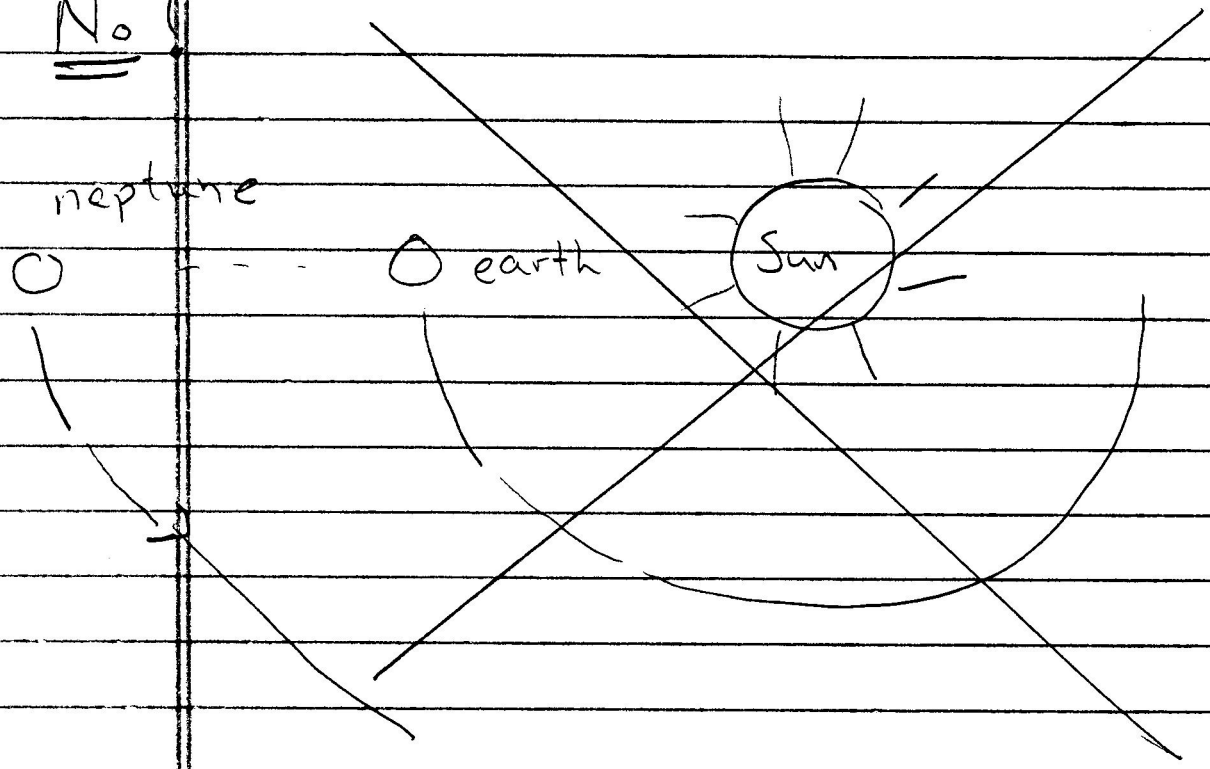
(1)

The sizes of things:

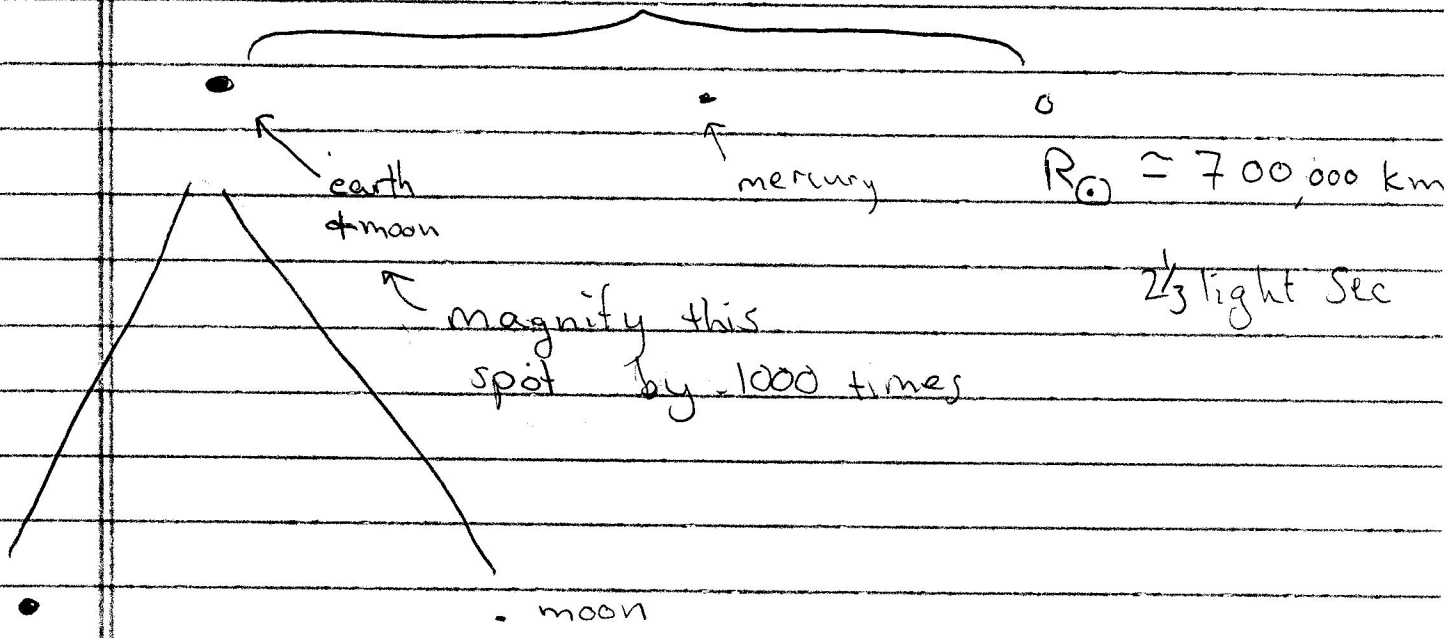
No



This is totally misleading!

The real picture:

1.5×10^8 km = 8 light minutes $\equiv 1 R_{ES}$



$R_E \simeq 6000$km $\quad R_{moon} = 1700$km

$R_{Em} = 3.8 \times 10^5$ km

$\simeq 1\frac{1}{4}$ light sec = distance to moon

$R_\odot \simeq 2 \times$ Distance to moon

$= 2 R_{Em}$

1 mile = 1.6 km

1 light sec $= 3 \times 10^8$ m

Ratios

"Angular Size of Sun" $= \frac{\text{Diameter of Sun}}{\text{Distance to Sun}} = \frac{2R_{\odot}}{1R_{ES}}$

$= \frac{2 \times 7 \times 10^5 \text{ km}}{1.5 \times 10^8 \text{ km}} \simeq \frac{1}{108}$

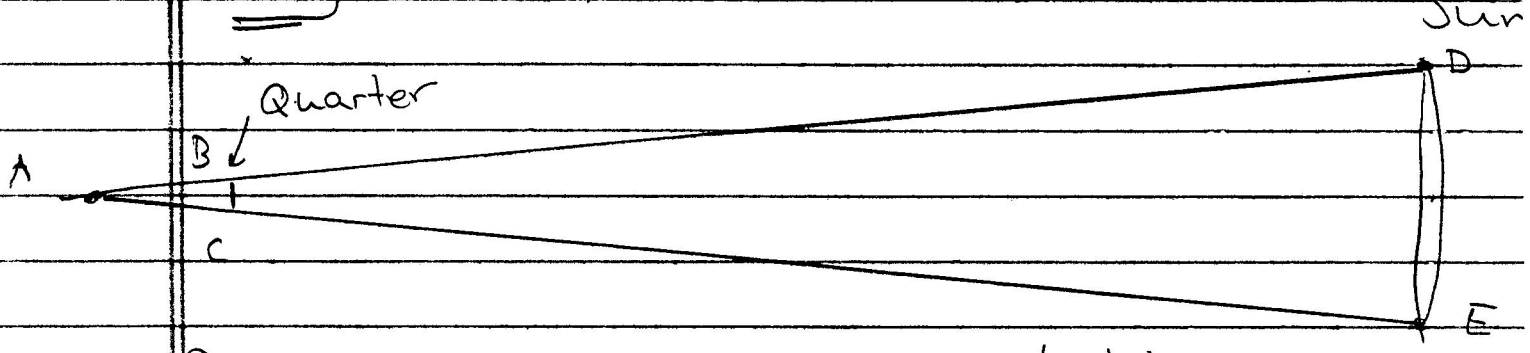
"Angular Size of moon" $= \frac{\text{Diameter of Moon}}{\text{Earth moon Distance}}$

$\simeq \frac{2R_{moon}}{R_{E \text{ to Moon}}} = \frac{2 \times 1.7 \times 10^3 \text{ km}}{3.8 \times 10^5}$

$\simeq \frac{1}{111} \simeq$ approximately the same angular size of sun

How to measure ratios of Sizes with angles

Way out of Scale



Place a quarter in the sunlight it makes a shadow. The shadow has a conical shape

$$\text{Angle of Cone in Radians} = \frac{\text{Diameter of Sun}}{\text{Earth Sun Distance}}$$

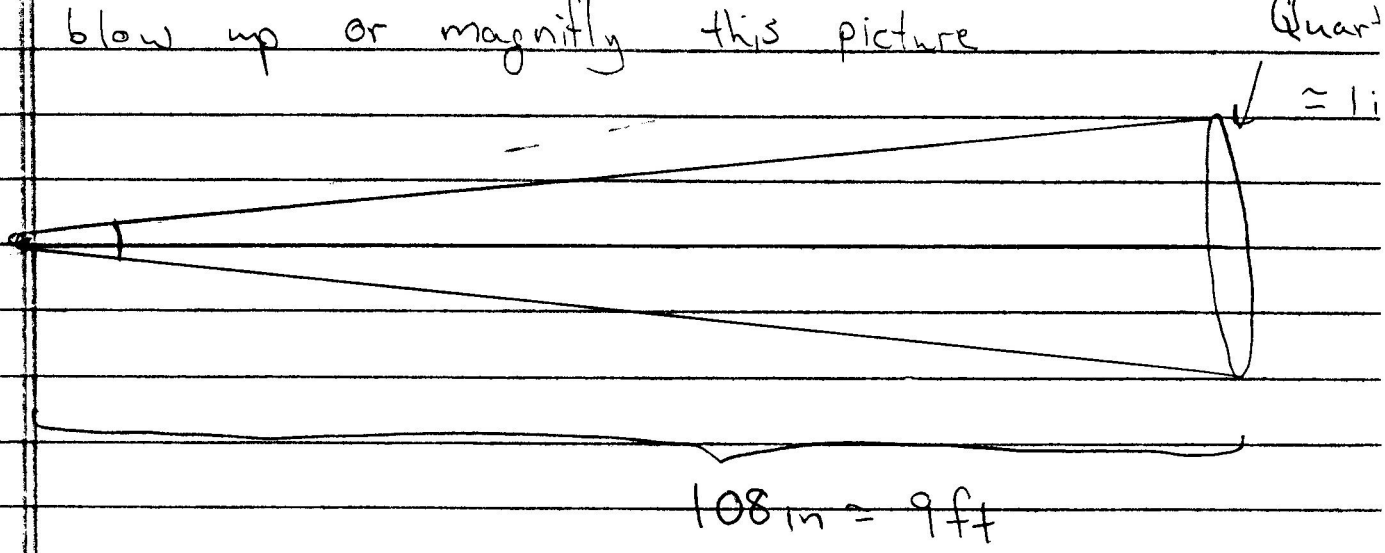
$$= \frac{1}{108}$$

angle in degrees $= 0.53^\circ$

So since ABC and ADE are similar triangles....

(5)

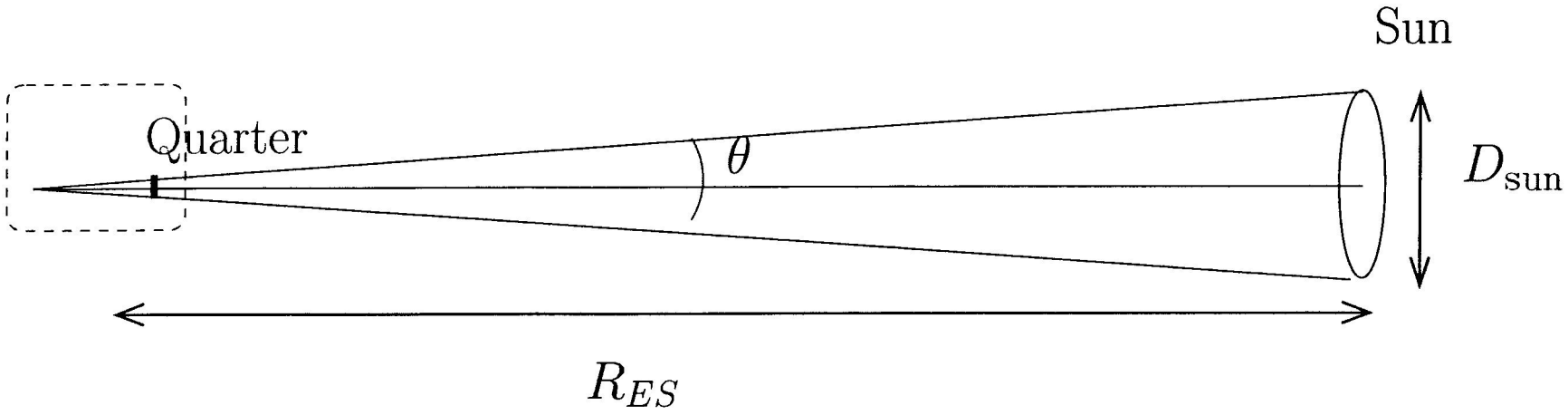
Now blow up or magnify this picture



Thus by measuring the conical shape/angle of the shadow can measure the ratio of two distance

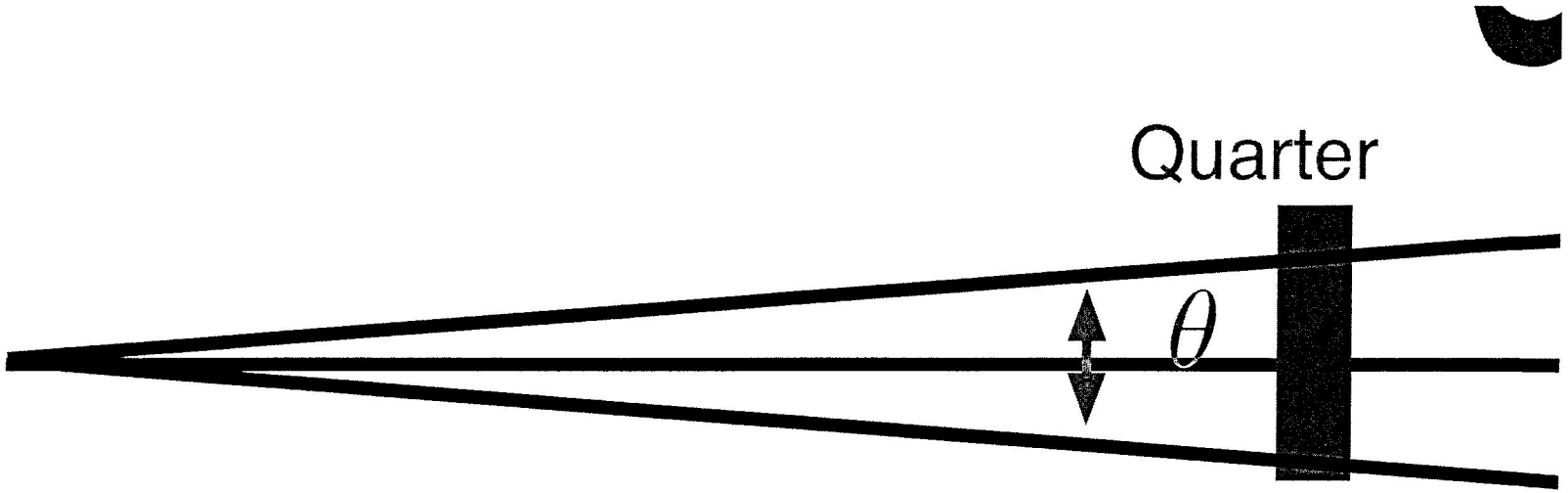
In general measuring ratios of sizes is much easier than absolute distances ...

Angular Separations



$$\theta = \frac{\text{Diameter of Sun}}{\text{Earth sun distance}}$$

Expanded Earthling View



$$\theta = \text{still the same} = \frac{\text{Diameter of Sun}}{\text{Earth sun distance}}$$

Measuring the size of the Solar System

How big is the earth? Eratosthenes 3 B.C

Observations

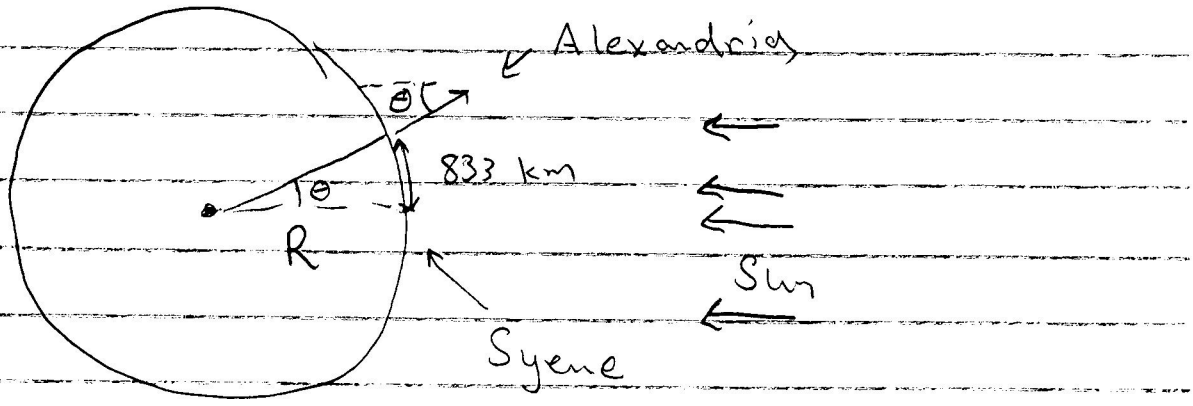
once a year ✓

- At midday (in summer) the sun went directly into a deep well in the town of Syene (close to the As dam and reflected off the bottom

- In Alexandria which is 833 km north of Syene (Aswan)

the closest the sun came to being directly overhead is 7.2°

$\Theta = 7.2° = 0.13$ radians



So

$$\theta_{\text{in radians}} = 0.13 = \frac{s}{R_E} = \frac{833\ \text{km}}{R_E}$$

So Solving for R_E

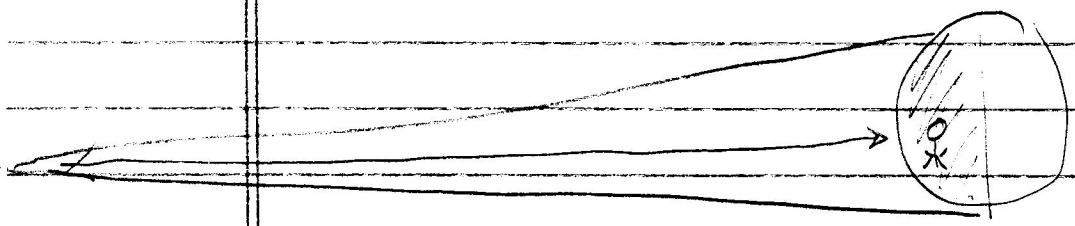
$$R_E = \frac{833\ \text{km}}{0.13} \simeq 6400\ \text{km}$$

Accepted value today is 6378 km

Measuring the Earth–Moon Distance:

- Aristarchus of Samos 310-230 BC using the lunar Eclipse

108x earth diameter Earth



108 x moon diameter Moon

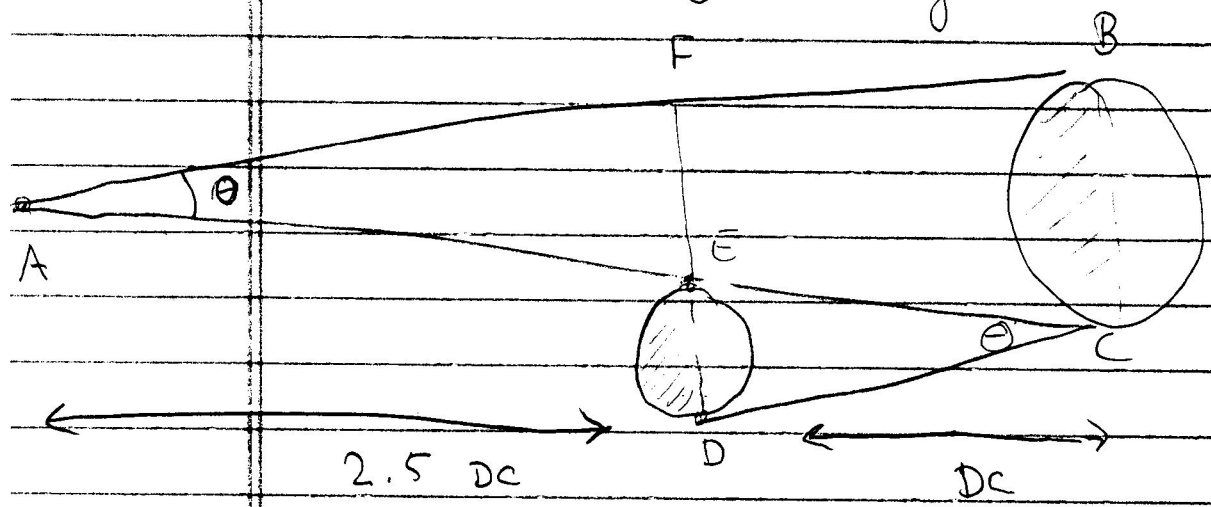
- During a lunar eclipse the moon is blocked from the sun by the earth's shadow

- Watch the video

Lunar Eclipse

- See this applet by Michael Fowler
- See this Nasa video
- The real thing Lunar Eclipse

Ok, so by timing:



(1) We know that $EF \simeq 2.5\,DE$, from timing the ec

(2) We also know that (by accident) the Sun and the moon have approximately the same angular size

Thus, AEF and DEC are similar triangles. Therefore

$AE = 2.5\,DC$ since $EF = 2.5\,DE$

So, $AC = 2.5\,DC + DC = 3.5\,DC$

length of earth's shadow = 108 x earths diameter

earth moon distance

So with earth's diameter 2×6400 km

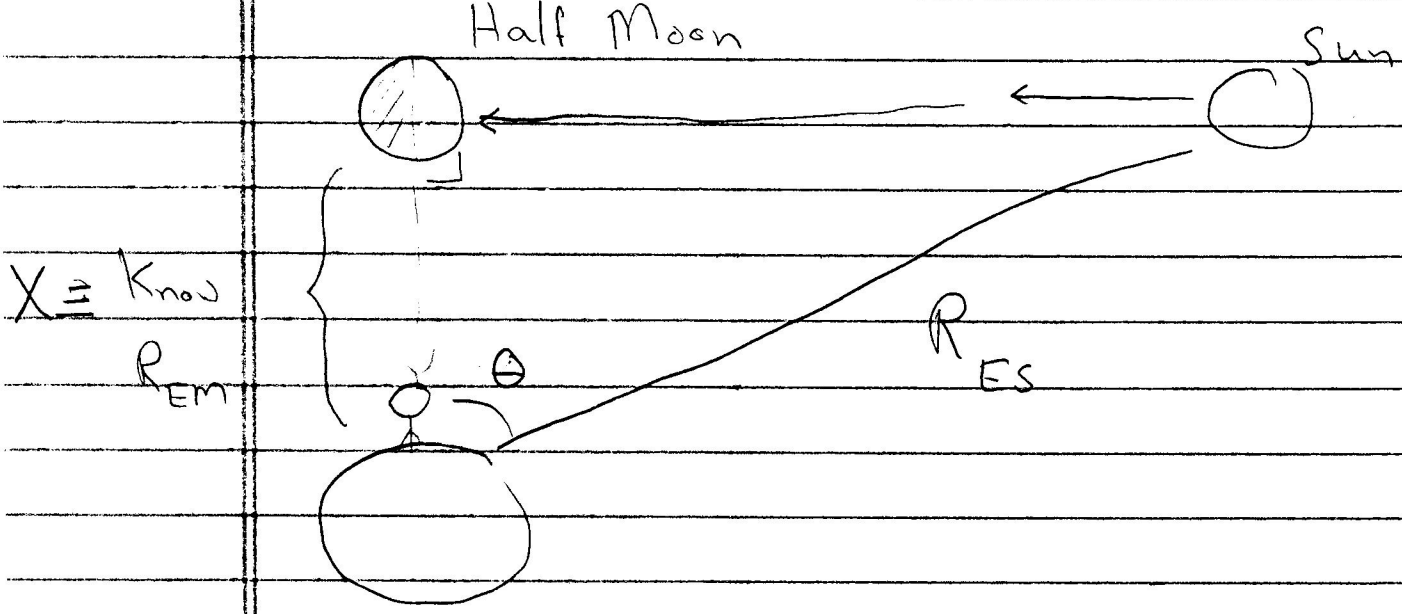
Earth Moon Distance $= \frac{108 \times \text{earths Diam}}{3.5}$

$= 3.9 \times 10^5$ km

Accepted value 3.8×10^5 km

A by product of this is the moons radius can be estimated

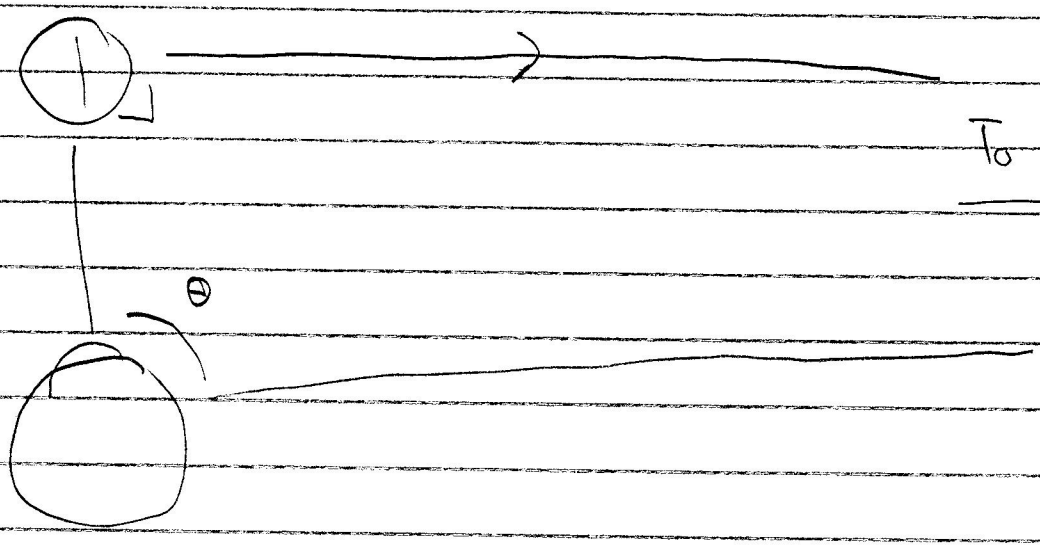
How far away is the sun? Aristarchos of So
(310 - 230



- Basic idea - Observer measures half a moon at daylight
- Then measure the angle to the sun.
Then trigonometry

$$\cos\theta = \frac{X}{R_{ES}} \Rightarrow R_{ES} = \frac{X}{\cos\theta}$$

The problem was that θ is almost 90° (89.853°)



From an estimate that $\theta > 87°$, found that the sun

$$R_{ES} > 20\, R_{Em}$$

So he concluded that the sun is very far away

In fact $R_{ES} = 390\, R_{Em} = 7 \times 10^5$ km

Copernicus (1530)

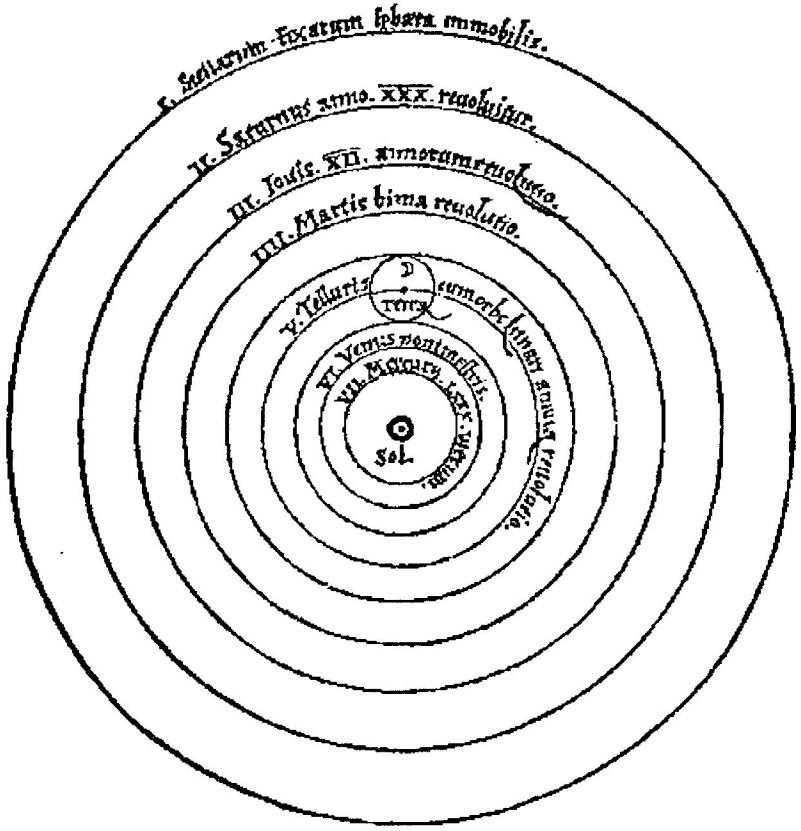
- First to suggest that the sun was at the center of the solar system challenging the Ptolemeic View. Pope Clement VII approved of Copernicus and asked for a copy
- Questions
  - → There is one exception the moon orbiting the earth

    Why?

  - → Stress would cause the earth to fly apart (Aristotle)

- The real answer to these questions came from Galileo and the telescope

Copernican View – Heliocentric view

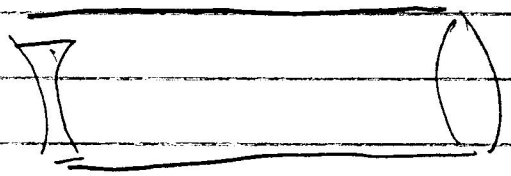


Galileo and the telescope

- Excerpt from "Siderews Nuncius"

"the starry messenger" pg. 21

- The invention of the telescope by Hans Lipperhey ~ 1608 but was unable to get a patent because it was considered to easy to fabricate



- Galileo - greatly improved the design pg. 29

- Galileo views the moon

- Galileo views the moons of jupiter

a anything showed clearly that he had
printing. If his two minor works had
e who shared that opinion, *The Starry*
ucceeded.

From: Discoveries + Opinions of Galileo, Translation + Notes by Stillman Drake

THE STARRY MESSENGER

Revealing great, unusual, and remarkable spectacles, opening these to the consideration of every man, and especially of philosophers and astronomers;

AS OBSERVED BY GALILEO GALILEI
Gentleman of Florence
Professor of Mathematics in the
University of Padua,
WITH THE AID OF A
SPYGLASS
lately invented by him,
In the surface of the Moon, in innumerable
Fixed Stars, in Nebulae, and above all
in FOUR PLANETS
swiftly revolving about Jupiter at
differing distances and periods,
and known to no one before the
Author recently perceived them
and decided that they should
be named
THE MEDICEAN STARS

Venice
1610

that its diameter appears almost
urface nearly nine hundred times,
seven thousand times as large as
aked eye. In this way one may learn
f sense evidence that the moon is
and polished surface but is in fact
red everywhere, just like the earth's
ninences, deep valleys, and chasms.
a matter of no small importance to
about the Milky Way by making
the very senses as well as to the
ll be a pleasant and elegant thing to
nature of those stars which astrono-
alled "nebulous" is far different from
ed hitherto. But what surpasses all
hat particularly moves us to seek the
mers and philosophers, is the discov-
stars not known or observed by any
enus and Mercury, which have their
sun, these have theirs about a cer-
nicuous among those already known,
precede and sometimes follow, with-
m it beyond certain limits. All these
and observed by me not many days
spyglass which I devised, after first
divine grace. Perhaps other things,
will in time be discovered by me or
ith the aid of such an instrument, the
n of which I shall first briefly explain,
on of its having been devised. After-
the story of the observations I have

ago a report reached my ears that a

a curious one, as astronomers of all schools
the maximum distance of the moon was
errestrial radii. Still more curious is the
er nor any other correspondent appears to
attention to this error; not even a friend
size the calculations in this very passage.

certain Fleming[5] had constructed a spyglass by means of which visible objects, though very distant from the eye of the observer, were distinctly seen as if nearby. Of this truly remarkable effect several experiences were related, to which some persons gave credence while others denied them. A few days later the report was confirmed to me in a letter from a noble Frenchman at Paris, Jacques Badovere,[6] which caused me to apply myself wholeheartedly to inquire into the means by which I might arrive at the invention of a similar instrument. This I did shortly afterwards, my basis being the theory of refraction. First I prepared a tube of lead, at the ends of which I fitted two glass lenses, both plane on one side while on the other side one was spherically convex and the other concave. Then placing my eye near the concave lens I perceived objects satisfactorily large and near, for they appeared three times closer and nine times larger than when seen with the naked eye alone. Next I constructed another one, more accurate, which represented objects as enlarged more than sixty times. Finally, sparing neither labor nor expense, I succeeded in constructing for myself so excellent an instrument that objects seen by means of it appeared nearly one thousand times larger and over thirty times closer than when regarded with our natural vision.

It would be superfluous to enumerate the number and importance of the advantages of such an instrument at sea as well as on land. But forsaking terrestrial observations, I turned to celestial ones, and first I saw the moon from as near at hand as if it were scarcely two terrestrial radii away. After that I observed often with wondering delight both the planets and the fixed stars, and since I saw these latter to be very crowded, I began to seek (and eventually found)

[5] Credit for the original invention is generally assigned to Hans Lipperhey, a lens grinder in Holland who chanced upon this property of combined lenses and applied for a patent on it in 1608.

[6] Badovere studied in Italy toward the close of the sixteenth century and is said to have been a pupil of Galileo's about 1598. When he wrote concerning the new instrument in 1609 he was in the French diplomatic service at Paris, where he died in 1620.