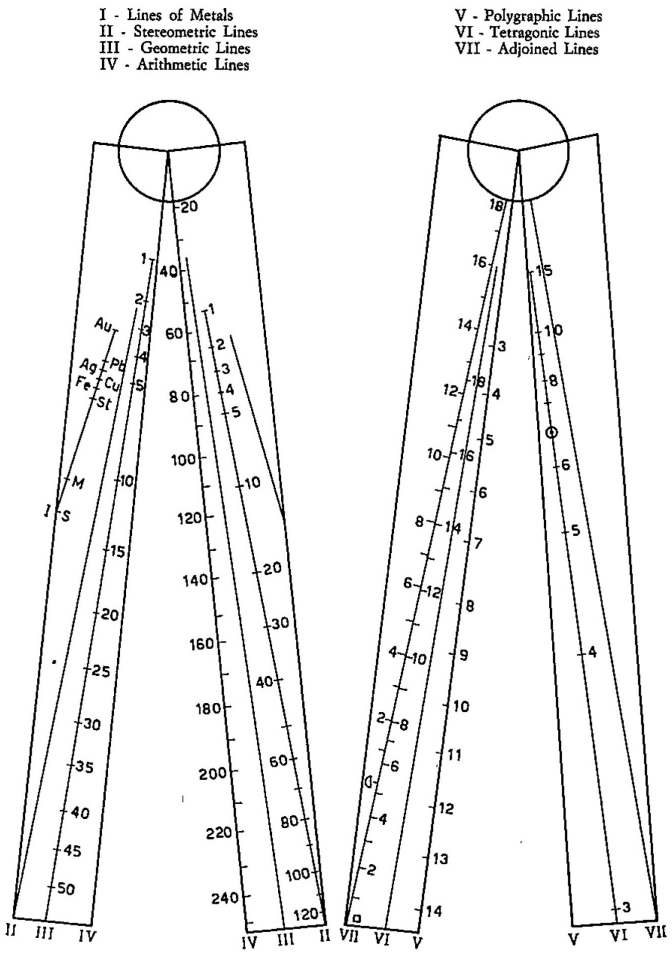
It is not by chance that even in the years preceding the use of the telescope, his researches were devoted to both astronomy and the study of local motions, having in mind the unification of Heaven and Earth physics.

The first mechanical computing device



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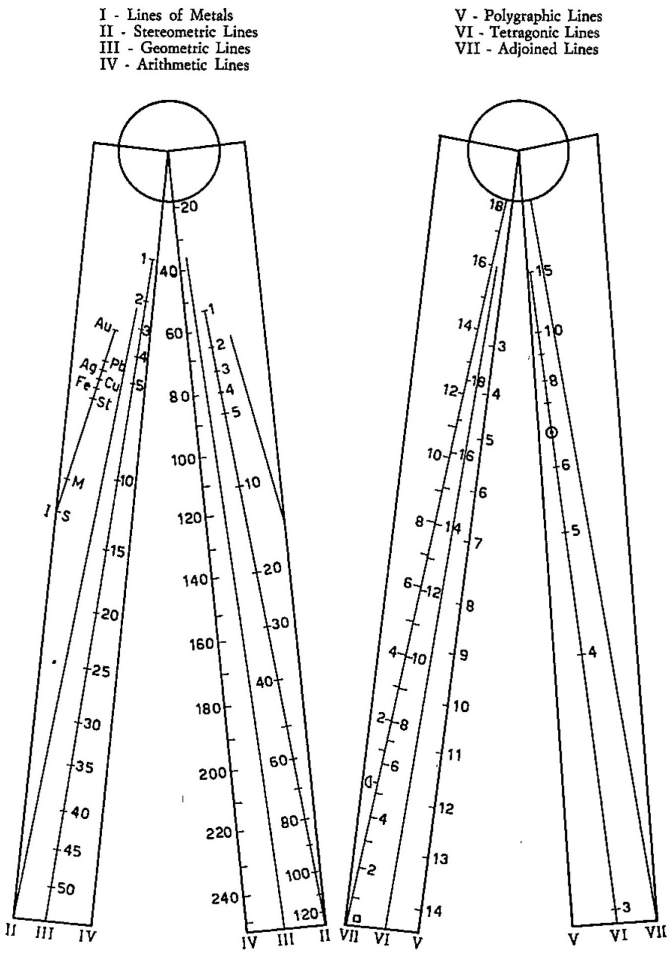

1597-98: The “sector” or geometric and military compass

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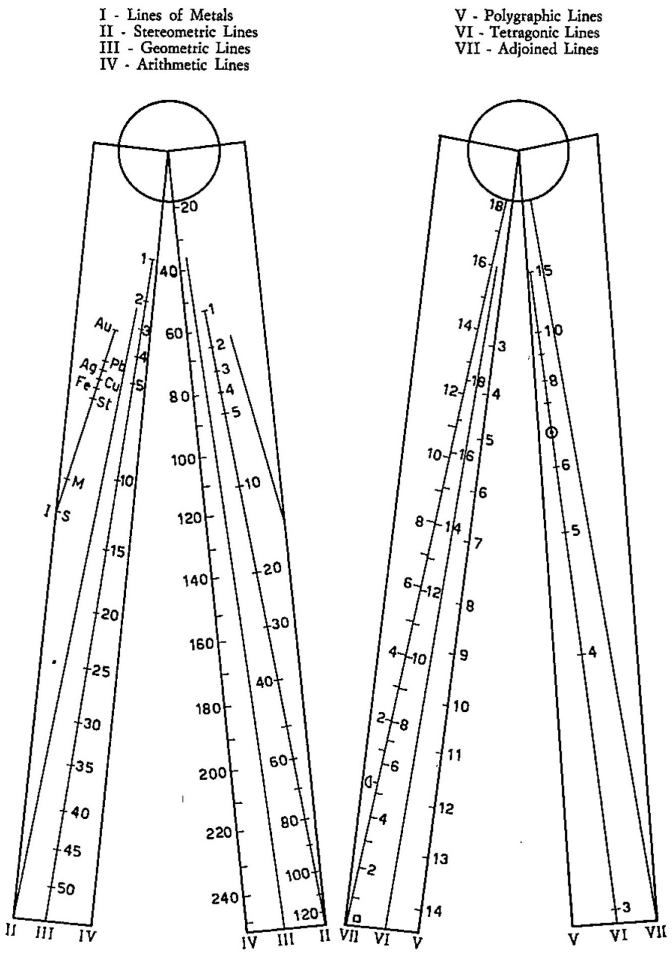

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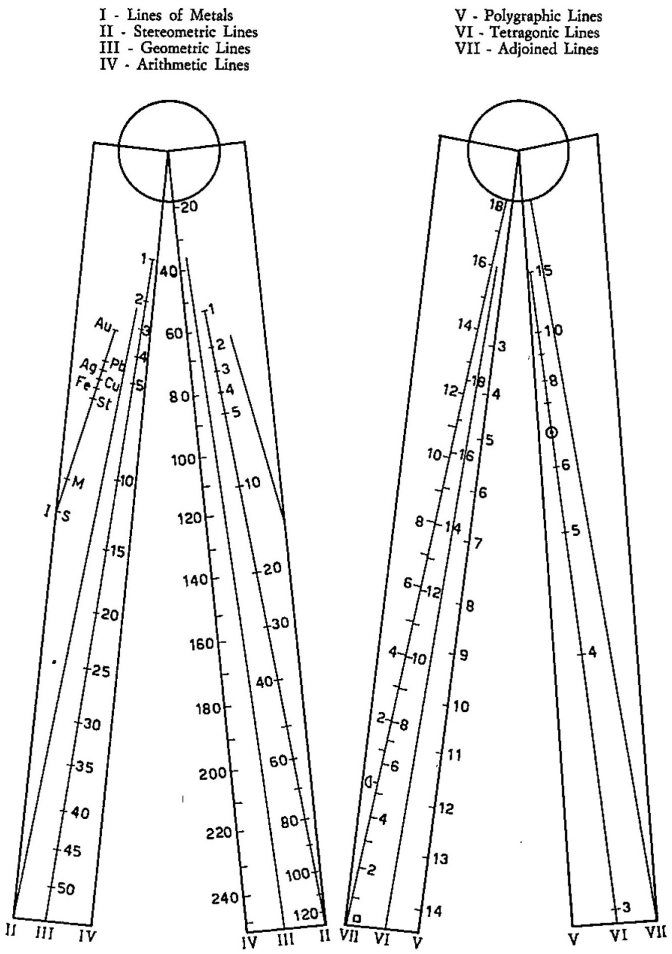

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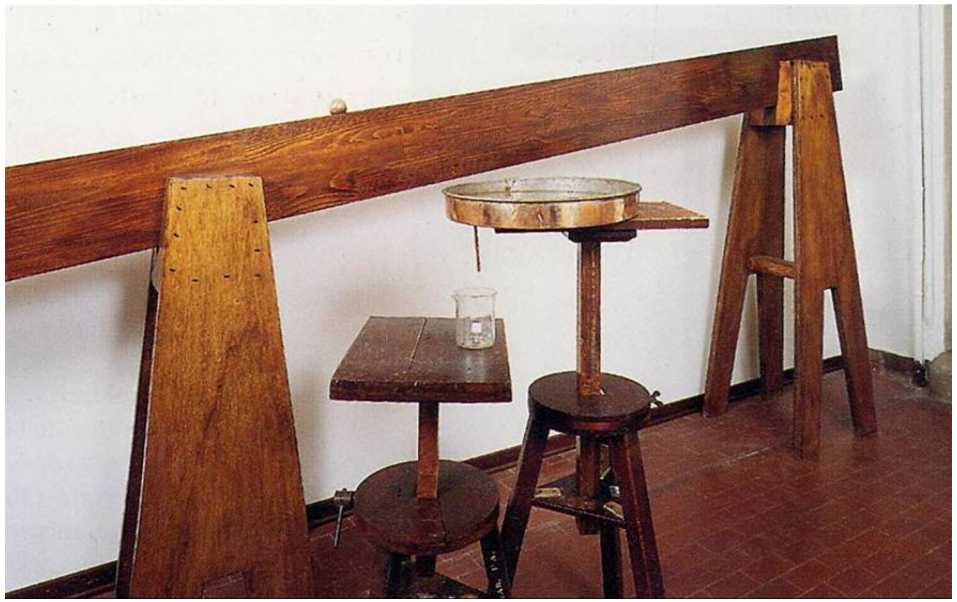
In the course of doing so he came to see that mechanical means could be made available for solving all the practical mathematical problems of the day, much as our practical problems in mathematics are now solved by electronic devices. [Stillman Drake, Essays on Galileo, vol. 3, pp. 5-14]

Inclined plane and water clock



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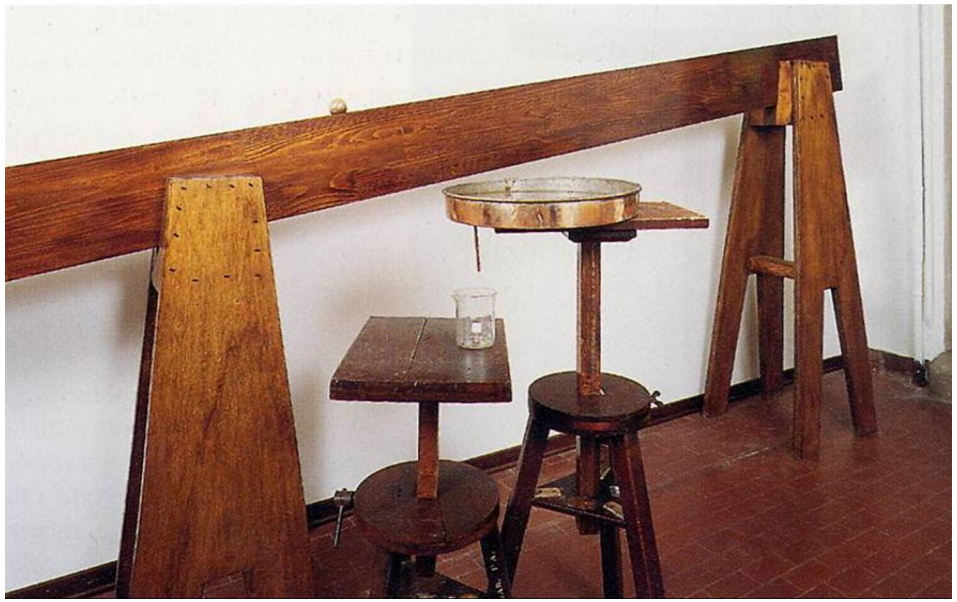

In Aristotle's physics acceleration was irrelevant: falling bodies passed in a very small fraction of time from rest to their own velocity, constant along the motion [velocity $=$ weight$/$(frictional resistance of the medium)].

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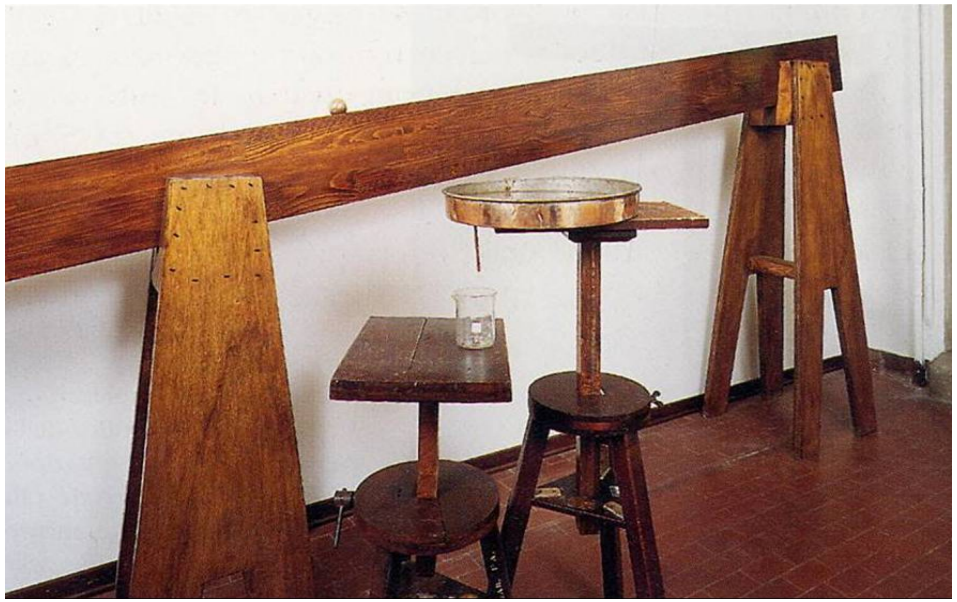

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Using water clocks (more precise than mechanical clocks at that time) and inclined planes, Galileo discovered (1602-1604) the law of uniform accelerated motions (and, by extrapolation, of the free fall).

1604: researches on local motions meet astronomy

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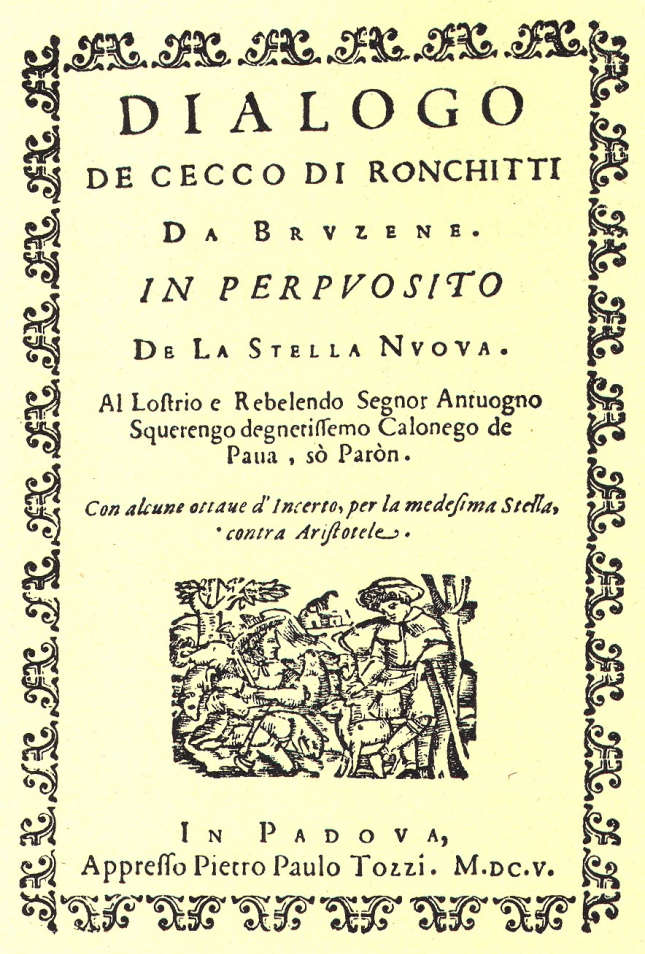
More explicitly in a short booklet published under a pseudonym in 1605, Galileo conjectured the unification of the physics of Heavens and Earth, also alluding to the Copernican system.


DIALOGO
DE CECCO DI RONCHITTI
DA BRVZENE.
IN PERPVOSITO
DE LA STELLA NVOVA.
Al Lostrio e Rebelendo Segnor Antuogno Squerengo degnetissemo Calonego de Paua, sò Paròn.
Con alcune ottaue d'Incerto, per la medesima Stella, contra Aristotele.
IN PADOVA,
Appresso Pietro Paulo Tozzi. M.DC.V.

Dialogue of Cecco Rochitti from Bruzene on the New Star

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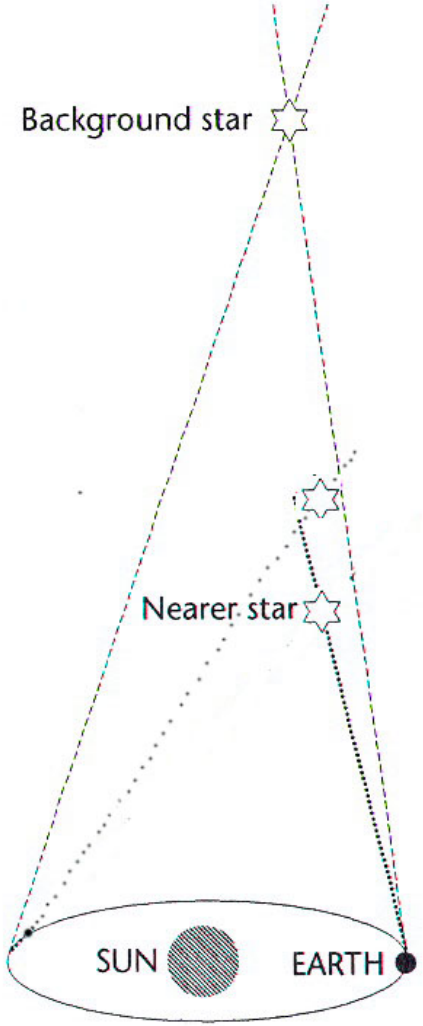
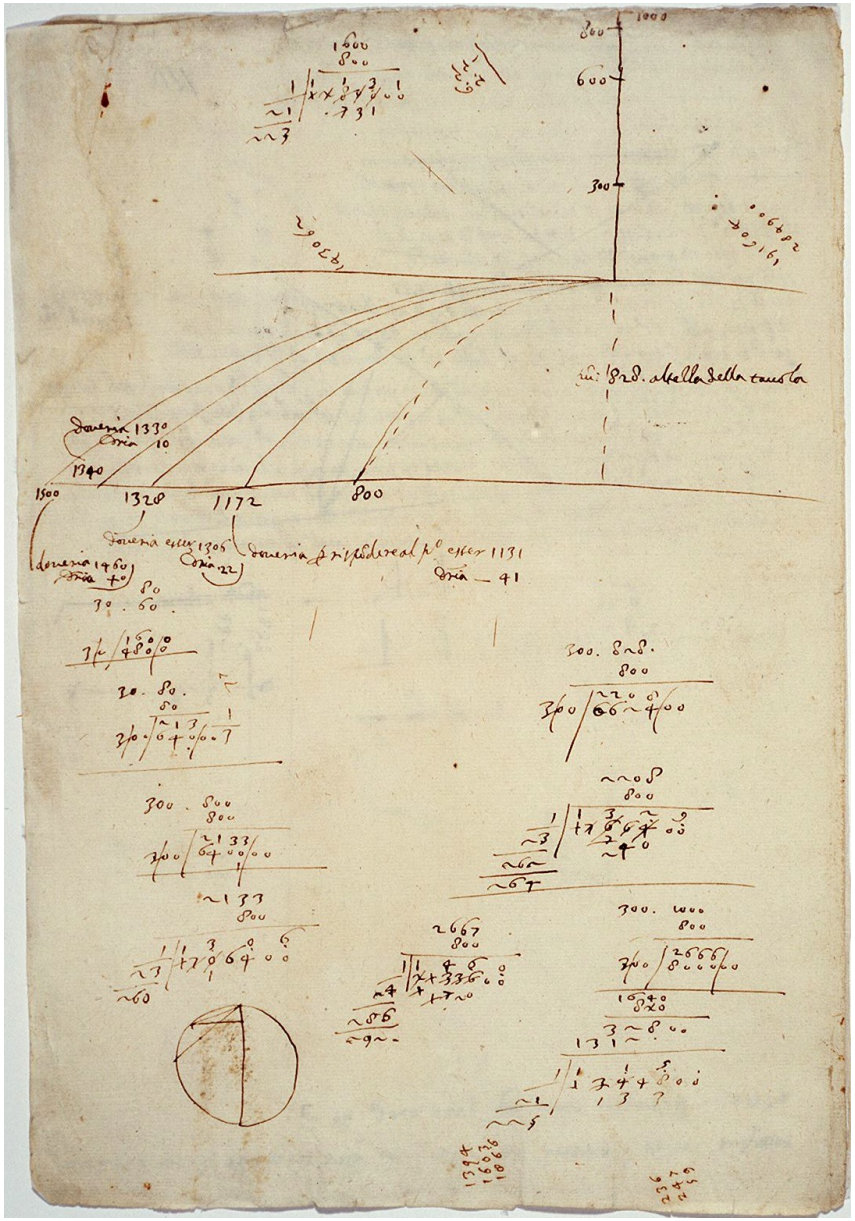
This would have been a definitive proof supporting the Copernican system, against both the Ptolemaic system and the Tychonic hybrid system.



Relative parallax of the ascending *nova*

Parabolic trajectory of horizontally launched projectiles



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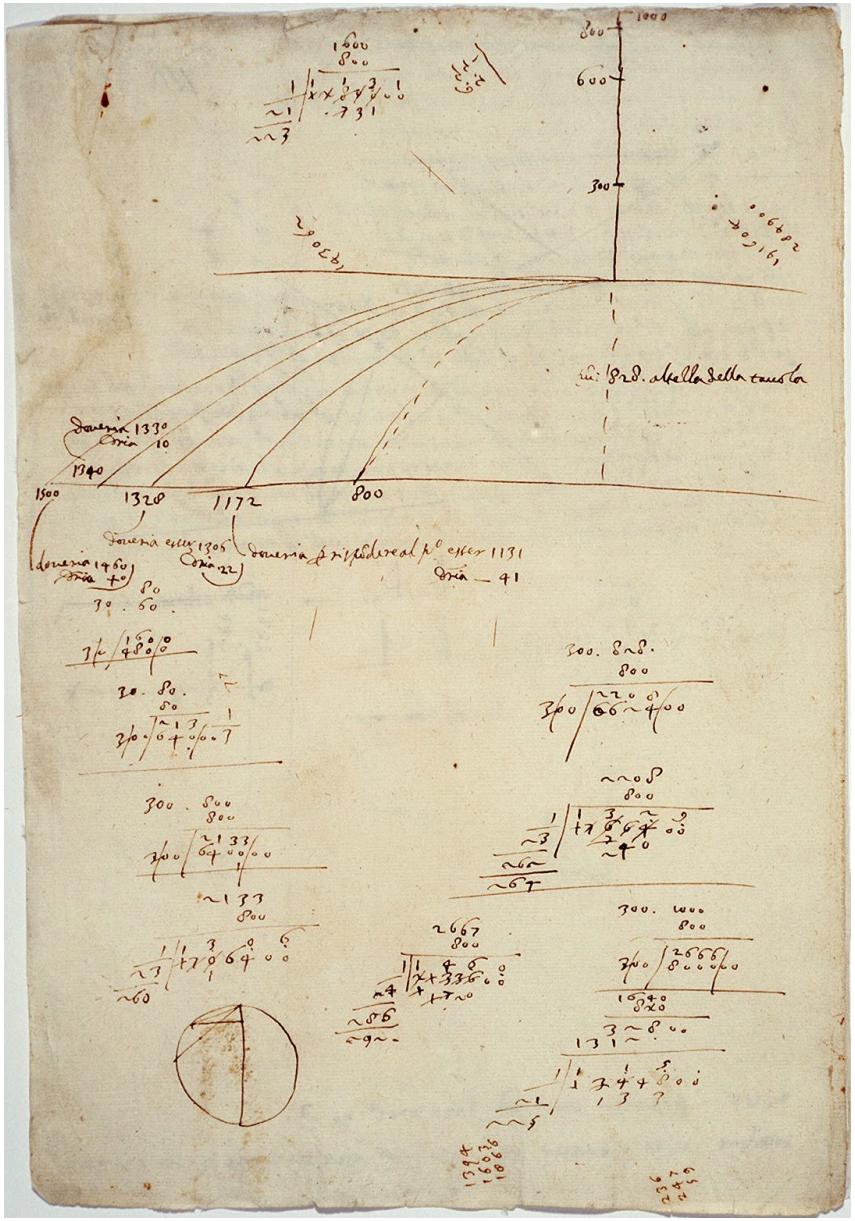

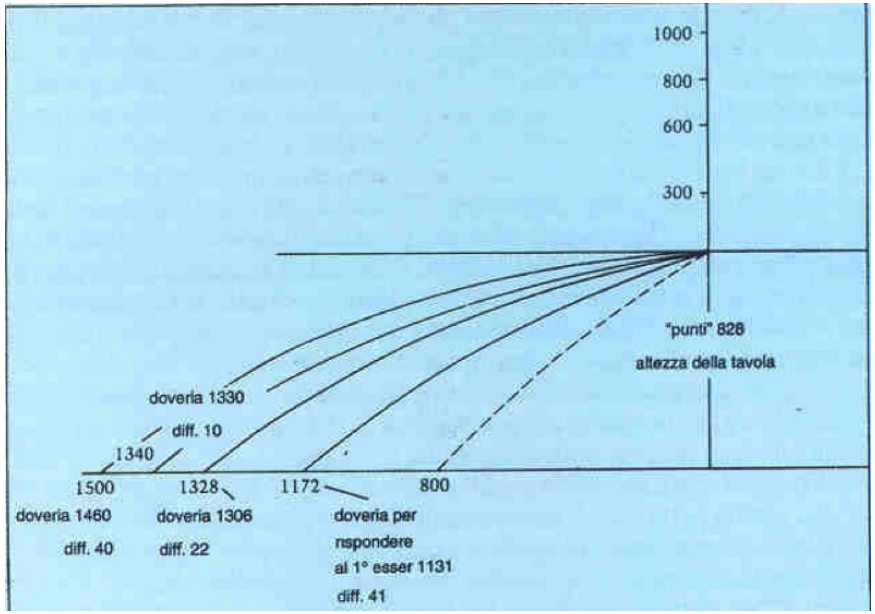

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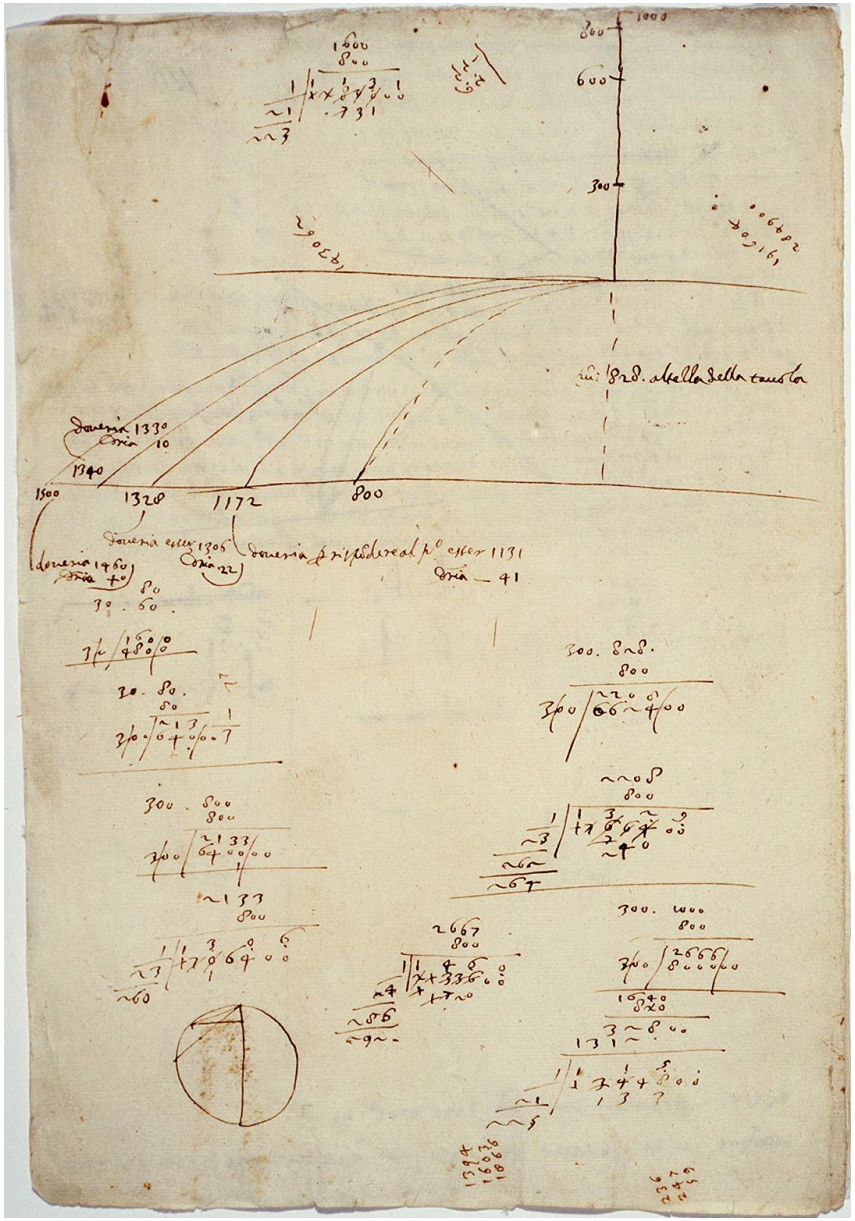

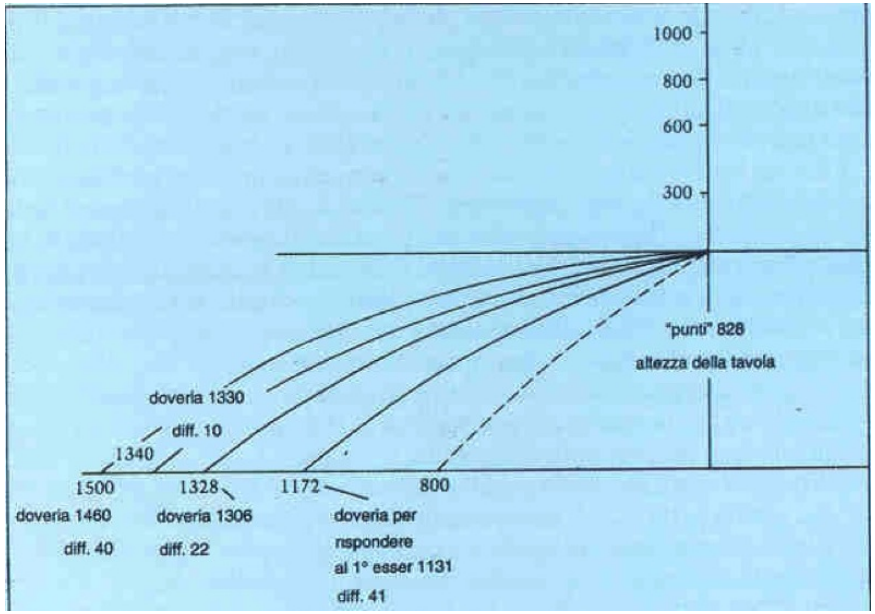

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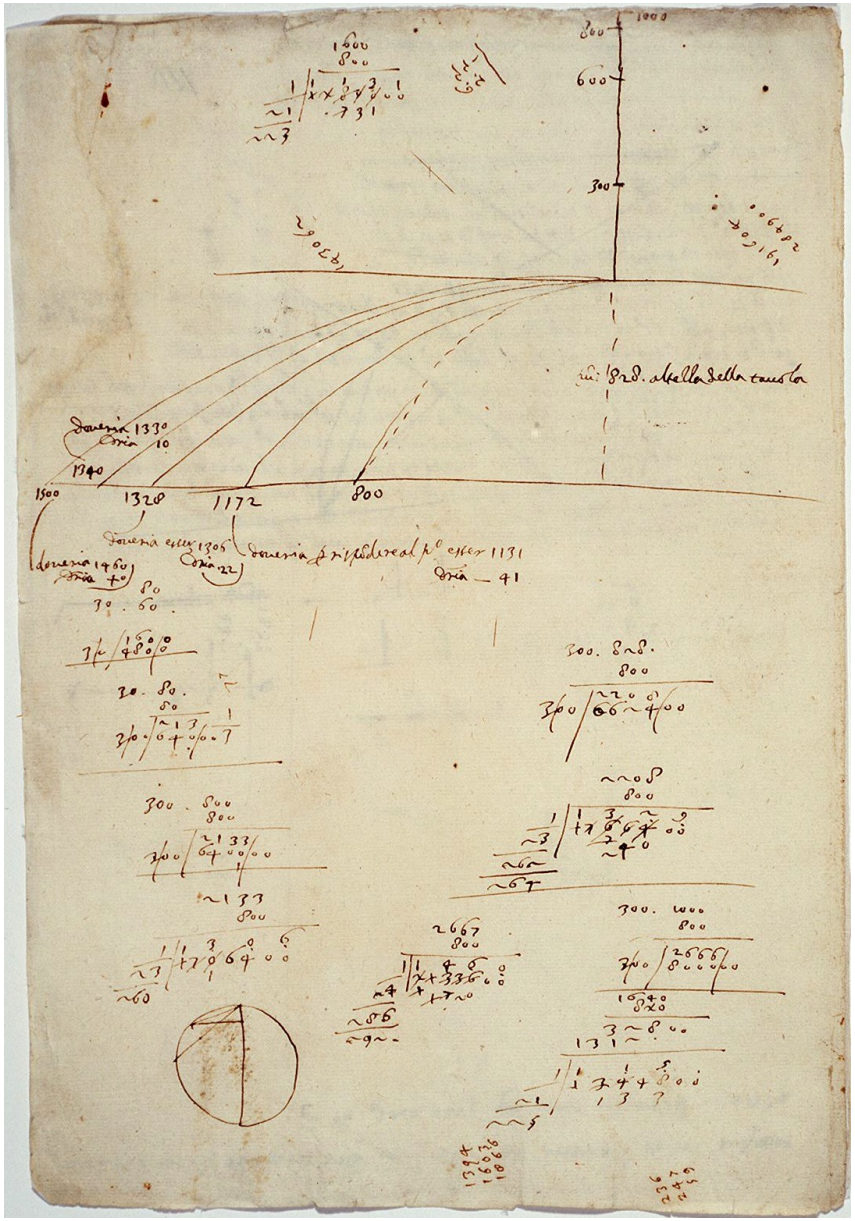

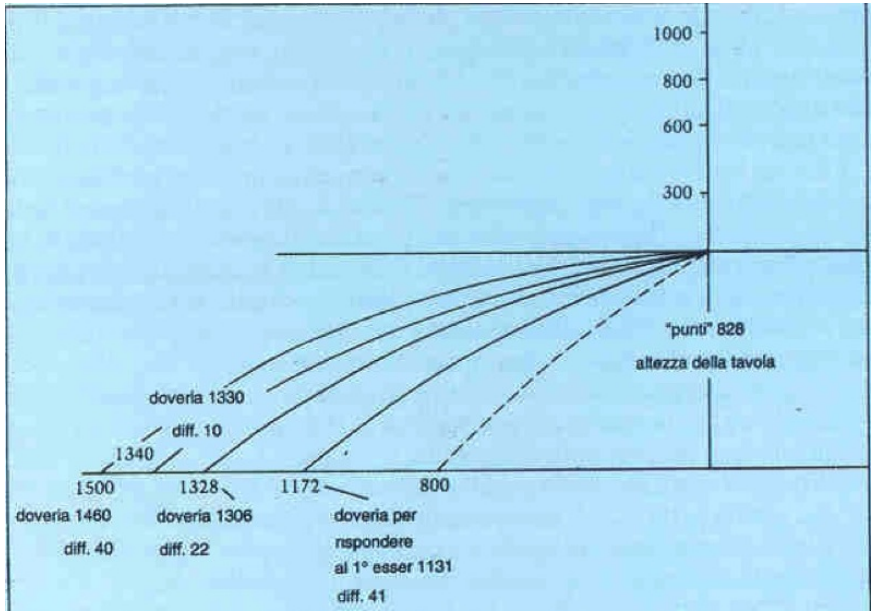

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On the vertical line, the height of the starting points of balls on an inclined plane. On the left, the accurate measure of the ranges (ca.1607).

The telescope

Galileo did not invent the telescope, but he improved it (from 5/6 to 28/30 magnifications) and used it as a scientific instrument, interpreting what he saw without prejudice, totally free from the authority of the “traditional world view”.

Sidereus Nuncius

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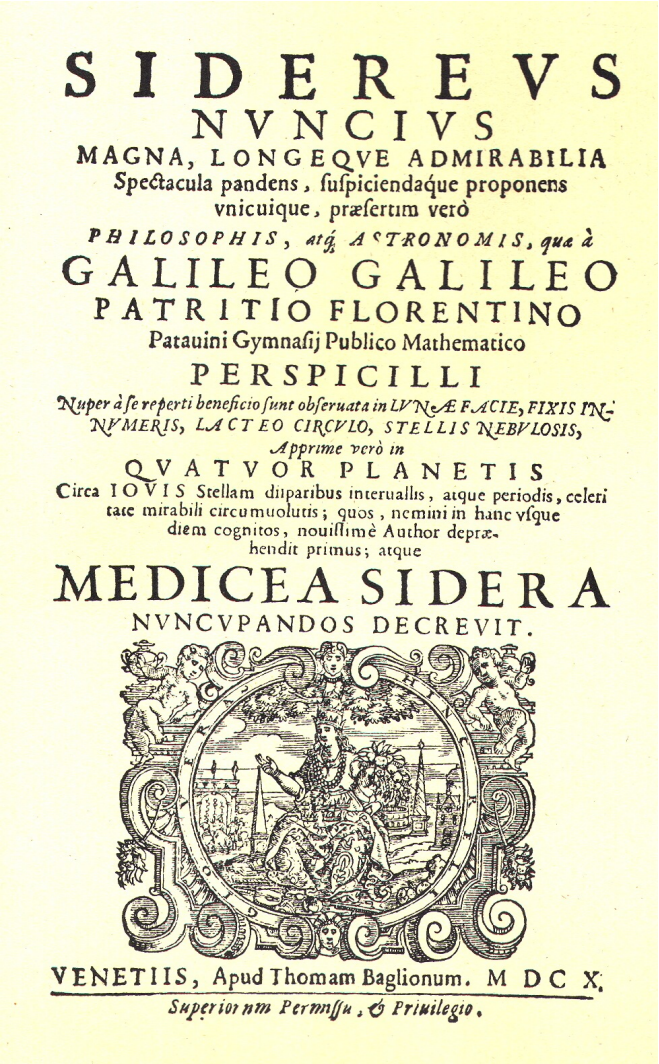
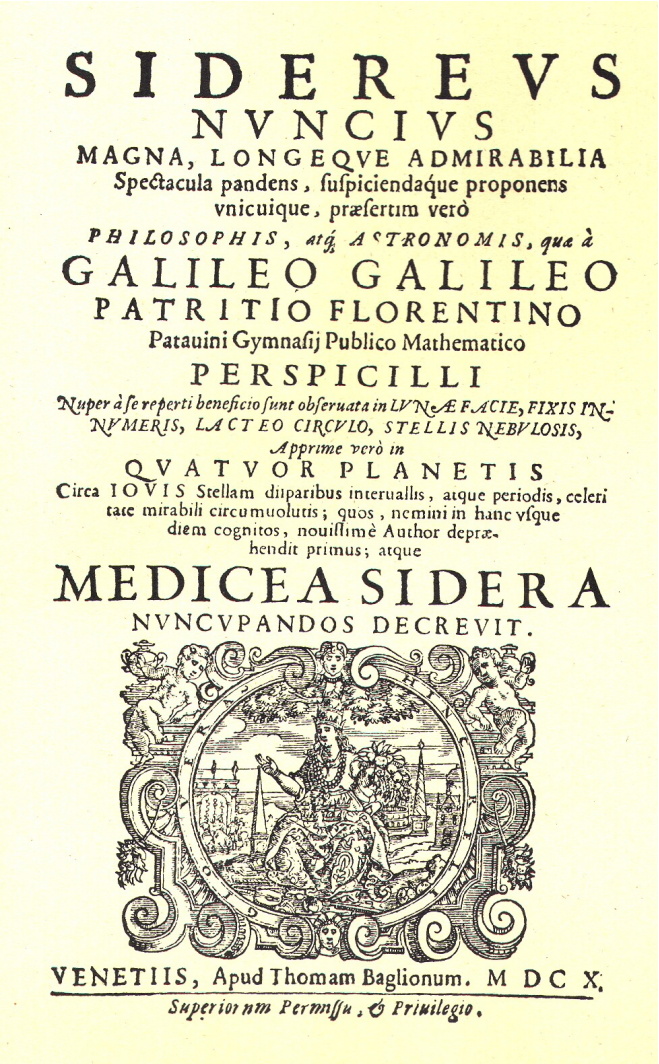


SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS IN-
NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeri
tate mirabili circumuolutis; quos, nemini in hanc vsque
diem cognitos, nouissimè Author depræ-
hendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.

Sidereus Nuncius

Starting his systematic observations in the fall of 1609, Galileo published his results in March 1610 in the *Sidereus Nuncius* ("Celestial or starring messenger or message"), a booklet written in latin, in which the illustrations were even more revolutionary than the text.

We just mention some of Galileo's conclusions that dramatically changed the thousand-year-old world view, marking the beginning of modern science.



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
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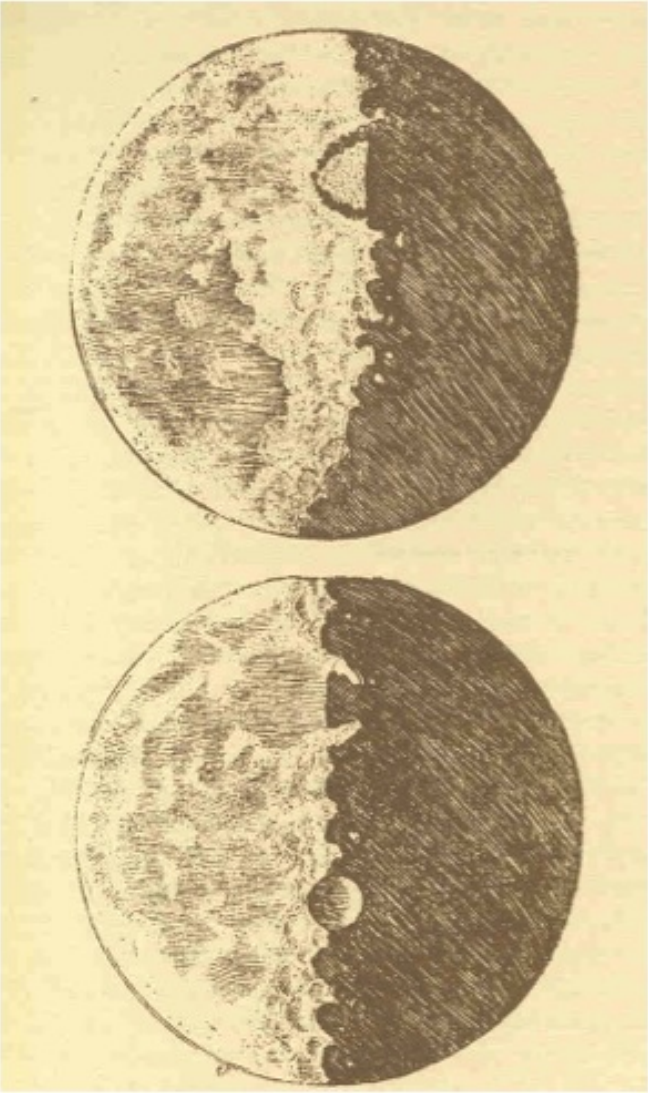
Celestial Messenger

The surface of the Moon

The surface of the Moon



Like on the Earth, the flecks of light on the Moon's night side and dark spots on the day side indicated the illumination of mountain tops and the shadows cast by crater walls.

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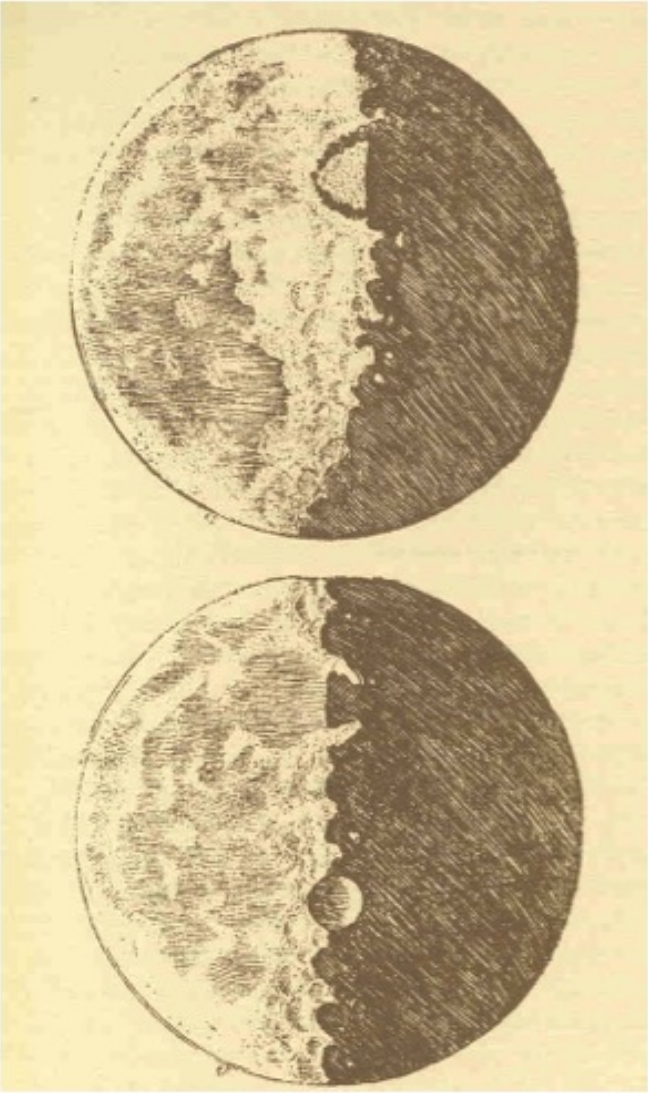

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The surface of the Moon is like that of the Earth. It is not at all the perfect spherical celestial body described by Aristotelian tradition.

Milky Way and constellations

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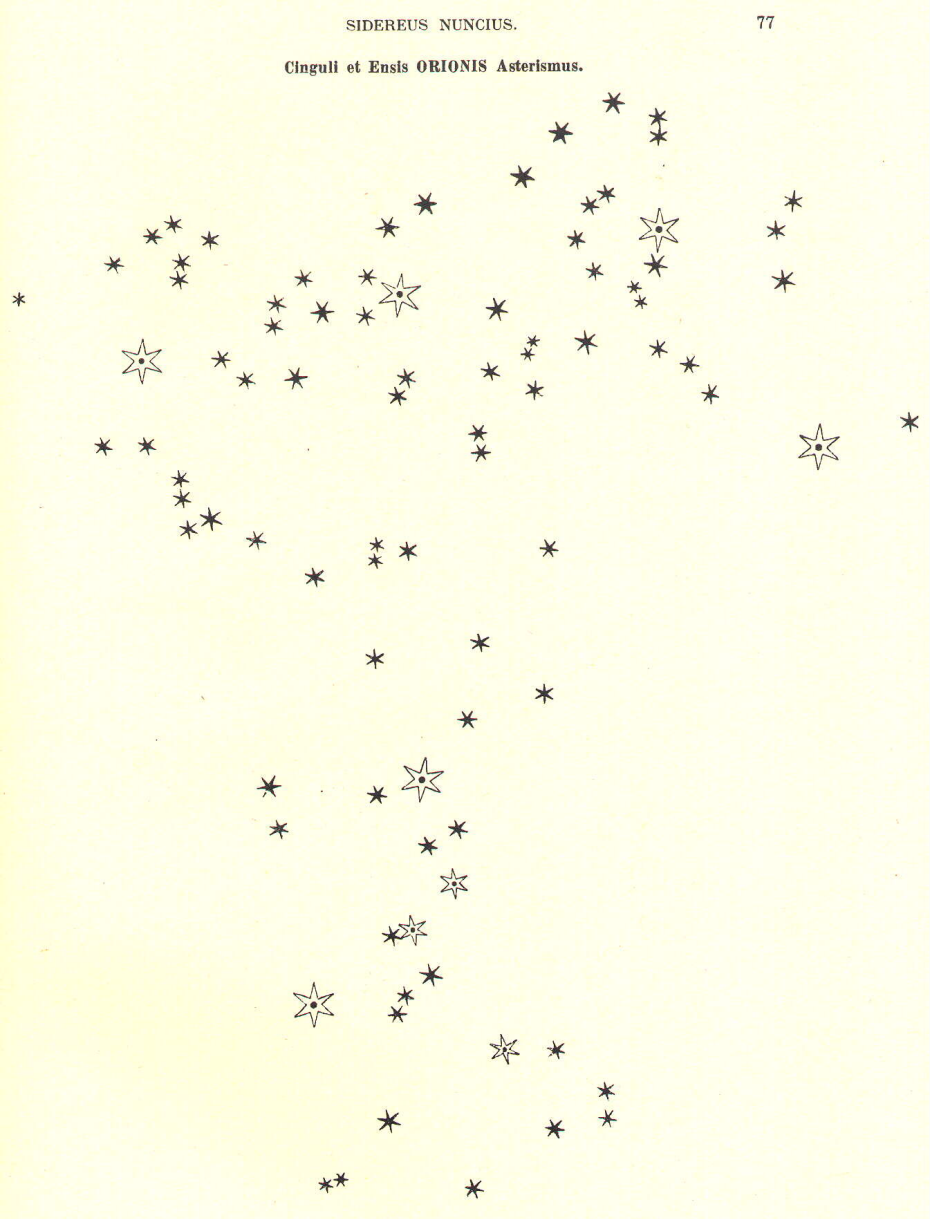
And even constellations were made of many more stars than one could see without the telescope.



Jovian Moons

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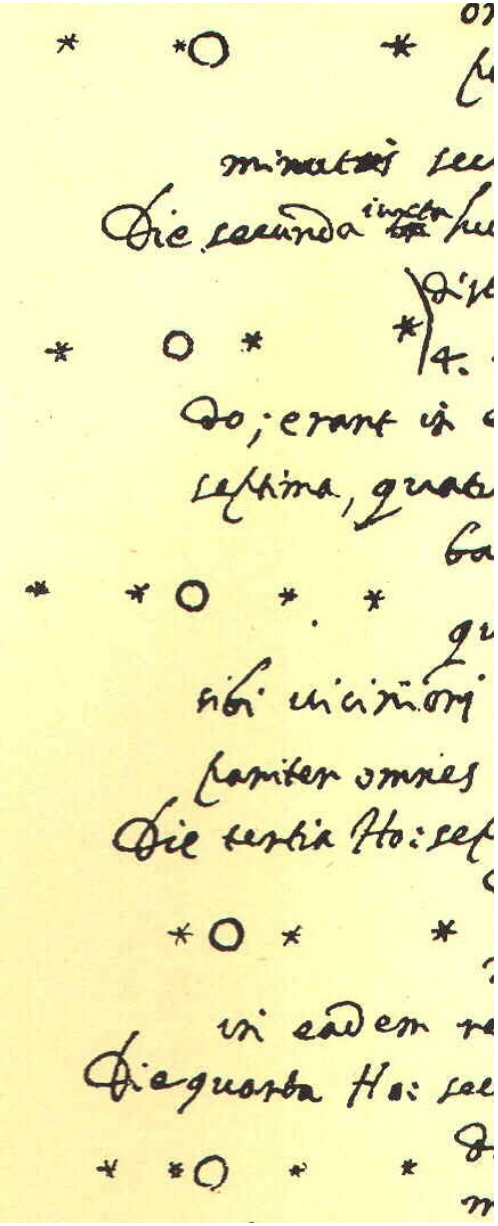
We have a notable and splendid argument to remove the scruples of those who can tolerate the revolution of the planets round the Sun in the Copernican system, yet are so disturbed by the motion of one Moon about the Earth, while both travel together around the Sun in the course of a year, that they consider that this theory of the constitution of the universe must be upset as impossible; for now we have not one planet only revolving about another, while both traverse a vast orbit about the Sun, but our sense of sight presents to us four stars circling about Jupiter, like the Moon about the Earth while all of them together with Jupiter traverse a great orbit moving around the Sun in the period of twelve years. [Galileo, Sidereus Nuncius]



The microscope

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In the figure, a rare Galileian microscope, signed “Eustachio Divini a Roma 1671”, kept at the Museum of History of Physics, Padua University.

Conclusion ... in perspective

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The first section was on telescopes; then science of motion; materials science; science of vacuum; studies on light and Sun; and the concluding section "from microscopes to particle accelerators".

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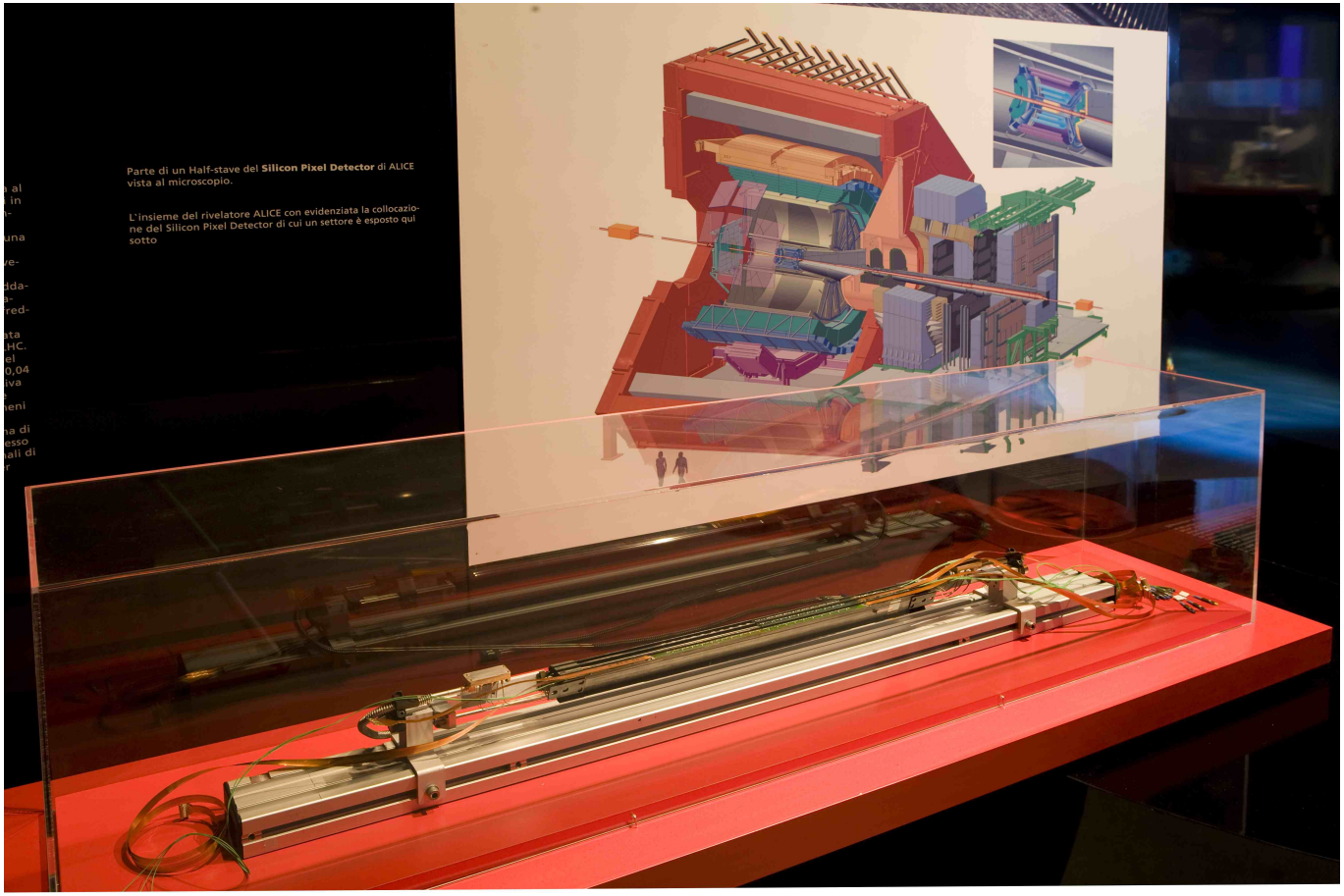

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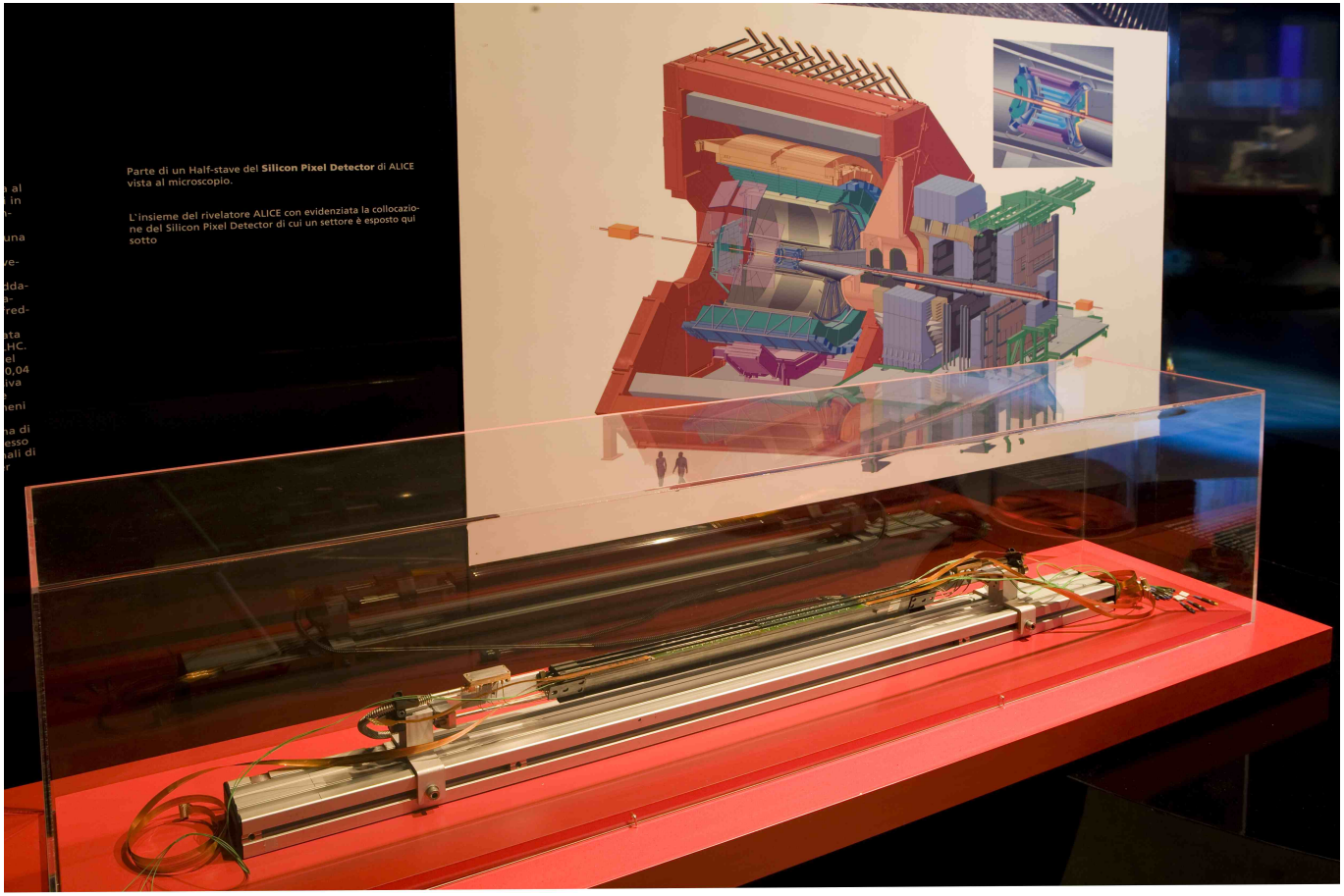

The exhibition gave an idea of the fil rouge connecting most of Galileo's researches, results, inventions, conjectures to contemporary physics.

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All these features - Galileo knew them well - are not only important for doing science, but also to make us human beings, citizens of the world.

Thank you for your attention