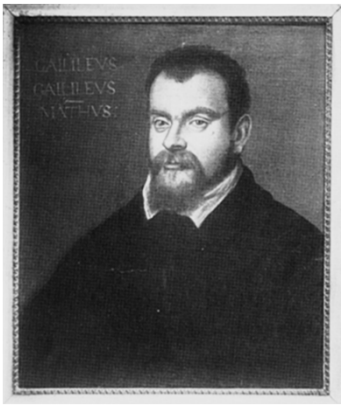
Galileo & the Telescope—Sept 23

- Announcements
  - Test 1 on Wed. See announcements on next slide.
- Outline
  - Newton derives the law of gravity
  - Galileo makes a telescope and makes 5 discoveries.
    - A model of discovery enabled by a new instrument



Galileo by Tintoretto
http://galileo.rice.edu/images/people/galileo/g_tintoretto.gif

Test 1

- Test 1, Wed, 28th
  - Low stakes. To calibrate your efforts.
    - Test 1 counts for 5% of grade;Tests 2 & 3 each count for 14%.
  - Practice Test (test from 2010) is on angel.
    - Link is on Syllabus on angel
  - Missouri Club
    - Tues, 27th, 7:40-8:40, BPS1420
  - Common cheat sheet
    - Send me formulas for cheat sheet by 10pm on 27th.

Do all objects fall the same amount?

- Galileo found out experimentally.
  - Drop a lead ball and a wooden ball at the same instant.
  - Lead and wooden balls hit ground at the same time.

1. Is the acceleration greater for the heavier ball?
   A. Y
   B. N

- Interpret using Newton's second law
  - Force of gravity = mass × acceleration

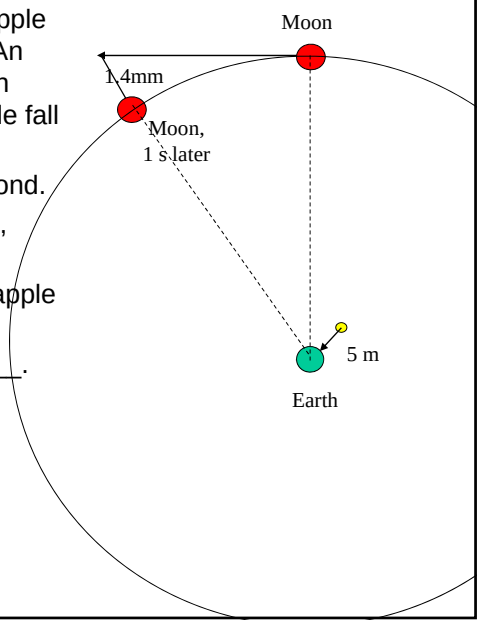
2. Is the force of gravity is proportional to mass?
   A. Y
   B. N

- The force of gravity has this mathematical form
  M1 M2 (some unknown dependence on distance)

Newton discovers the law of gravity

- Newton was sitting under an apple tree and looking at the moon. An apple falls on his head. Newton realizes the moon and the apple fall for the same reason.
- The moon falls 1.4mm in 1second.
- In a second, an apple falls 5 m, which is 3600 times greater.
- Moon is 60 times further than apple is from the center of earth.

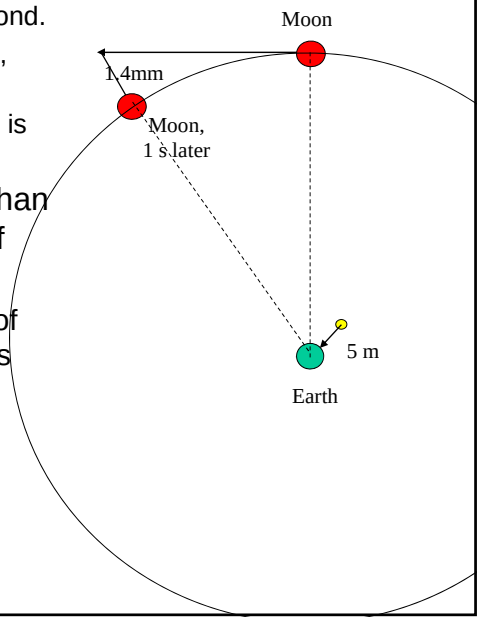
1. The moon falls less because____. R1: it is farther away. R2: it is heavier.
   A. of R1 only.
   B. of R2 only.
   C. of both reasons.



Newton discovers the law of gravity

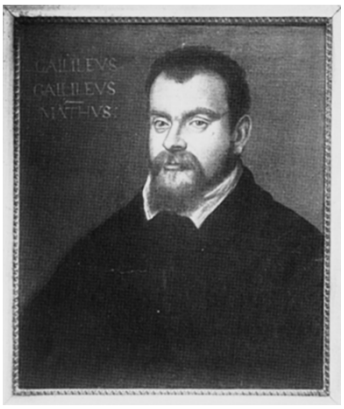
- The moon falls 1.4mm in 1second.
- In a second, an apple falls 5 m, which is 3600 times greater.
- The moon falls less because it is farther away
- Moon is 60 times further than apple is from the center of earth.
- The acceleration of gravity of earth on moon is 3600 times weaker than aogoeo apple.
- Therefore force of gravity depends on 1/distance^2.

$$F = GMm/d^2$$



Galileo & the Telescope

- Galileo makes a telescope in 1609
- Galileo discovers
  - Moons of Jupiter
  - Mountains on the moon
  - New stars
  - Milky Way has many stars
  - Phases of Venus
    - Disproves Ptolemy's earth-centered model
- A model of discovery enabled by a new instrument
  - What cannot be seen cannot be discovered
  - Many discoveries were made soon after a new technology or instrument was built.



Galileo by Tintoretto
http://galileo.rice.edu/images/people/galileo/g_tintoretto.gif

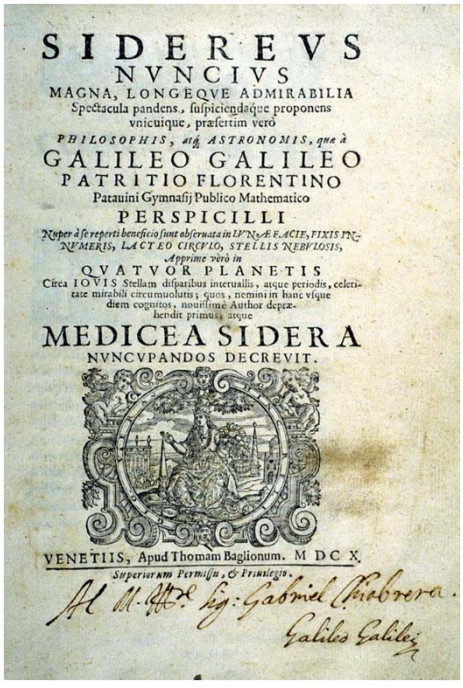
Galileo's telescope

Wood, paper; length: 1360mm, lens diameter 26mm
http://galileo.imss.firenze.it

Sidereal Messenger

Unfolding great and many wonderful sights and displaying to the gaze of everyone, especially philosophers and astronomers, the things that were observed by Galileo Galilei, Florentine patrician and public mathematician of the University of Padua, with the help of a spyglass lately devised by him, about the face of the moon, countless fixed stars, the Milky Way, nebulous stars, but especially about the four planets flying around the star of Jupiter at unequal intervals and periods with wonderful swiftness; which unknown by anyone until this day, the first author detected recently and decided to name Midicean Stars.
Venice 1610

—trans A van Helden, *Siderius Nuncius*, U Chicago, 1989


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 depre-
hendit primus, atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.
Galileo Galilei

Mountains on the Moon

- Imperfections on a heavenly object

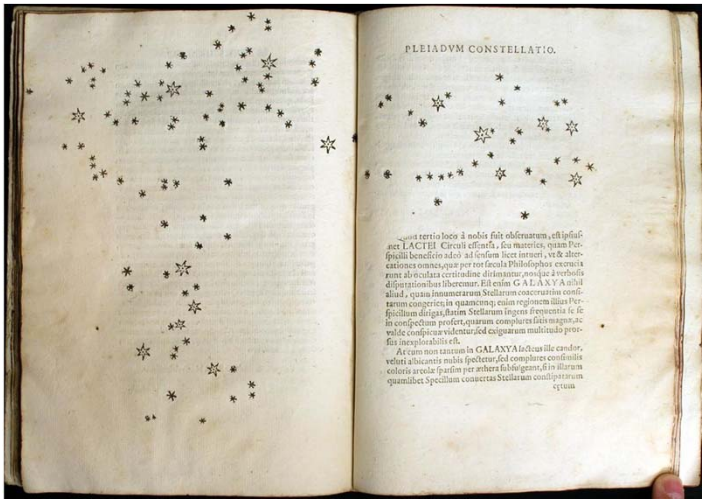
http://hsci.cas.ou.edu/exhibits/


RECENS HABITAE.

culorum exiguarum copia, omnino à tenebrosa parte separatarum, totam ferè plagam iam Solis lumine perfusam vndiquaquè conspergit, illa tantem excepta parte quæ magnis, & antiquis maculis est affecta. Adnotauimus autem, modo dictas exiguas maculas in hoc semper, & omnes conuenire, vt partem habeant nigricantem locum Solis respicientem; ex aduerso autem Solis lucidioribus terminis, quasi candentibus iugis coronentur. At consimilem penitus aspectum habemus in Terra circa Solis exortum, dum valles nondum lumine perfusas, montes verò illas ex aduerso Solis, circundantes iam iam splendore fulgentes intuemur: ac veluti terrestrium cauitatum vmbræ Sole sublimiora petente immimuuntur, ita & Lunares istæ maculæ, crescente parte luminosa tenebras amittunt.

Verum

Countless stars (Pleiades)


PLEIADVM CONSTELLATIO.

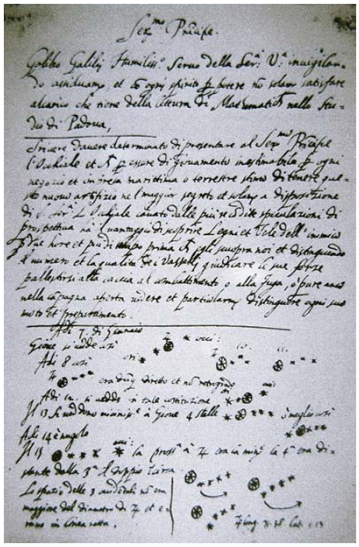
quæ tertio loco à nobis fuit obseruatum, est ipsius LACTEI Circuli effluuia, seu materies, quam Perspicilli beneficio adeò ad sensum licet intueri, vt & altercationes omnes, quæ per tot secula Philosophos exercuerunt abrasulata certitudine dirimantur, nosque à verbosis disputationibus liberemur. Est enim GALAXYA nihil aliud, quàm innumerarum Stellarum coacervatim consitarum congeries, in quamcunq; enim regionem illius Perspicillum dirigas, statim Stellarum ingens frequentia se se in conspectum profert, quarum complures satis magnæ, ac valde conspicuæ videntur, sed exiguarum multitudo prorsus inexplorabilis est.

At eam non tantum in GALAXYA lacteus ille candor, veluti albicantis nubis spectatur, sed complures consimilis coloris areolæ sparsim per æthera fulgurant, & in illarum quamlibet Specillum conuertas Stellarum constipatarum ceruum

Galilean moons of Jupiter

- This was a demonstration that objects orbit something other than the earth.

1. On 7 Jan 1610, what unusual hint did Galileo uncover about these “stars”?
   A. They were very bright.
   B. They were nearly on a line.



Galileo’s journal
http://galileo.rice.edu/images/things/journal_jup1.gif

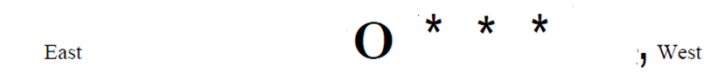
Jan 7

Accordingly, on the seventh day of January of the present year 1610,76 at the first hour of the night, when I inspected the celestial constellations through a spyglass, Jupiter presented himself. And since I had prepared for myself a superlative instrument, I saw (which earlier had not happened because of the weakness of the other instruments)77 that three little stars were positioned near him- small but yet very bright. Although I believed them to be among the number of fixed stars, they nevertheless intrigued me because they appeared to be arranged exactly along a straight line and parallel to the ecliptic, and to be brighter than others of equal size. And their disposition among themselves and with respect to Jupiter was as follows:78

East * * O * West

That is, two stars were near him on the east and one on the west; the more eastern one and the western one appeared a bit larger than the remaining one. I was not in the least concerned with their distances from Jupiter, for, as we said above, at first I believed them to be fixed stars. But when, on the eighth, I returned to the same

to be fixed stars. But when, on the eighth, I returned to the same observation, guided by I know not what fate,79 I found a very different arrangement. For all three little stars were to the west of Jupiter and closer to each other than the previous night, and separated by equal intervals, as shown in the adjoining sketch.[80] Even though at this point I had by no means turned my thought to the mutual motions of these stars, yet I was aroused by the question



of how Jupiter could be to the east of all the said fixed star1 when the day before he had been to the west of two of them. I was afraid, therefore, that perhaps, contrary to the astronomical comput~tions, his motion was direct and that, by his proper motion, h'e had bypassed those stars.[81] For this reason I waited eagerly for the\next night. But I was disappointed in my hope, for the sky was everywhere covered with clouds.

Then, on the tenth, the stars appeared in this position with regard to Jupiter. Only two stars were near him, both to the east. The

- How does the evidence disprove that they are stars?
- Assume the three objects seen near Jupiter on 7 Jan 1610 were real stars. Draw what Galileo would have seen on Jan 8th.

3. Spacing between the stars is ___as on the 7th.
   A. <u>the same</u>
   B. different
4. Distance from easternmost star to Jupiter is ___.
   A. precisely the same
   B. <u>different</u>.