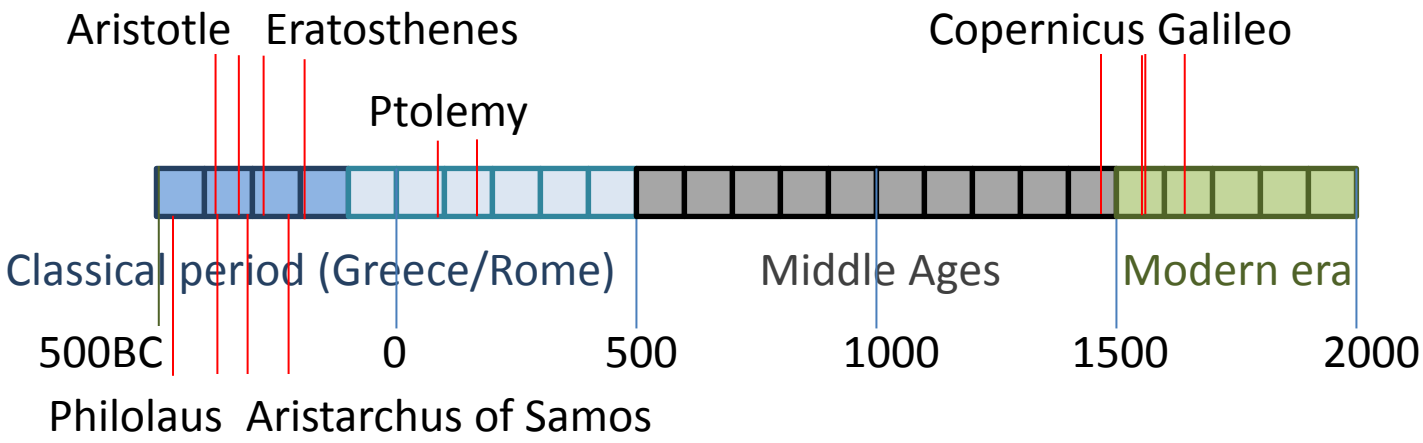
Looking outside Earth

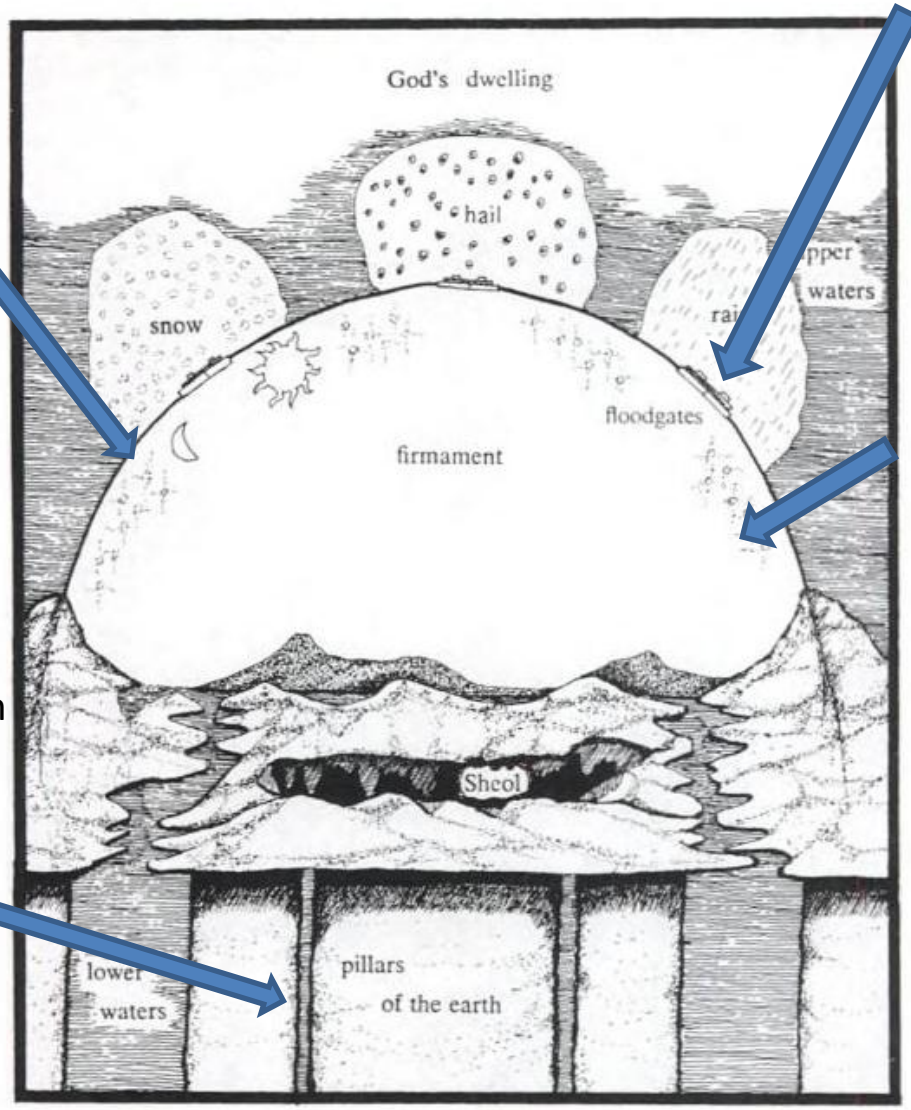
Big players in the developing the world view:



Ancient view of the universe (for example, the bible)

Let there be a firmament in the midst of the waters, and let it divide the waters from the waters

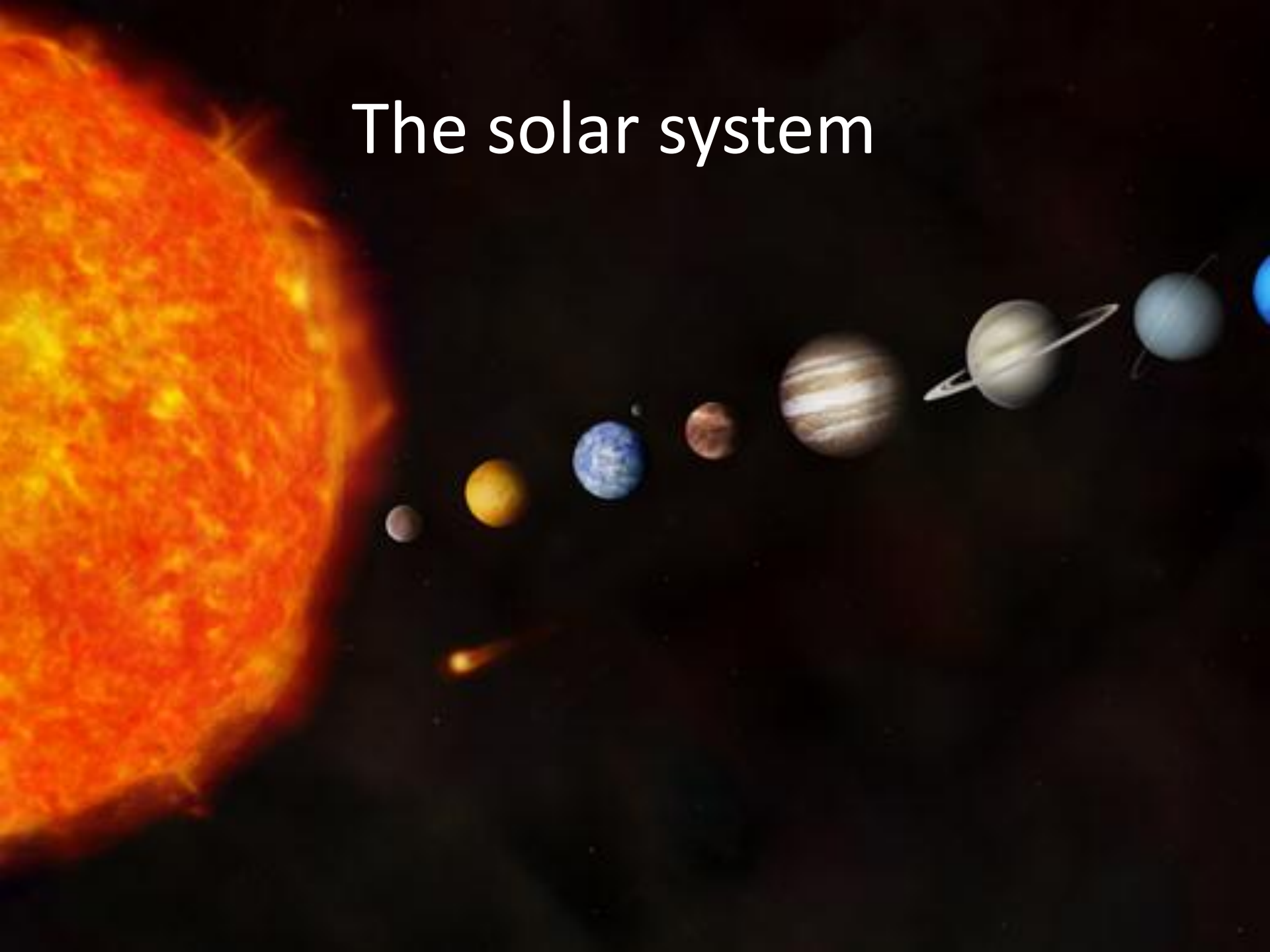
Now the springs of the deep and the floodgates of the heavens had been closed, and the rain had stopped falling from the sky.

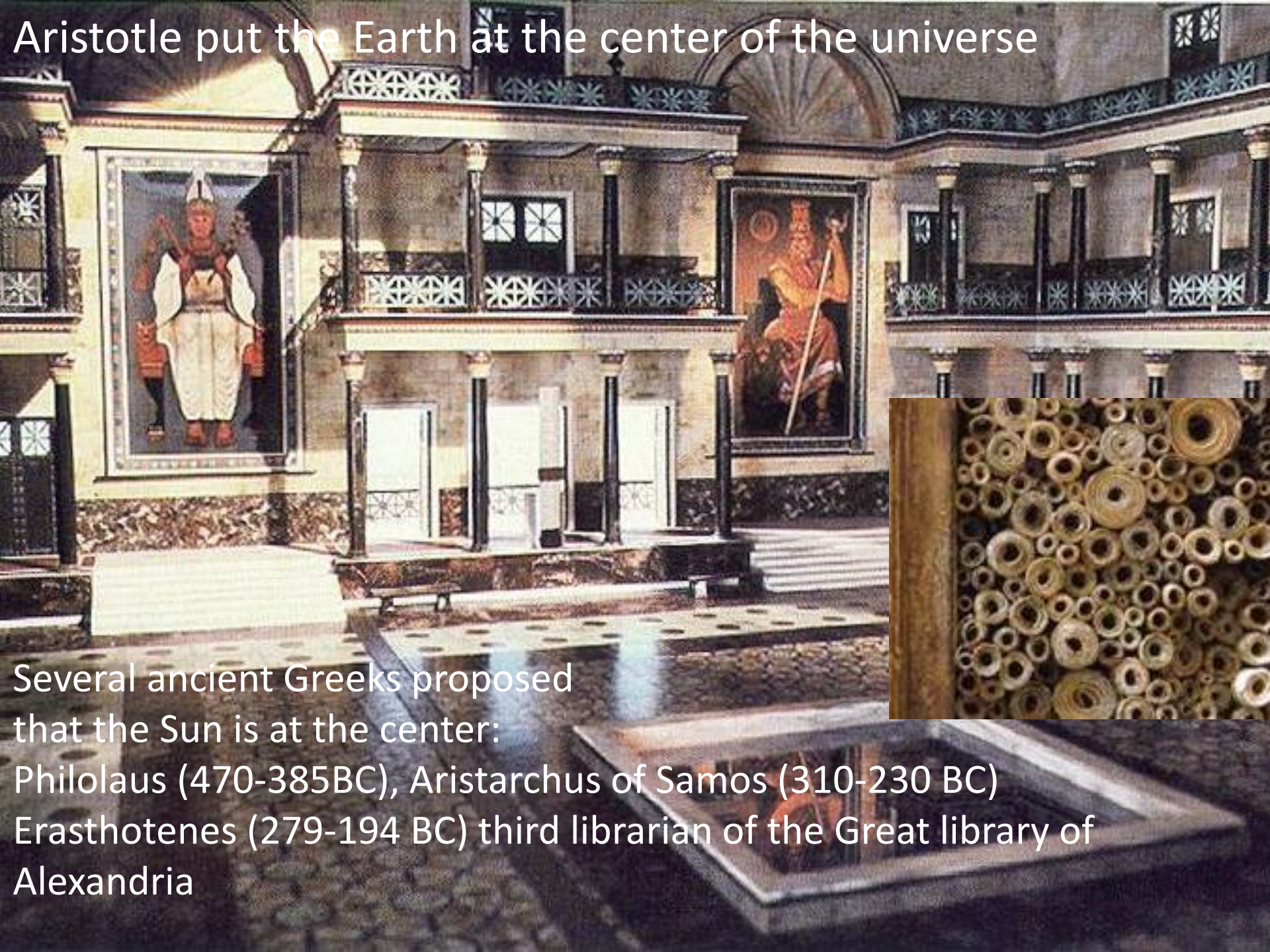


And let them be for lights in the firmament of the heaven to give light upon the earth: and it was so.

He shakes the earth from its place and makes its pillars tremble.

The solar system

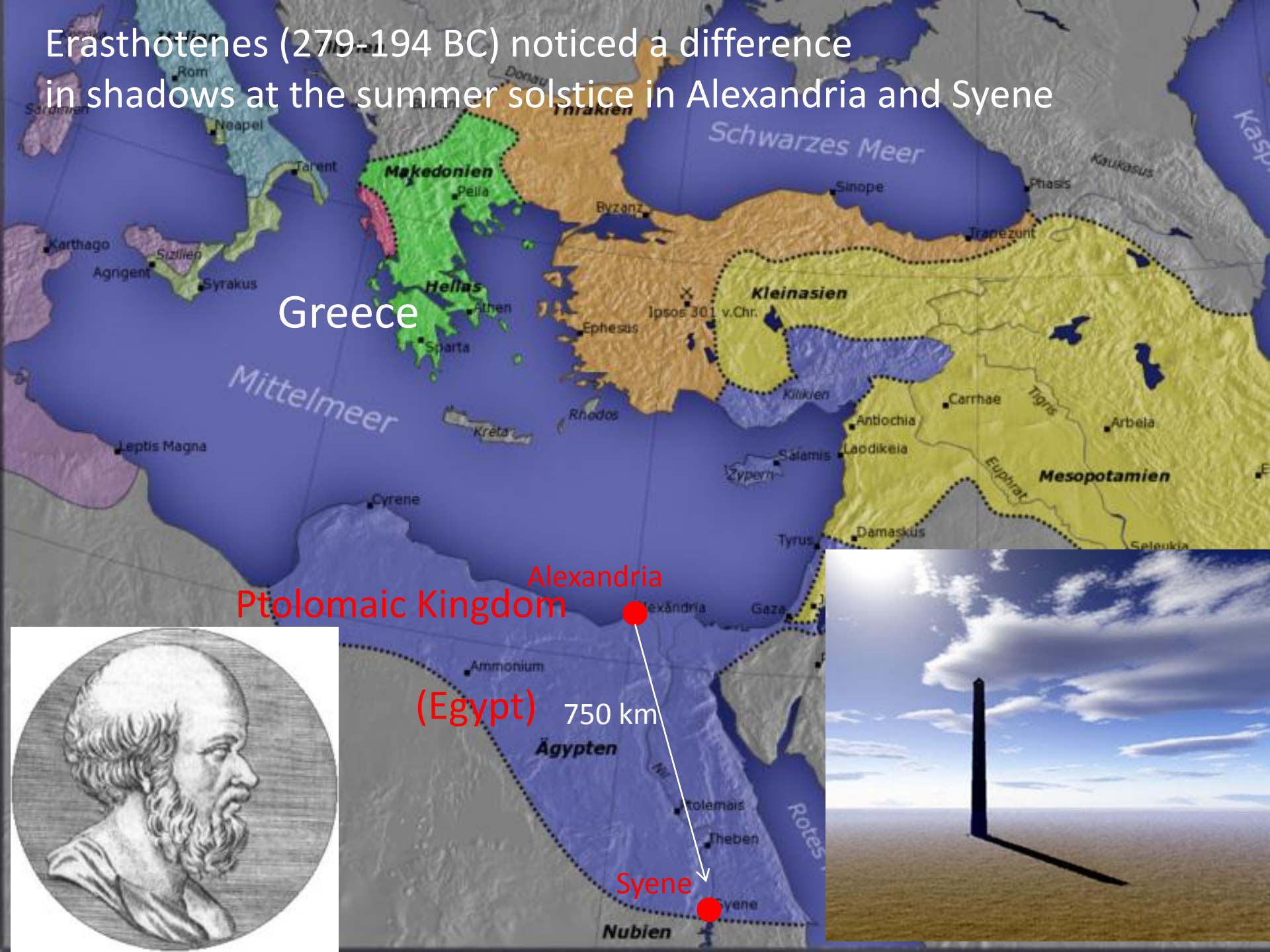


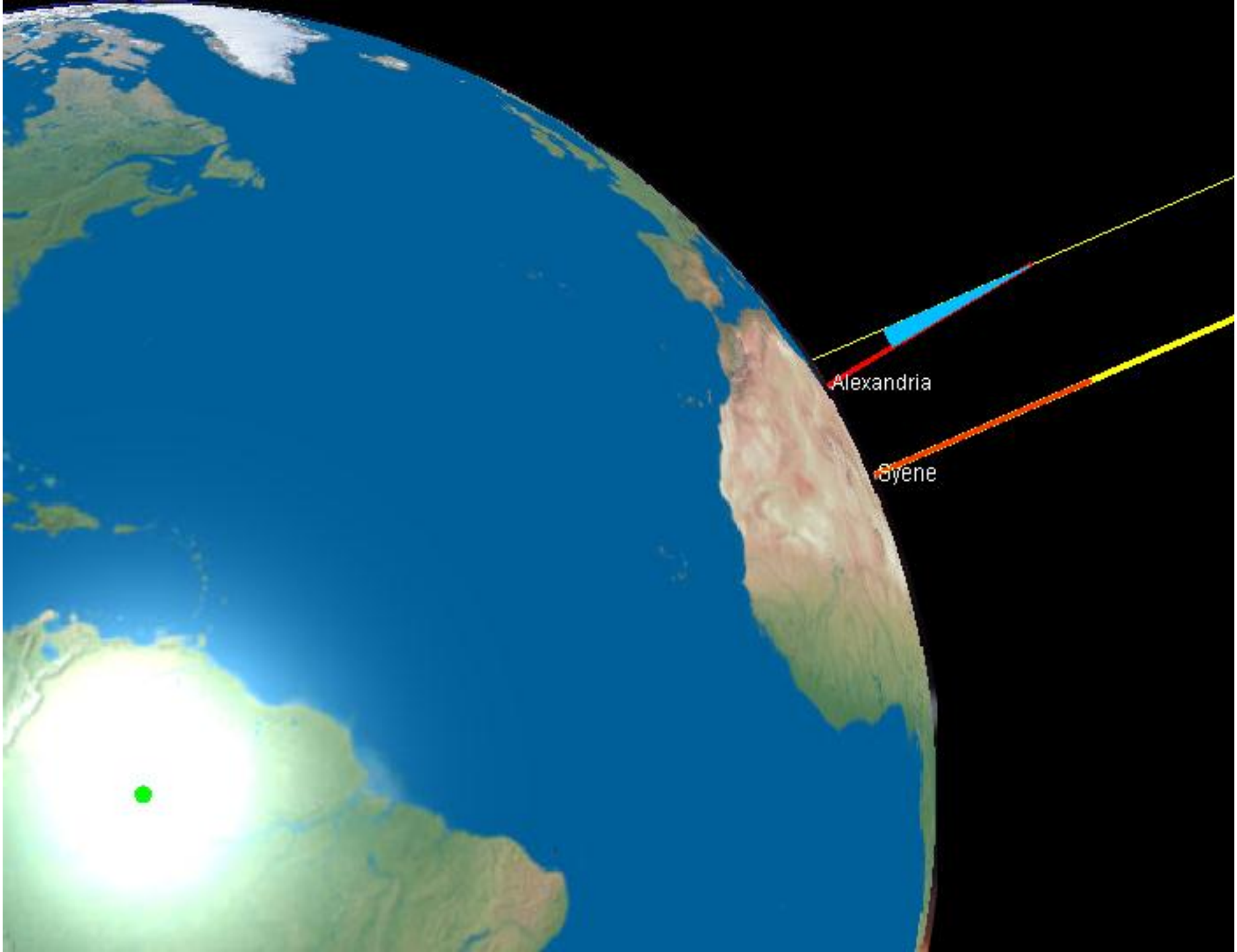


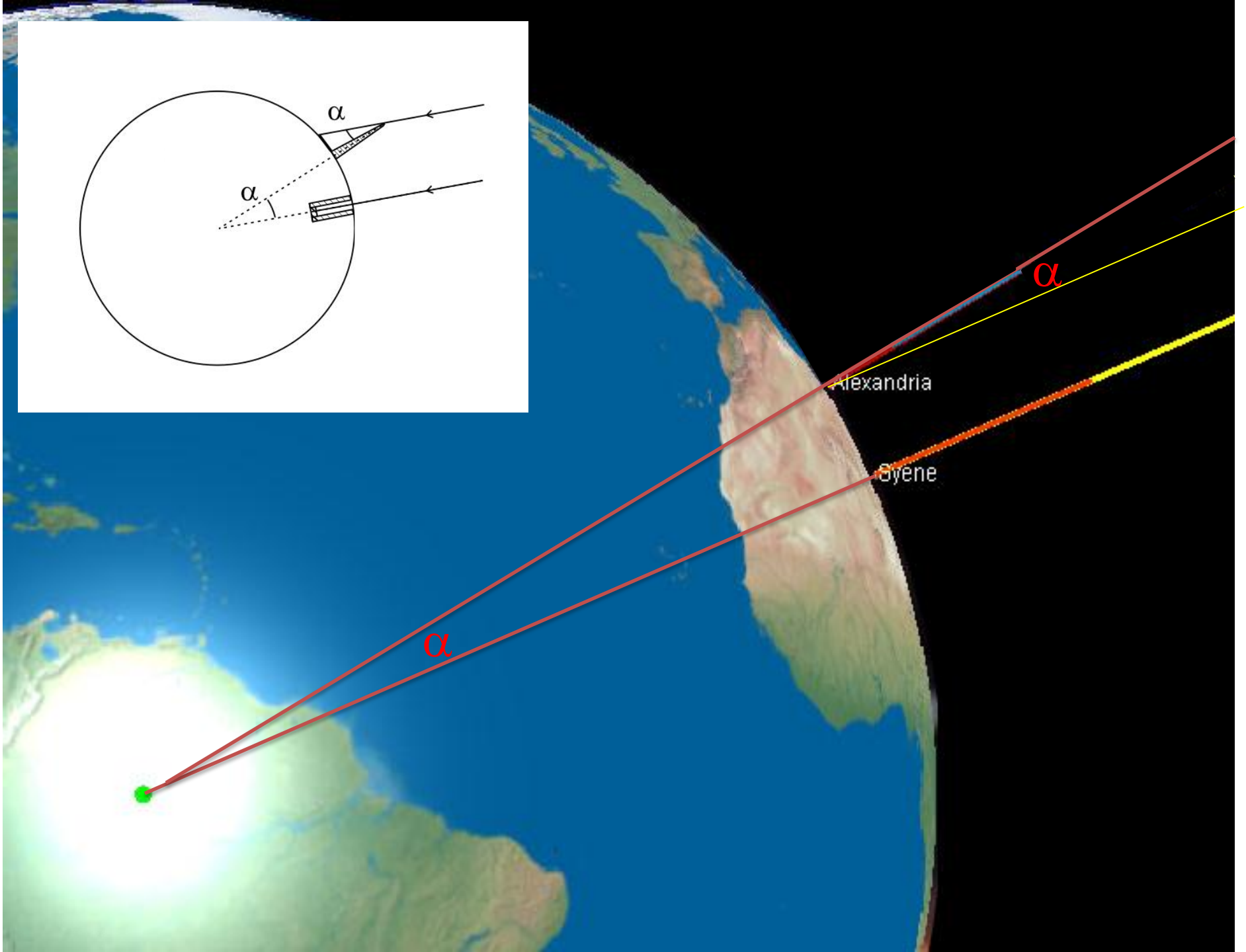
Aristotle put the Earth at the center of the universe

Several ancient Greeks proposed
that the Sun is at the center:
Philolaus (470-385BC), Aristarchus of Samos (310-230 BC)
Erasthotenes (279-194 BC) third librarian of the Great library of Alexandria

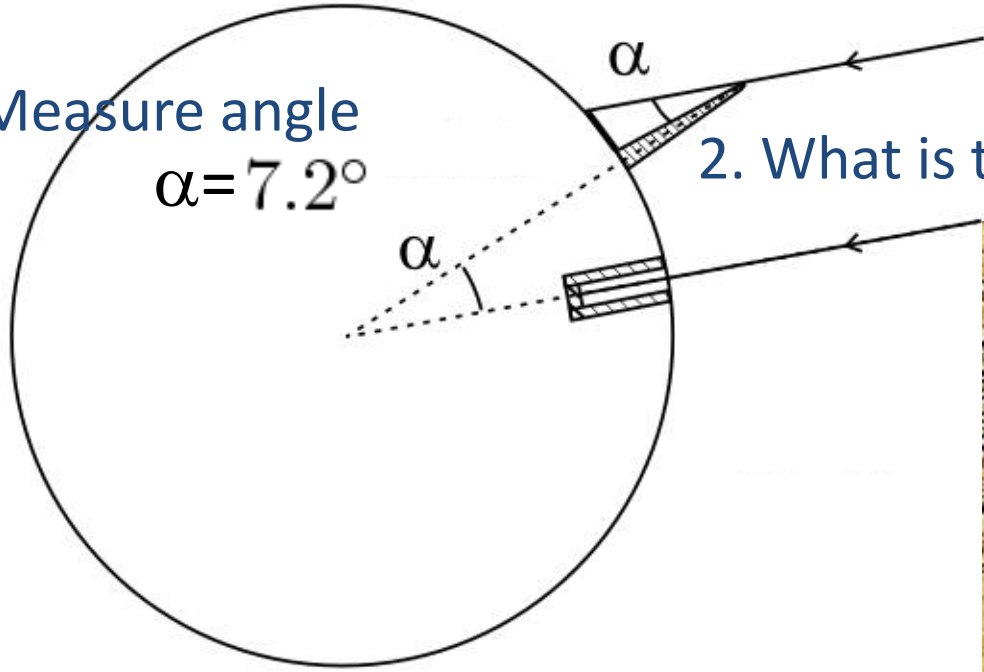
Erasthotenes (279-194 BC) noticed a difference in shadows at the summer solstice in Alexandria and Syene




Alexandria
Syene


α
α
α
α
Alexandria
Syene

1. Measure angle



2. What is this distance?

Send some soldiers on a march from Alexandria to Syene

3. Calculate portion of circumference

$$\text{circumference} = 750 \times \frac{360^\circ}{7.2^\circ} = 37,500 \text{ km}$$

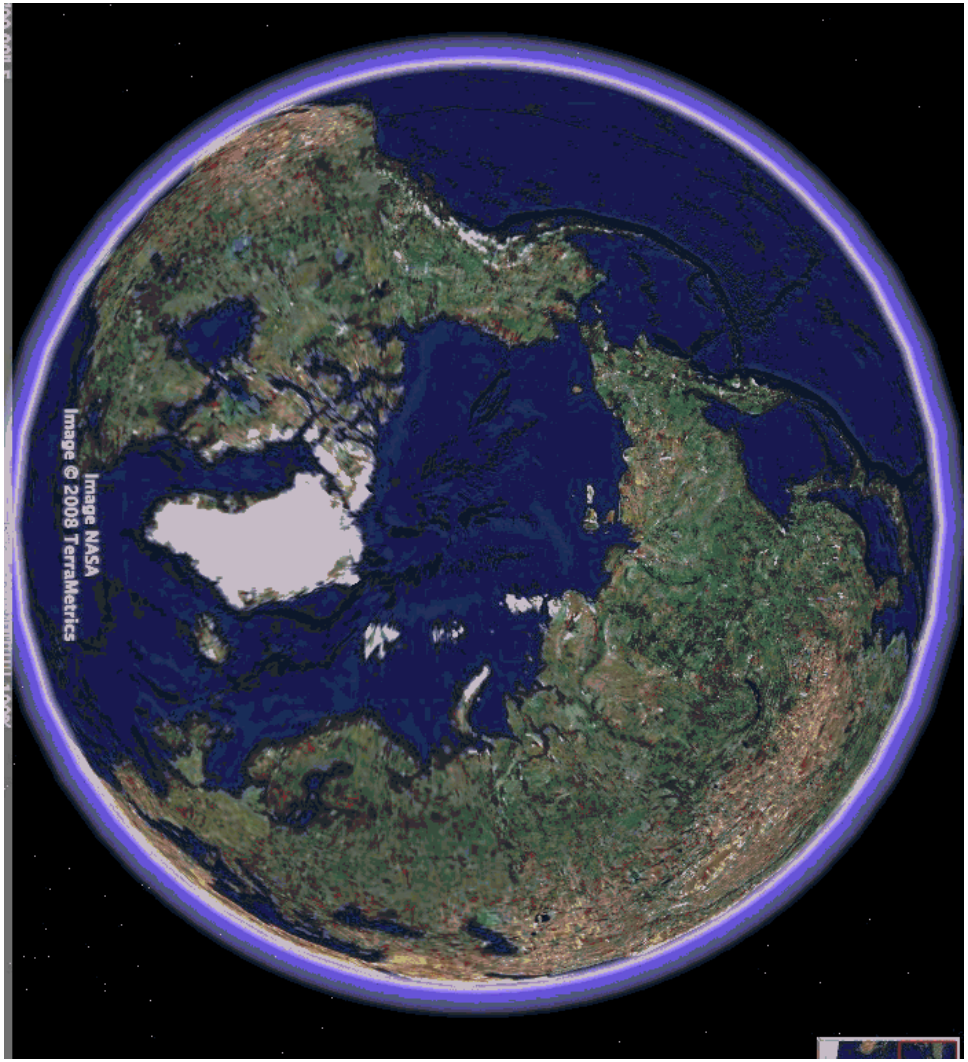
4. Diameter 37,500/π=12,700 km

Spinning

$v=2\pi\, 6350/24=1662$ km/h

As a reference:

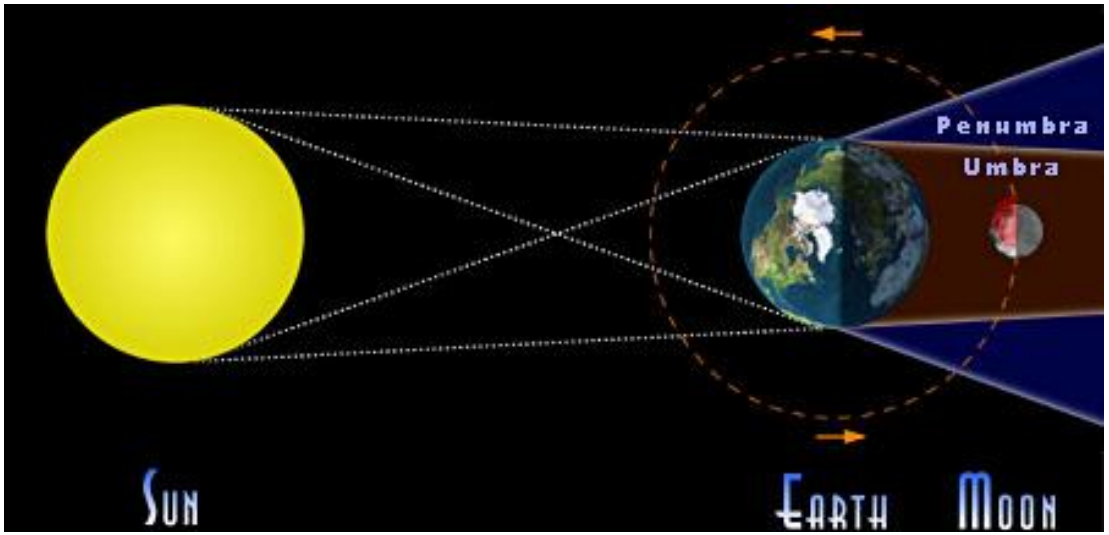
V=1200 km/h



What is the size of the Moon?

1. How long does it take for the Moon to traverse the Earth's radius

During a lunar eclipse the Moon has to go through the Earth's shadow (which is about the size of the Earth)

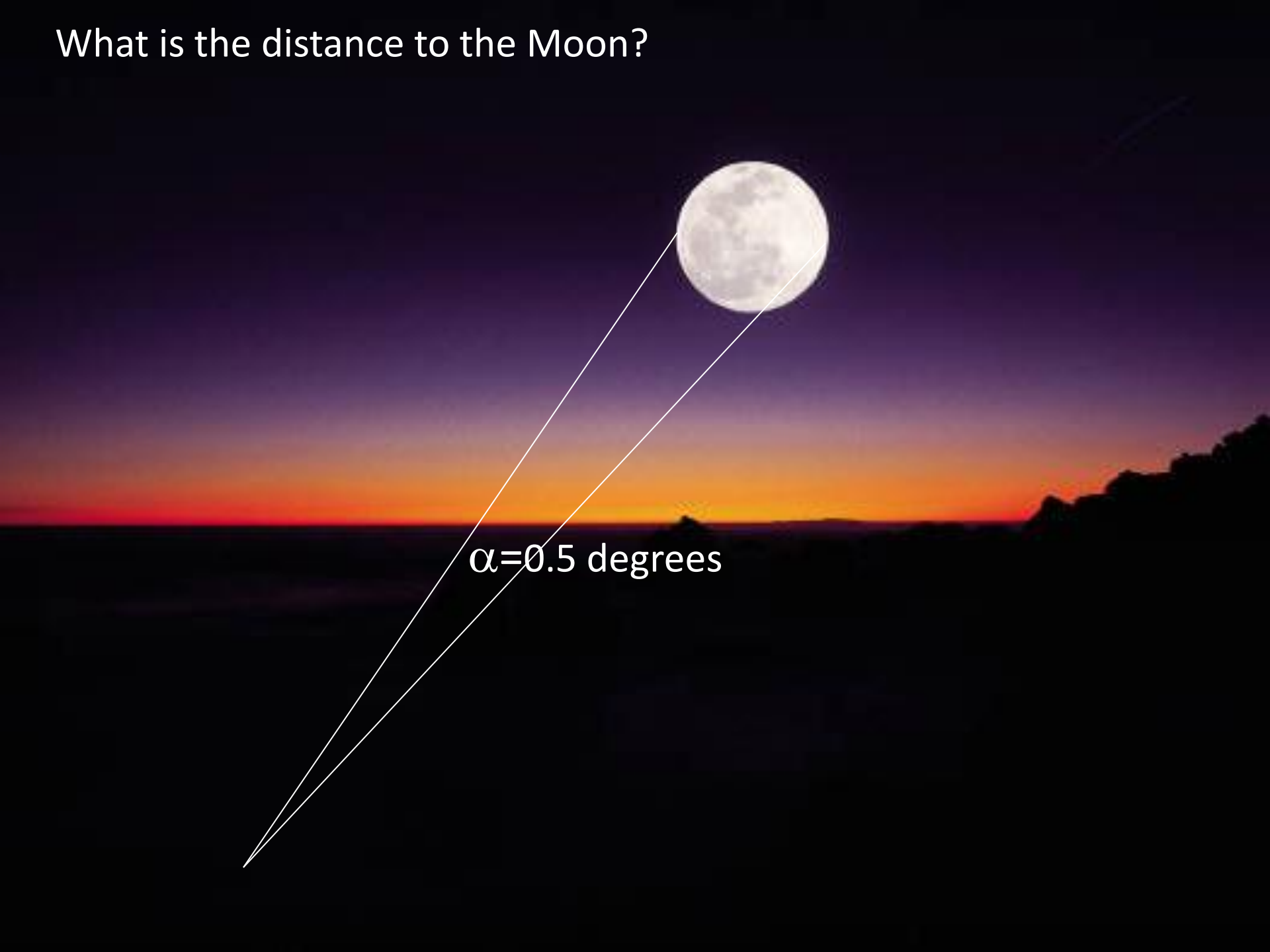


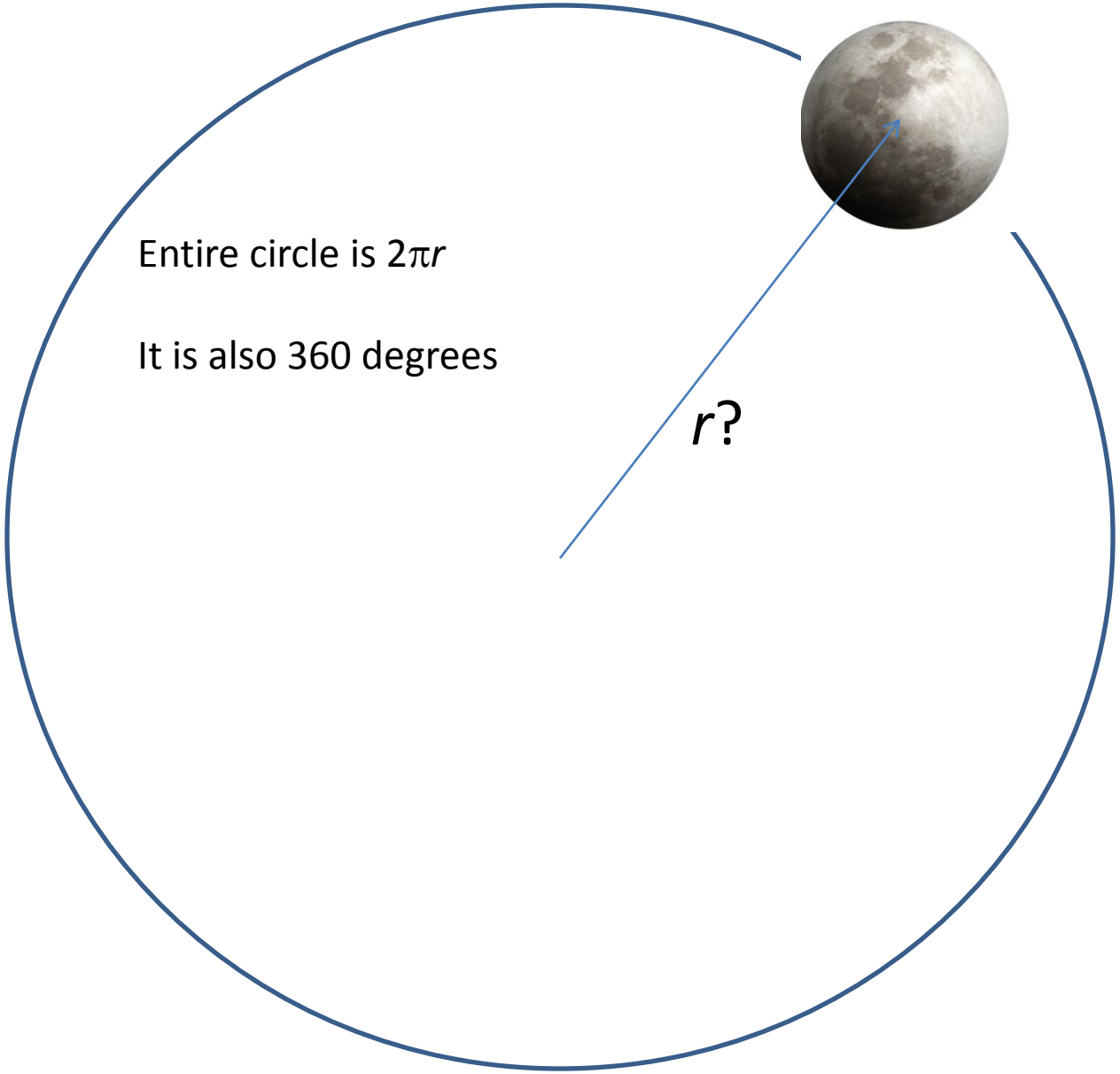
2. Compare this to the time needed for the Moon to traverse its own radius

3. Aristarchus had already found it was about 3/8 (it's actually closer to 1/4)

So the 3/8 x 12700 = 4700 km

What is the distance to the Moon?

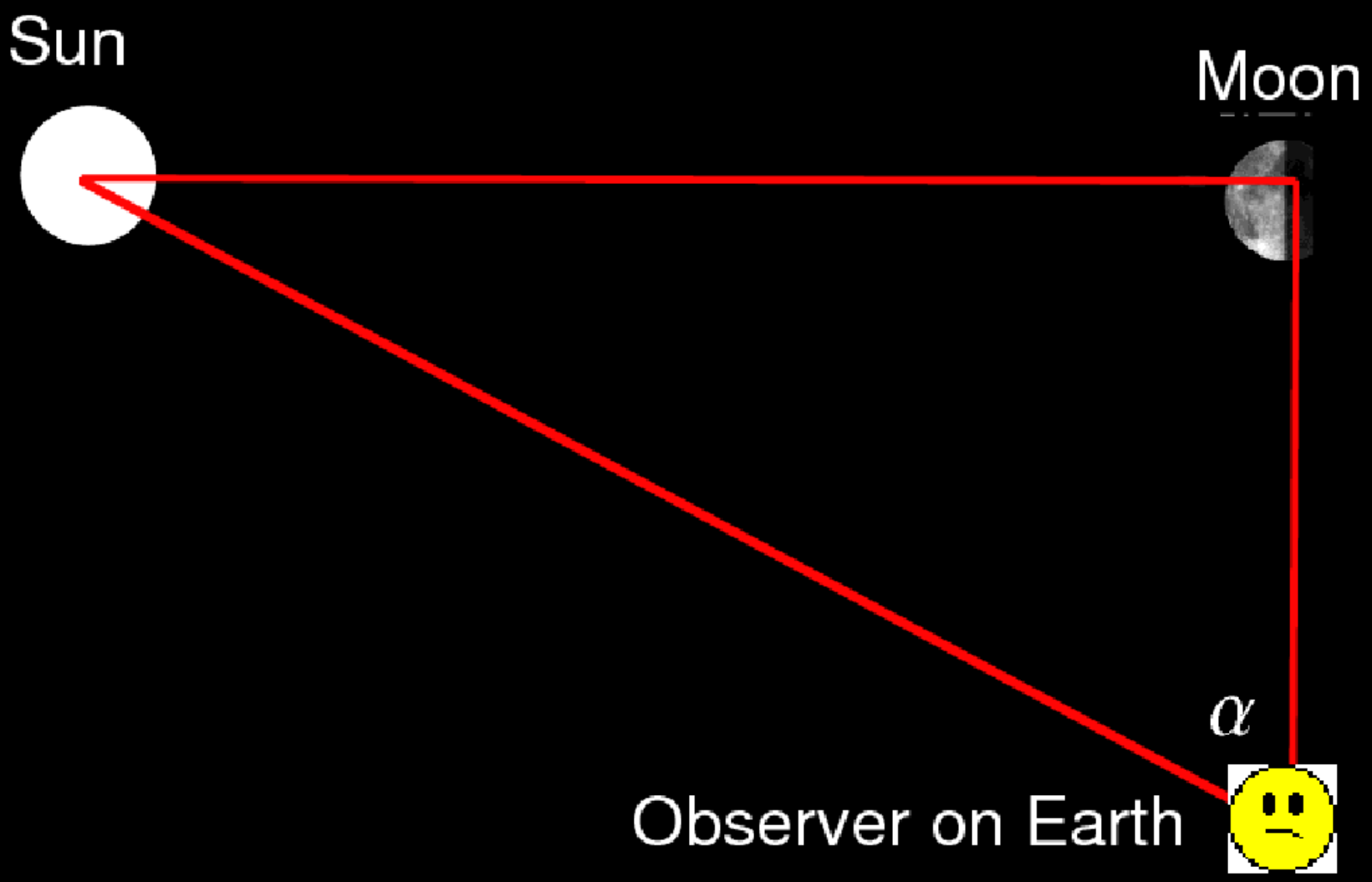




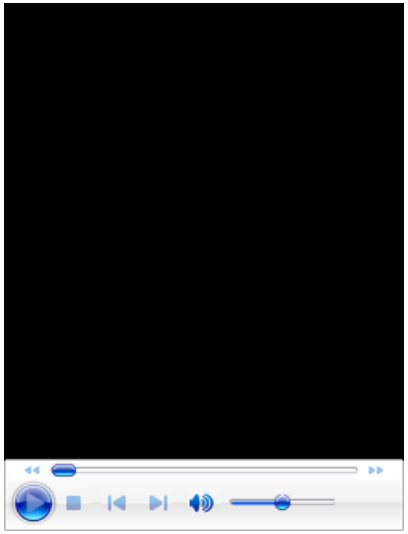
r_{Moon}=0.5/360 2 π r or r =r_{Moon} 360/ 0.5 2 π

With r_{Moon}=3476 km r =400,000 km

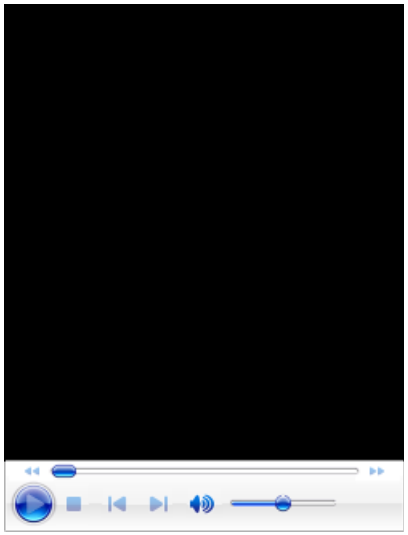
$$\text{distance}_{\text{Earth}-\text{Sun}} = \frac{\text{distance}_{\text{Earth}-\text{Moon}}}{\cos\alpha} = \frac{400,000}{\cos 89.85} \cong 150,000,000 \text{ km}$$



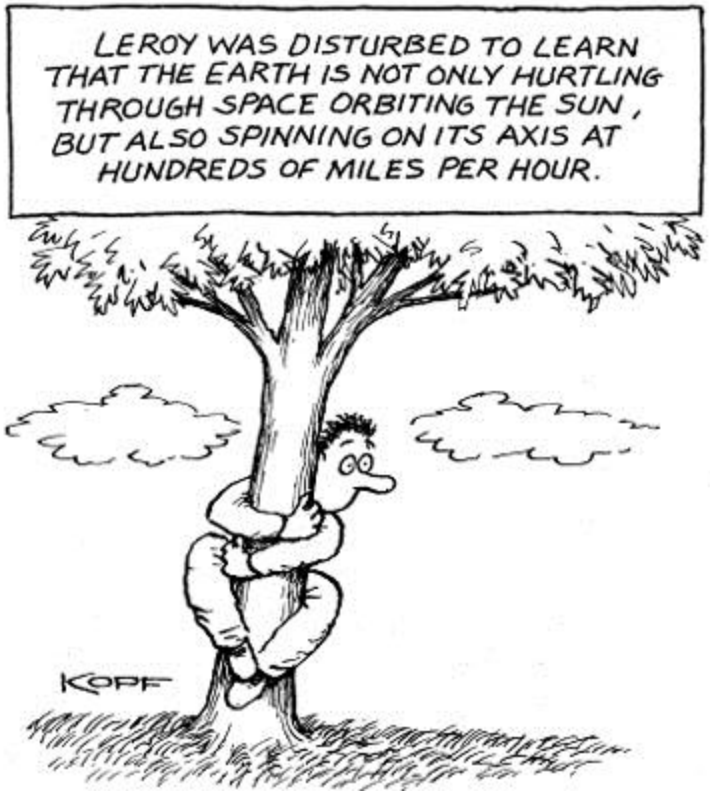
Speed: 2 π 150,000,000 /(365 x 24)=108,000 km/h



For comparison: Rocket sled 10,385 km/h
(10 times slower)



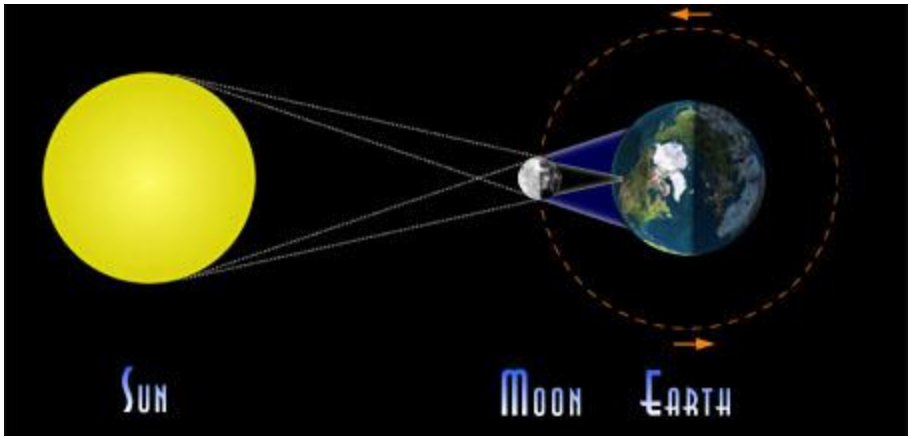
For comparison: NASA X-43A 12,144 km/h
(9 times slower)

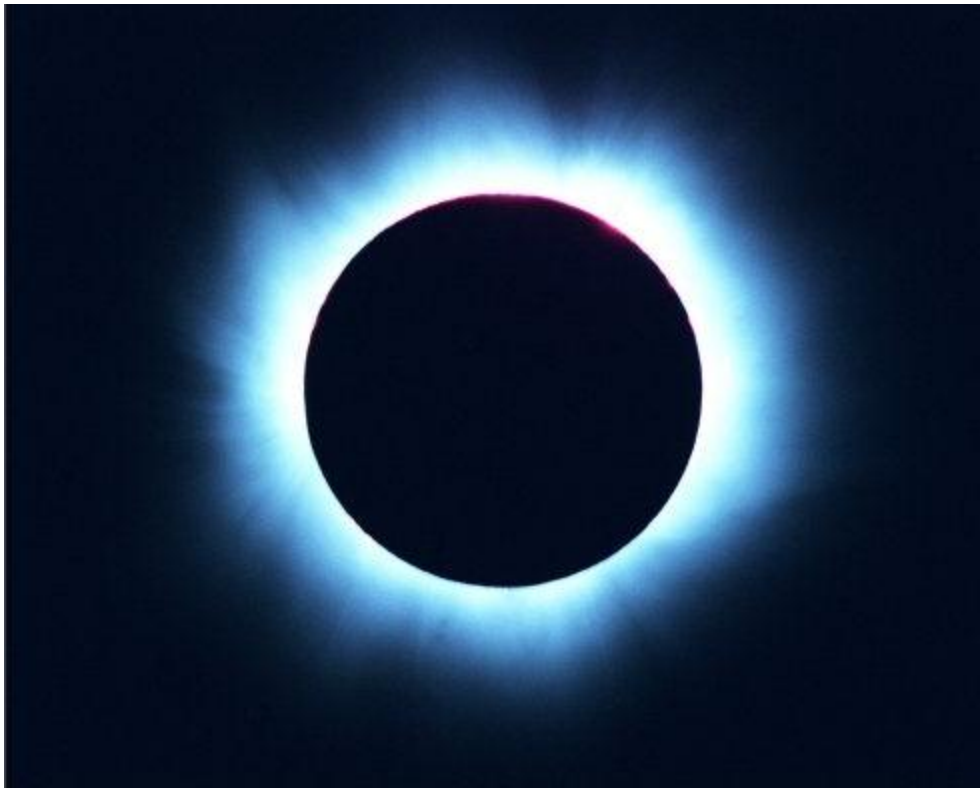


Somewhat less impressive in comparison….

Size Sun?

The Sun takes up about the same are in the sky as the Moon (accidentally)

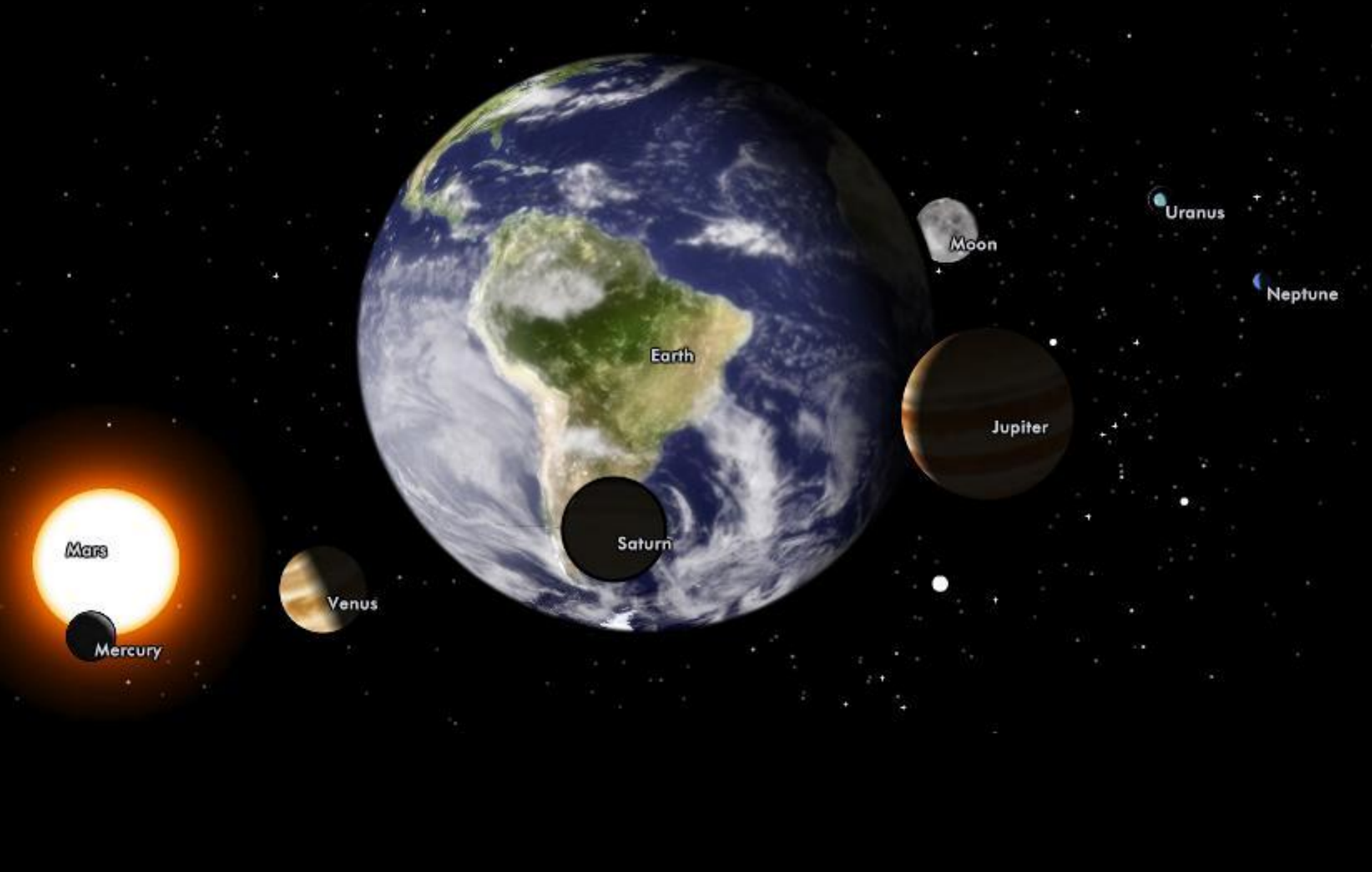




$$\text{diameter} = 150 \times 10^6 \text{ km} \times \frac{0.5^\circ}{360^\circ} \times 2\pi \cong 1.3 \times 10^6 \text{ km}$$

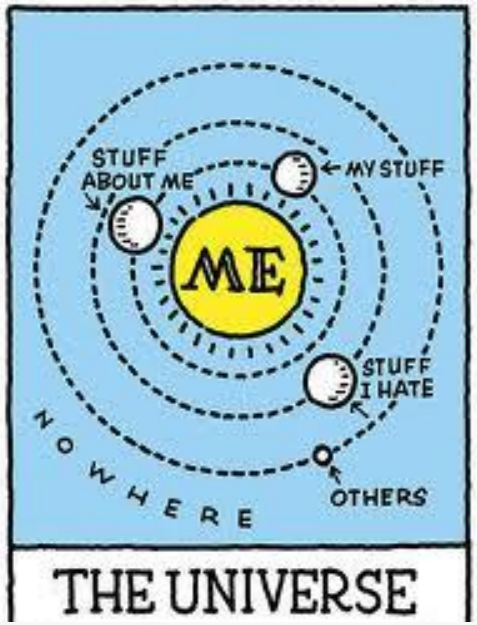
So the Sun is kinda big…..

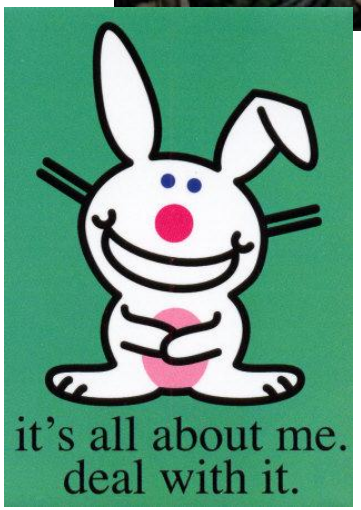
In the end, the geocentric view prevailed

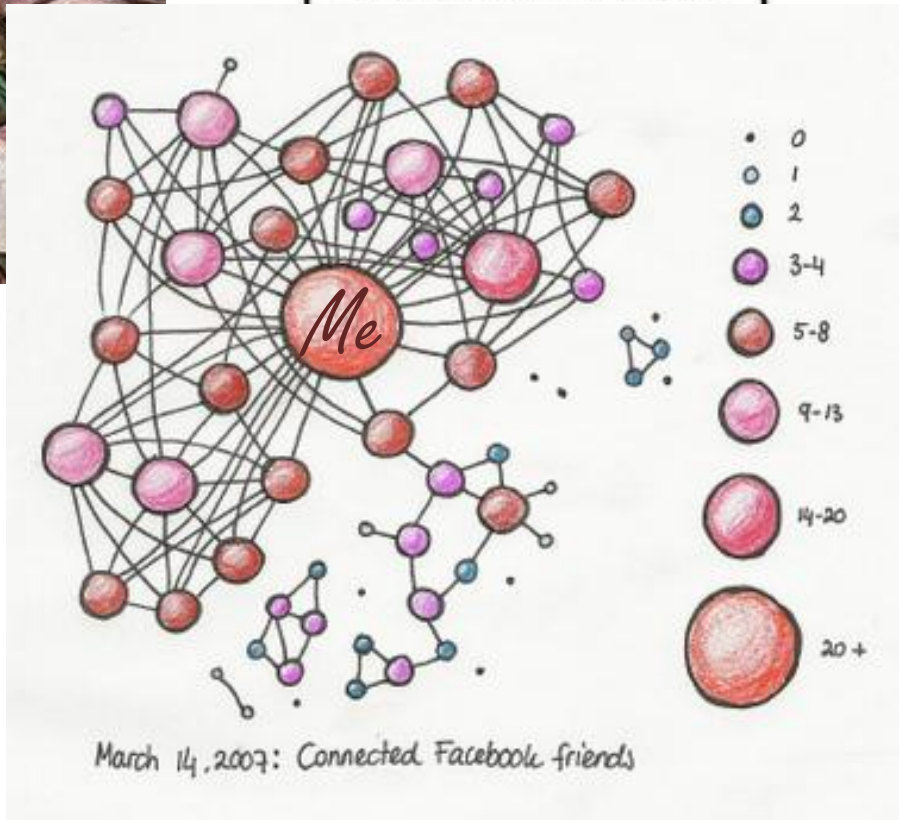


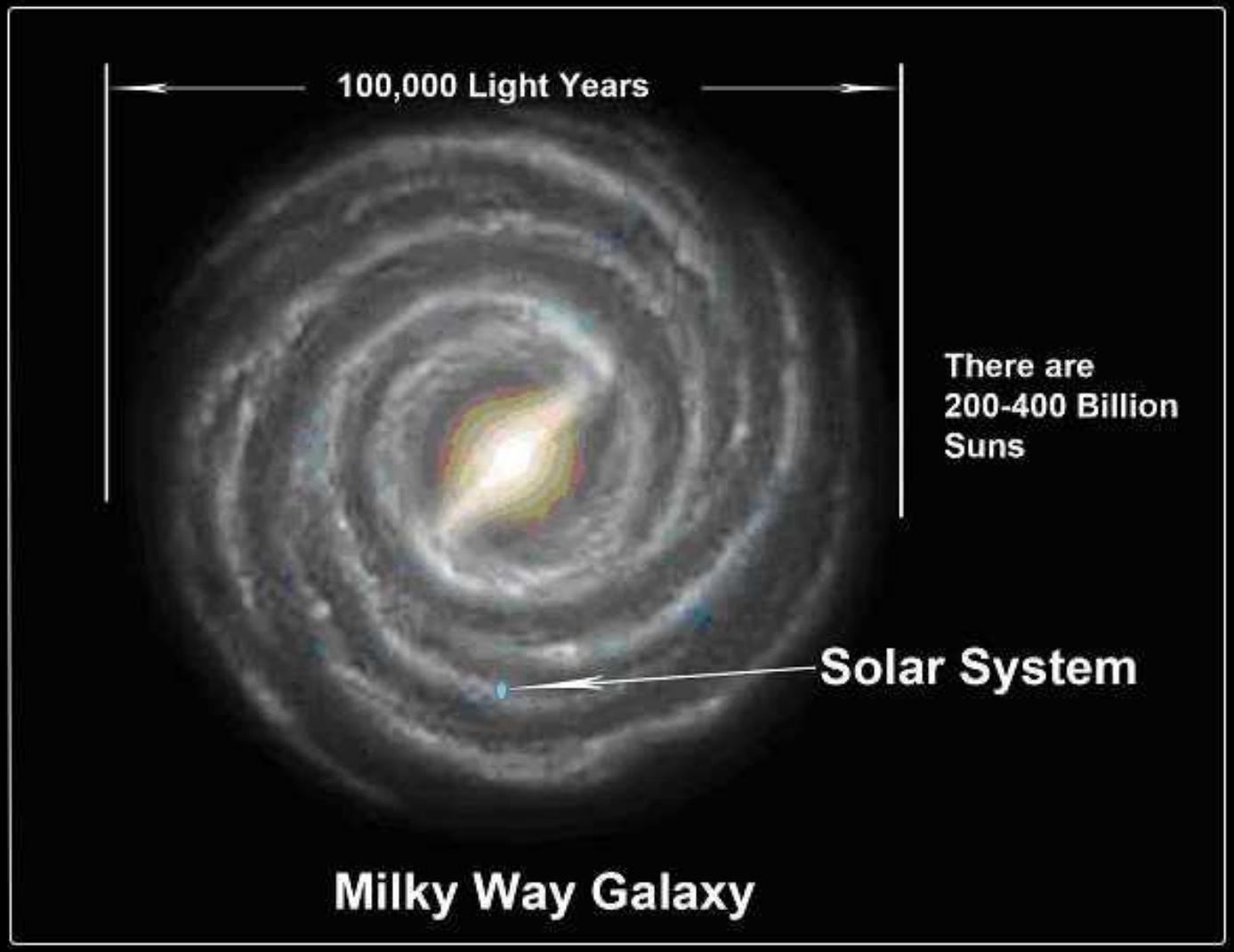
So why did people think the Earth was at the center?

Of course, everything is centered around us









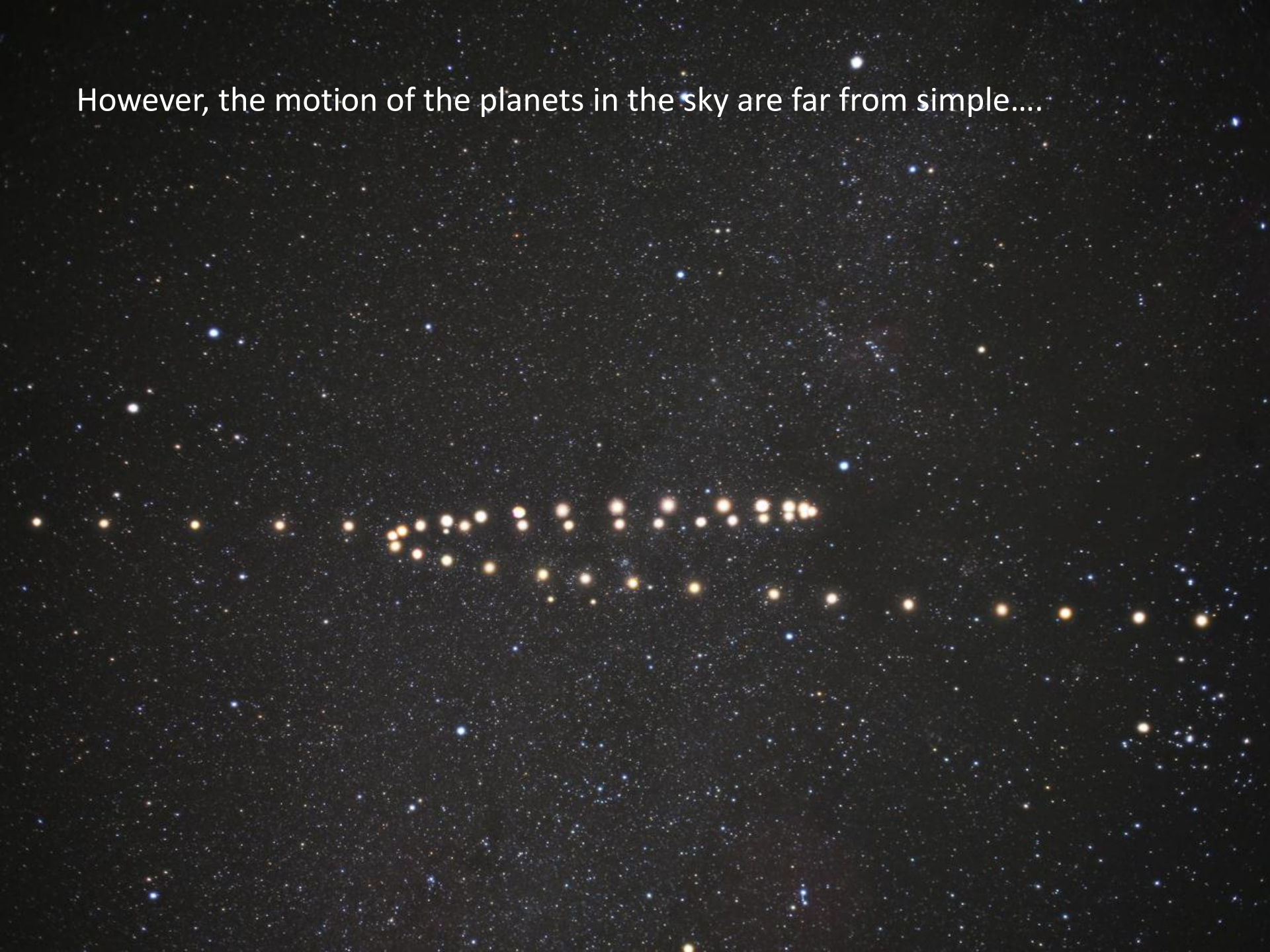
SELF IMPORTANCE

YOU REALLY AREN'T THE CENTER OF THE UNIVERSE

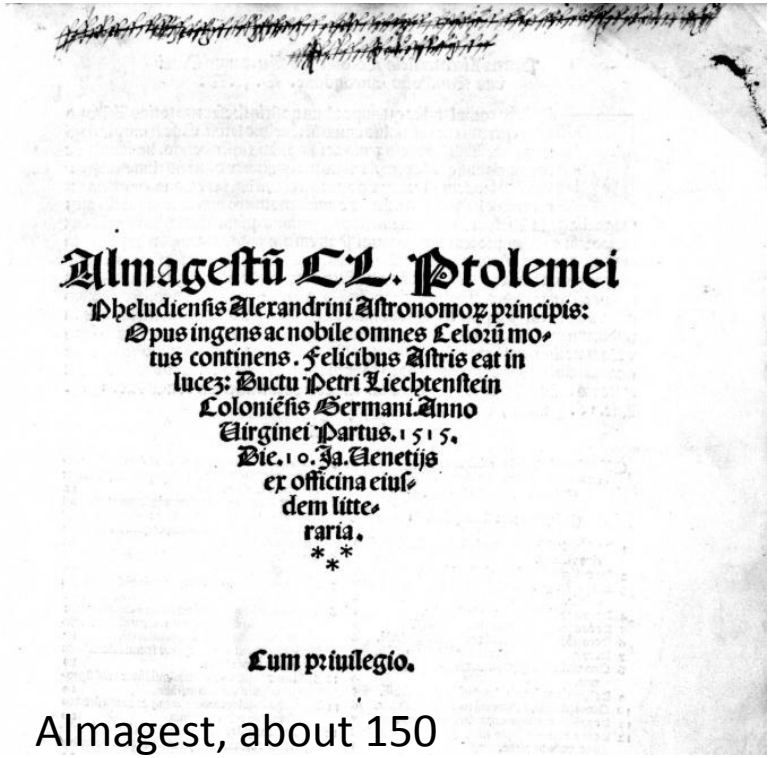
The most comprehensive system was developed by Ptolomy (90-168)

- The universe existed of celestial spheres
- The Sun was at 1210 Earth radii (off by a factor of about 20)
- The outer sphere of the stars was at 20,000 Earth radii (this is actually the distance to the Sun), but is only 0.000015 lightyear about 7 light minutes

However, the motion of the planets in the sky are far from simple….

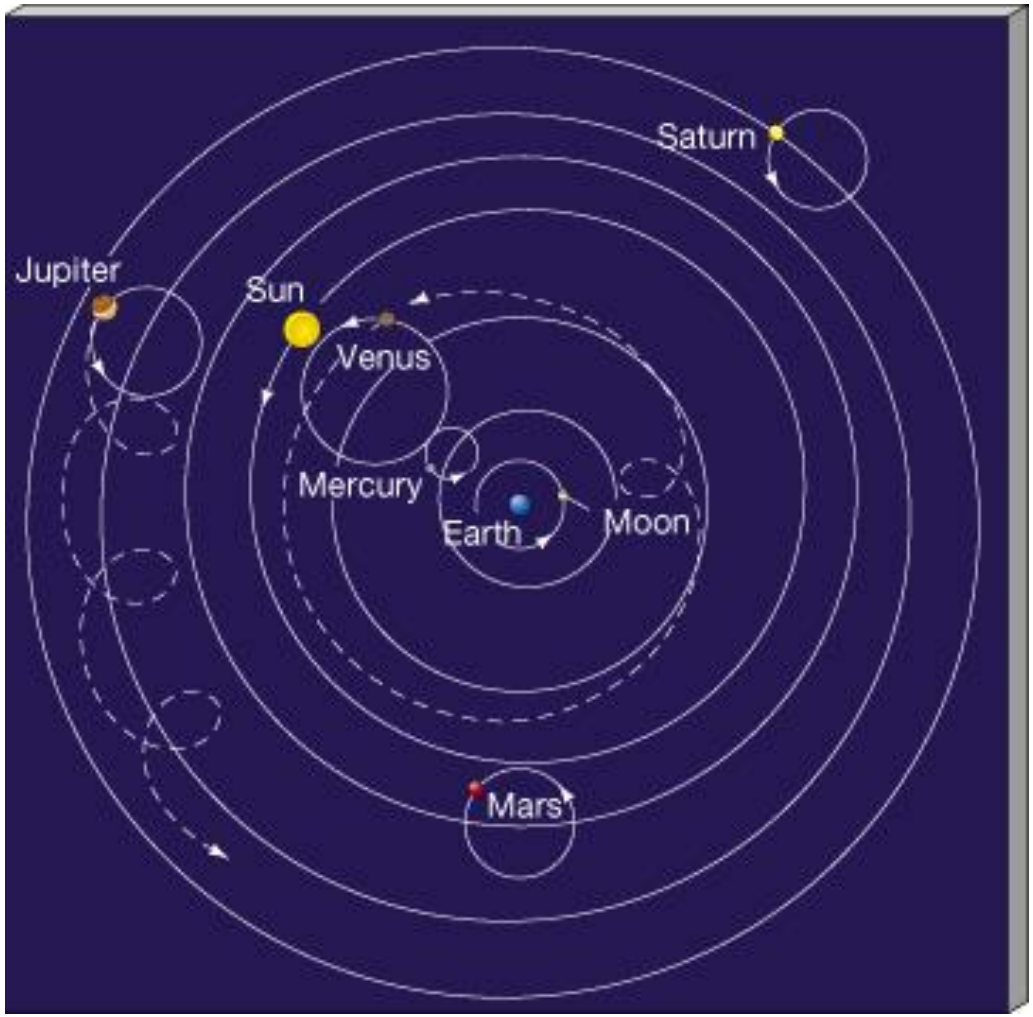


This was explained by Ptolomy using so-called epicircles

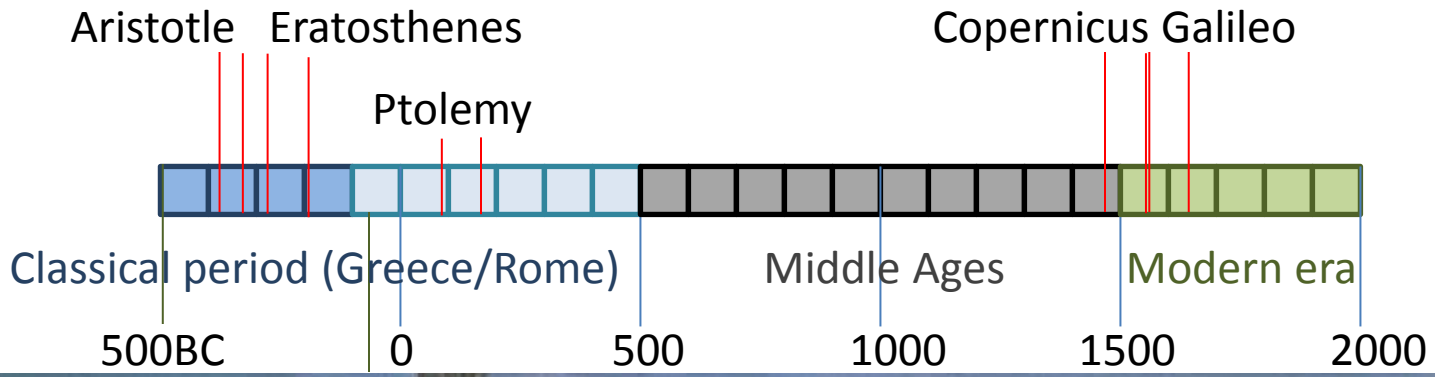


Almagestũ CL. Ptolemei
Pheludiensis Alexandrini Astronomoz principis:
Opus ingens ac nobile omnes Celozũ mo-
tus continens. Felicibus Astris eat in
lucez: Ductu Petri Liechtenstein
Coloniẽsis Germani. Anno
Virginei Partus. 1515.
Die. 10. Ja. Venetijs
ex officina eius-
dem litte-
raria.
* *
Cum priuilegio.

Almagest, about 150



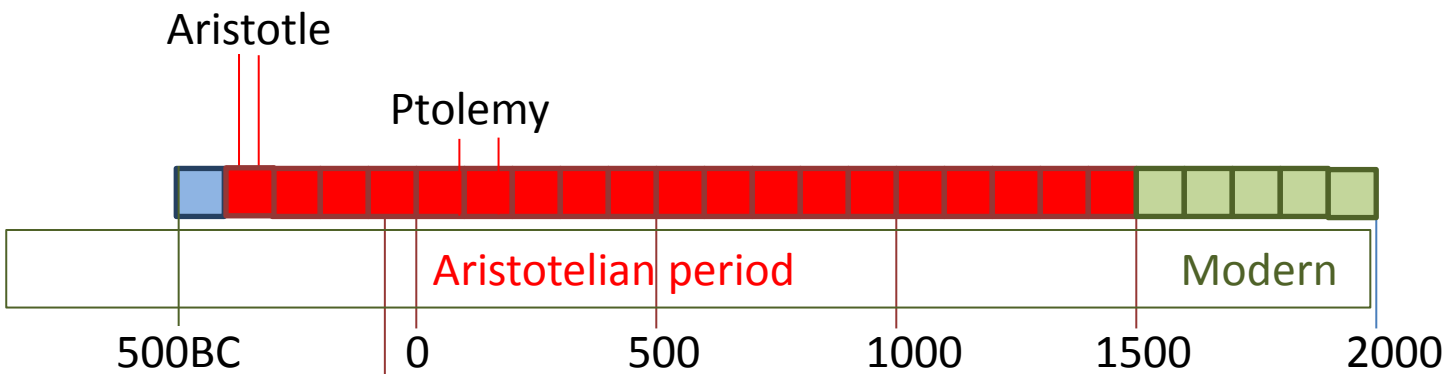
So where are we now in time?



Around the time of Ptolomy, the Roman empire was at its greatest extent

Ptolomy was Greek, like Eratosthenes, but now working in the Roman empire

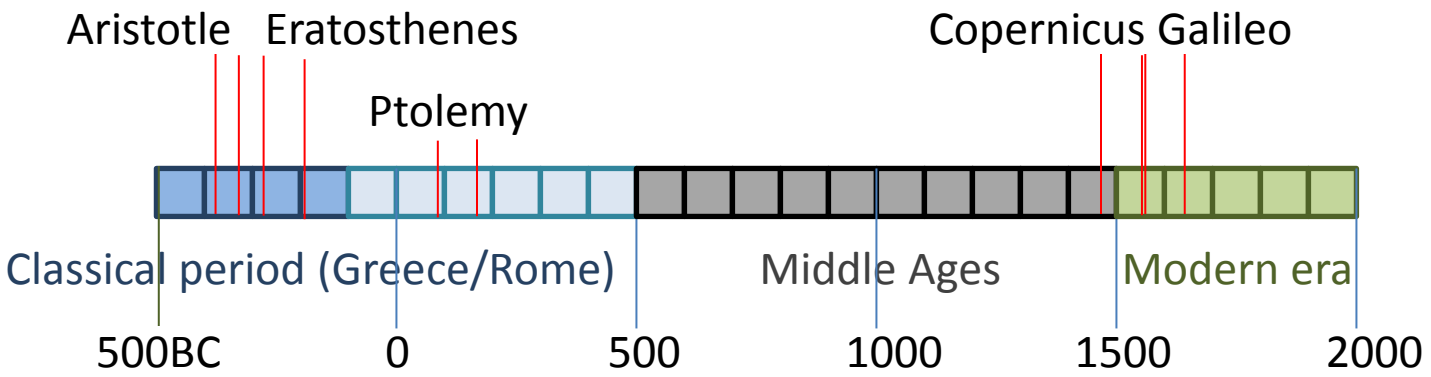
This view again held till about 1450-1600…

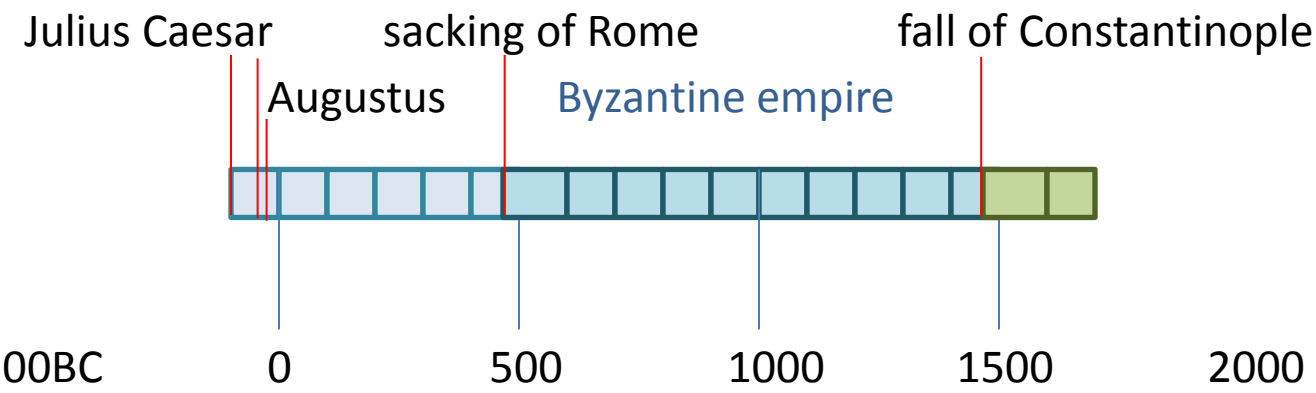


We keep jumping between the ancient Greeks and the renaissance

So nothing really happened in between…?

The Roman Empire

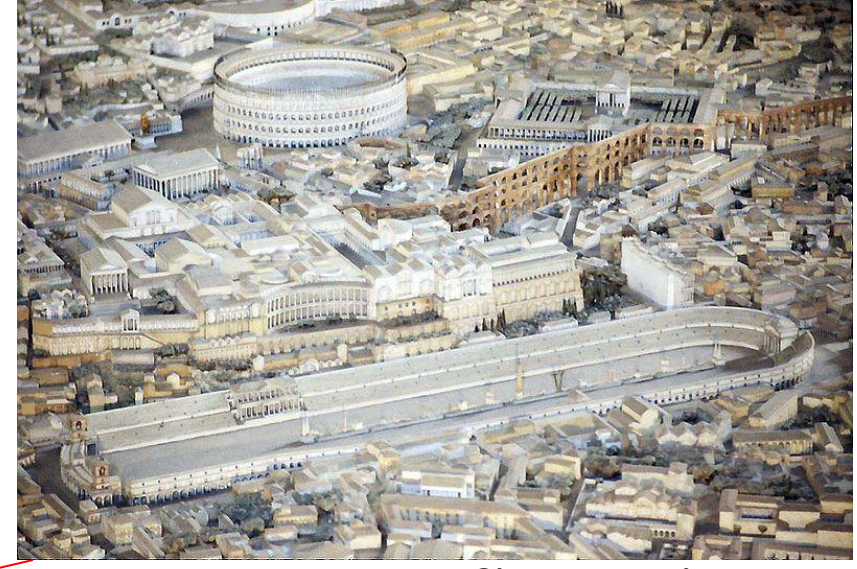




So did nothing of scientific interest happen in Rome?

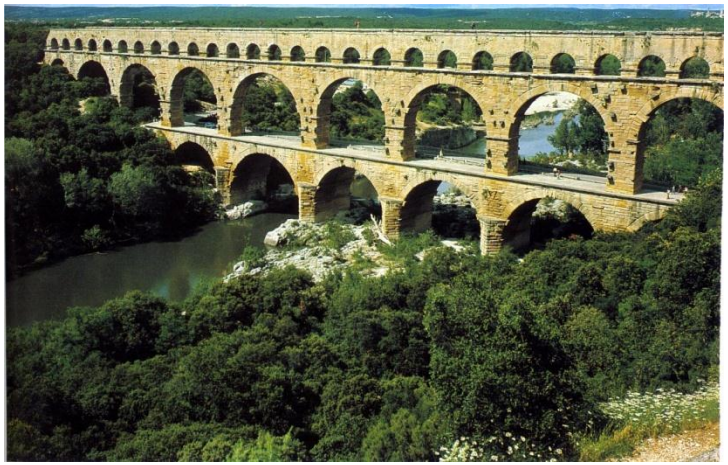
First, the Romans were much more practical than the Greeks

They were magnificent architects



Circus Maximus

Hagia Sophia (Istanbul/Constantinople
6th cent. Mosque from 1453)



aqueducts

Pantheon, Rome 126

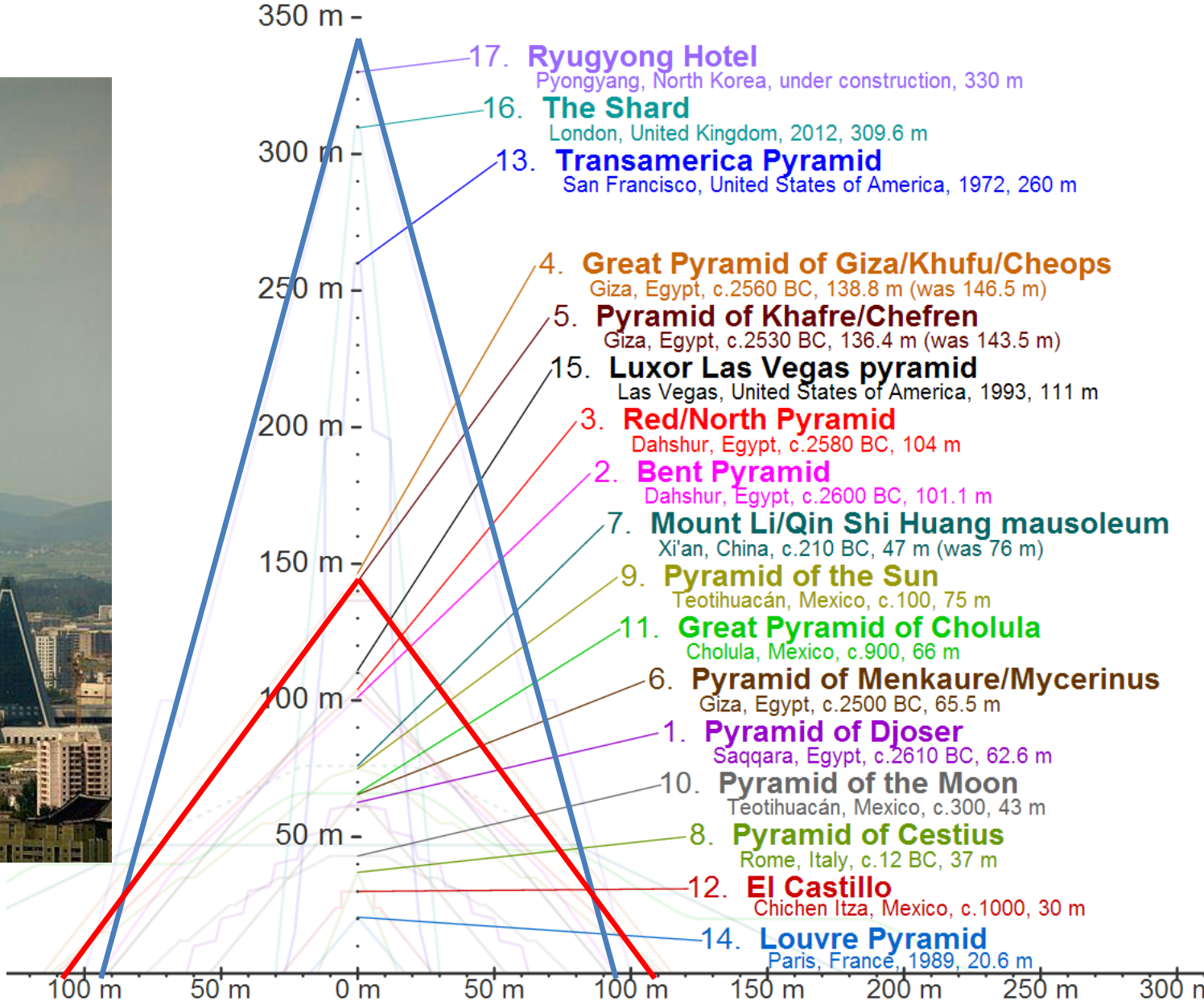
This is truly a great building from antiquity


Although some might say the pyramids are a greater achievement.
Well, they are bigger….

But this is not really fair, since the pantheon was built by Romans

But the pyramids were built by aliens

Now the pyramids in Egypts are not the biggest

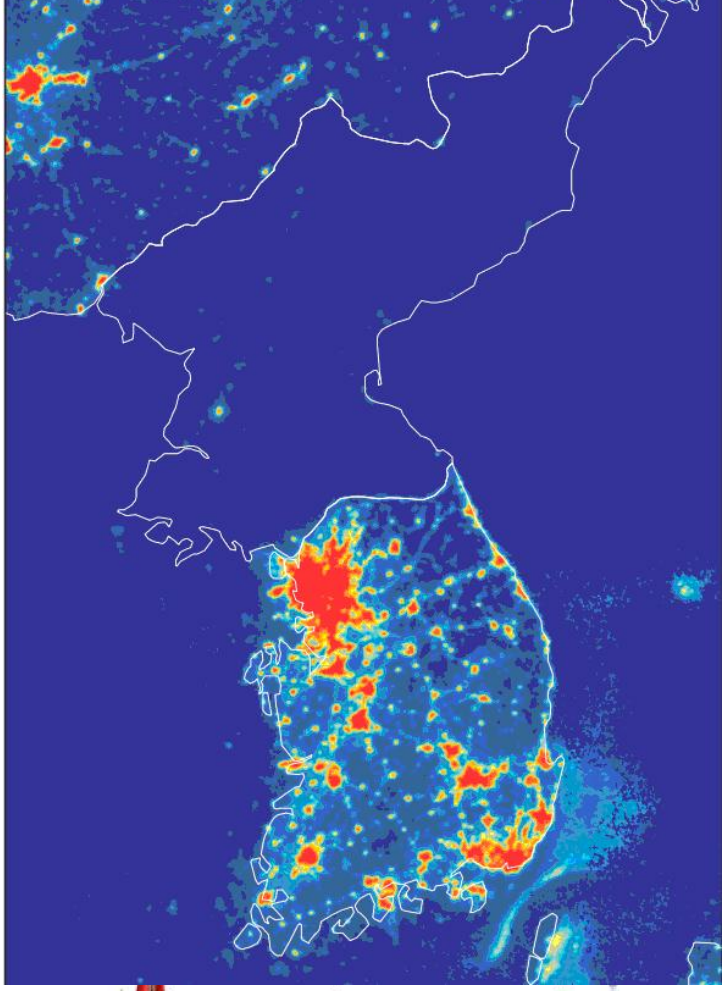


Ryugyong Hotel,
Pyongyang, North Korea

The New York Times

Asia Pacific

North Korean Rocket Fails Moments After Liftoff



Can’t launch a rocket, but they can certainly build pyramids!

So a civilization possessing interstellar space travel comes to Earth…


To stack stones…..?
They're not even buildings, they're mounds….

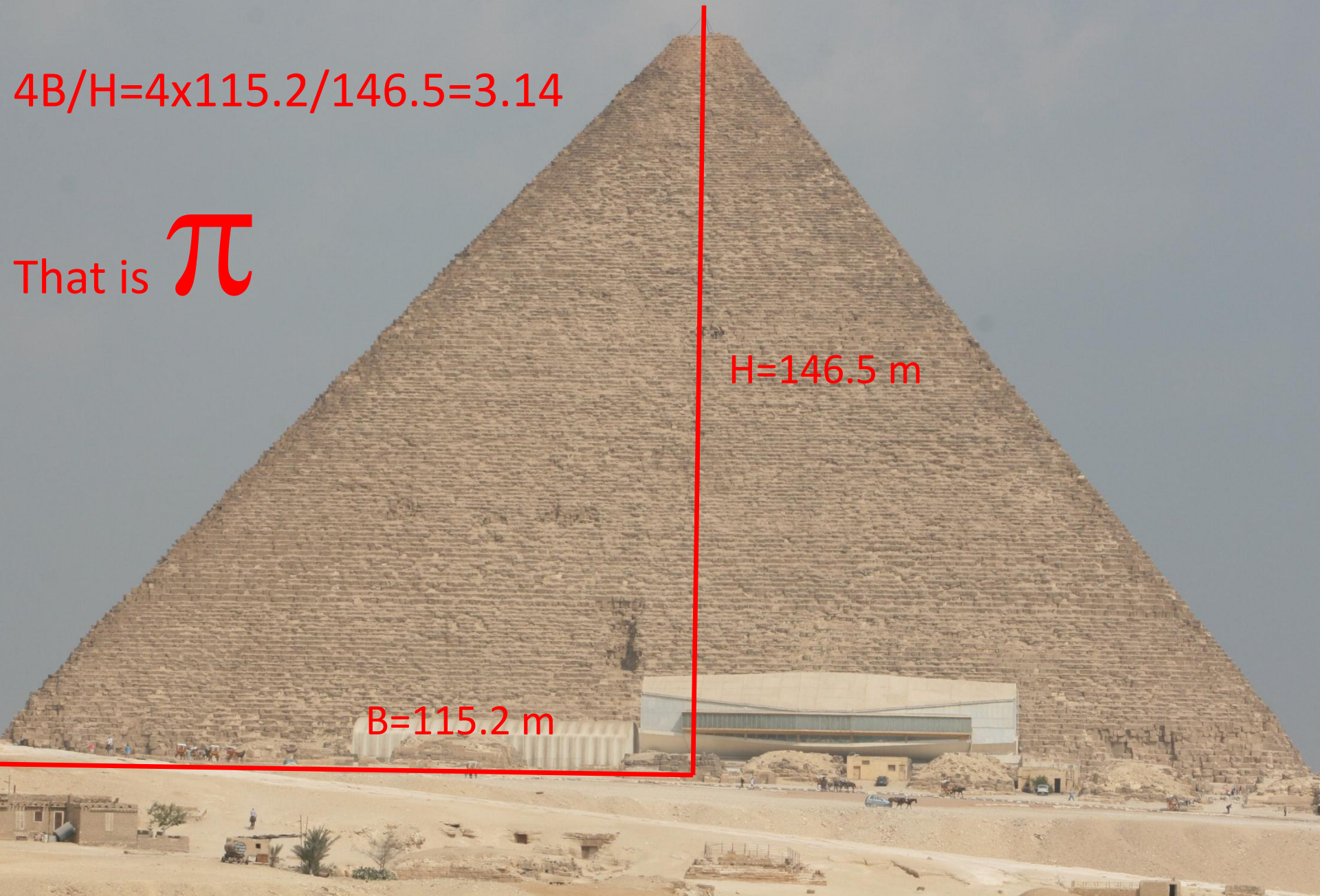
Also they sucked at it first….

Ok, alien proponents would say that these are not built by aliens…
Only the really big ones.

Extra terrestials

North Koreans

However the pyramids have many more mysteries!

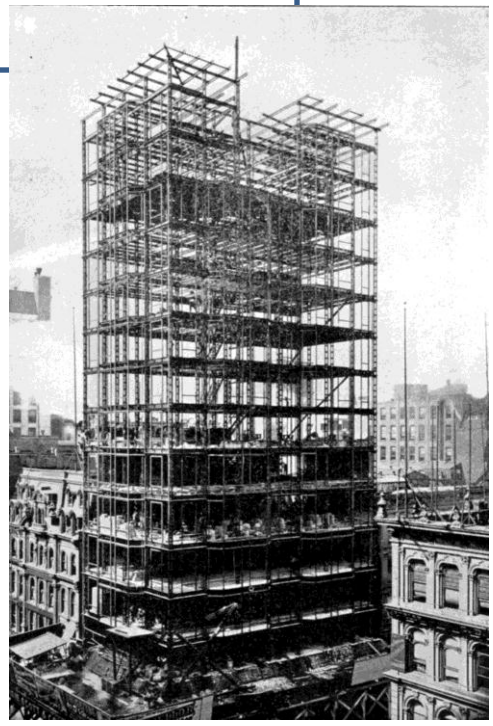


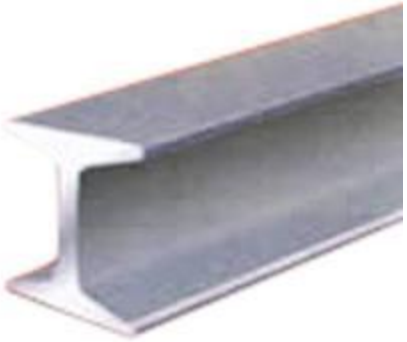
Now, the Egyptians did not know the number π

Also these pyramids are big and impressive, hence aliens!

However, wouldn't this make more sense?

All right Egyptians, here's the deal. You are living in the bronze age. That's cool…Now bronze kind of sucks. Let us show you how to make stainless steel. Then we turn that into nice beams that you can use to make steel frames. Then you can construct awesome buildings, and then you can make…





A pyramid that might actually be useful….
(Several thousands of guest rooms, instead of one tomb…)

And when you're ready
we'll give you kryptonite

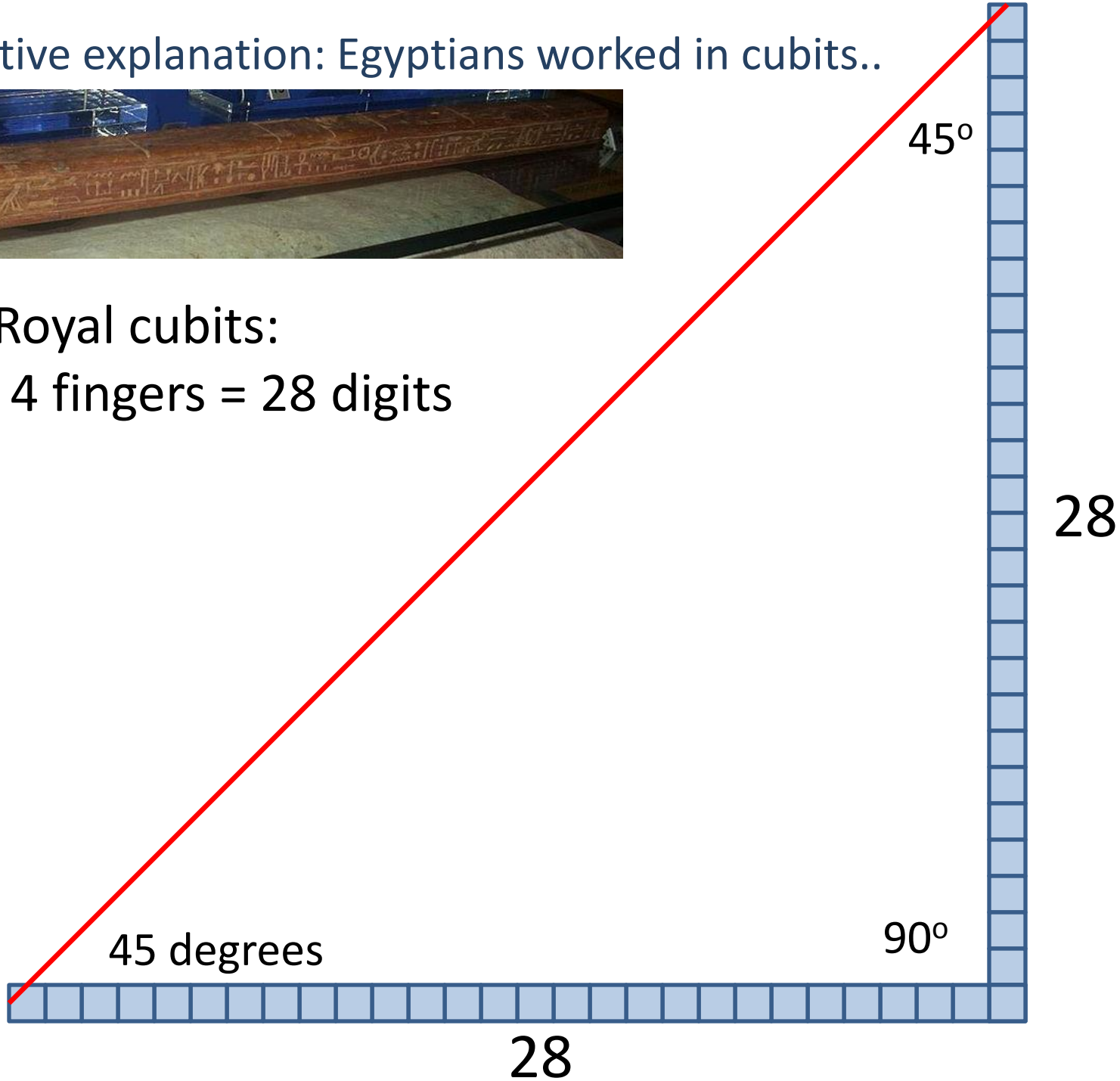
Sure, but what about

π?

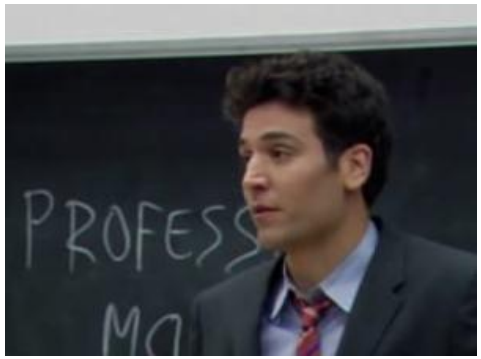
Alternative explanation: Egyptians worked in cubits..

Egyptian Royal cubits:

7 palms x 4 fingers = 28 digits

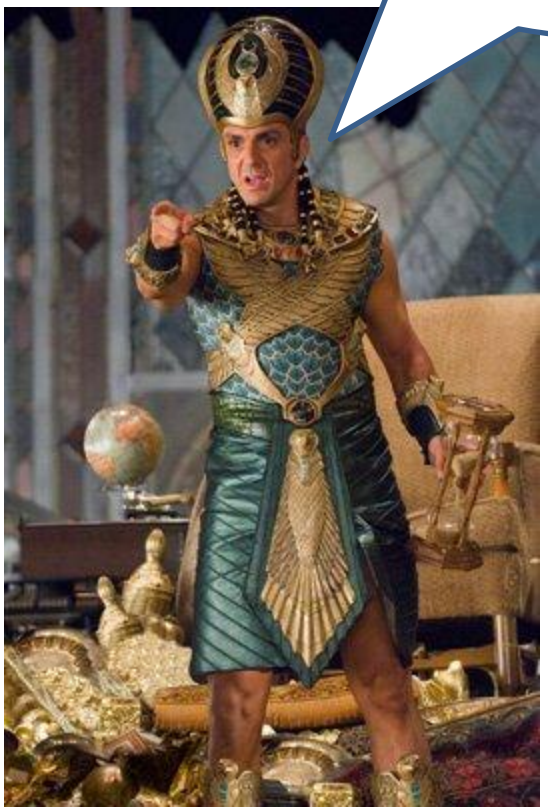


Now some Egyptian architects Moses van der Rohe or Ted Mosesby
(Moses being an Egyptian name…)



NO! NO! NO!
45 degrees is for loosers! Give me something steeper

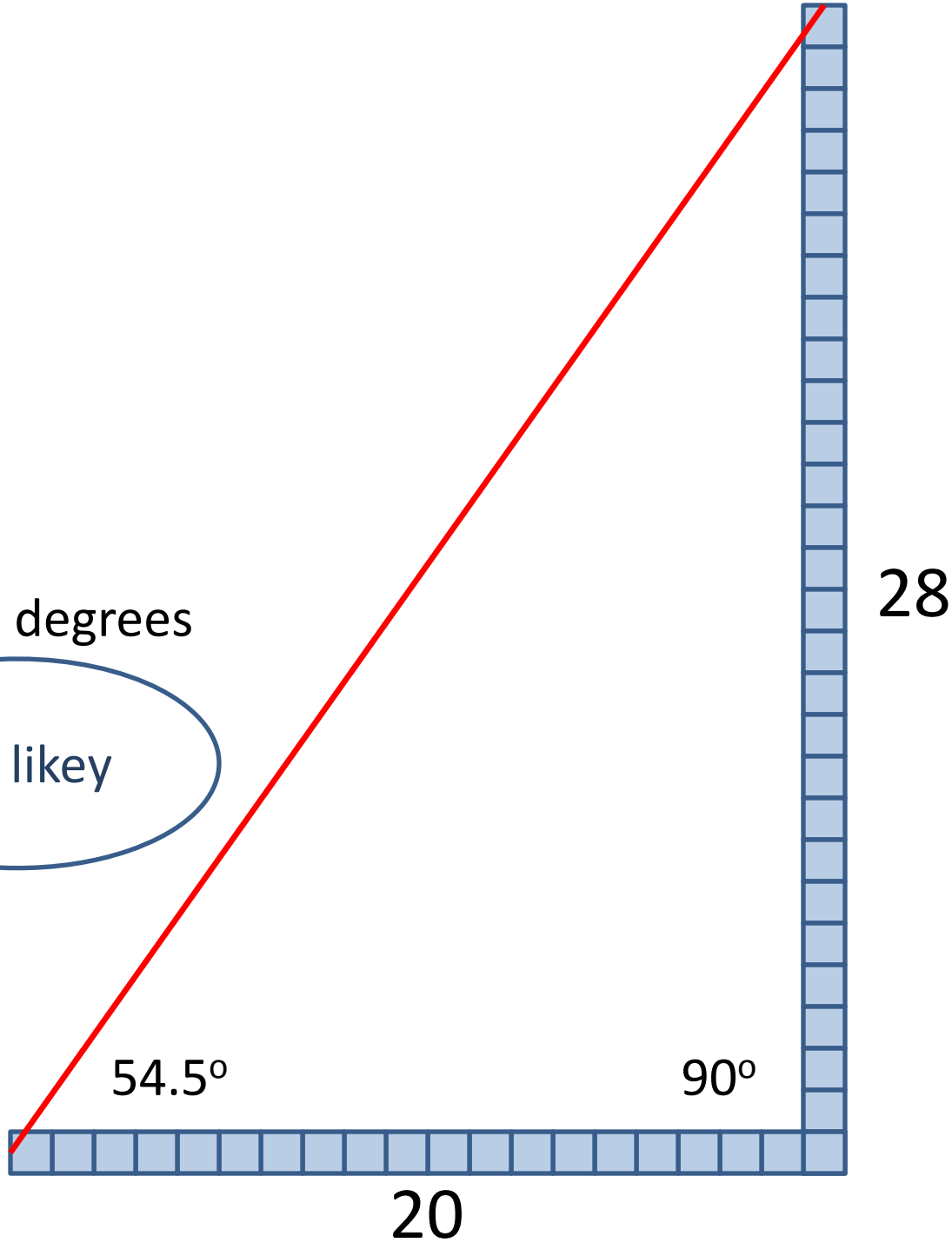
Suggest some nice little pyramid



Statue approximation of Sneferu

20?

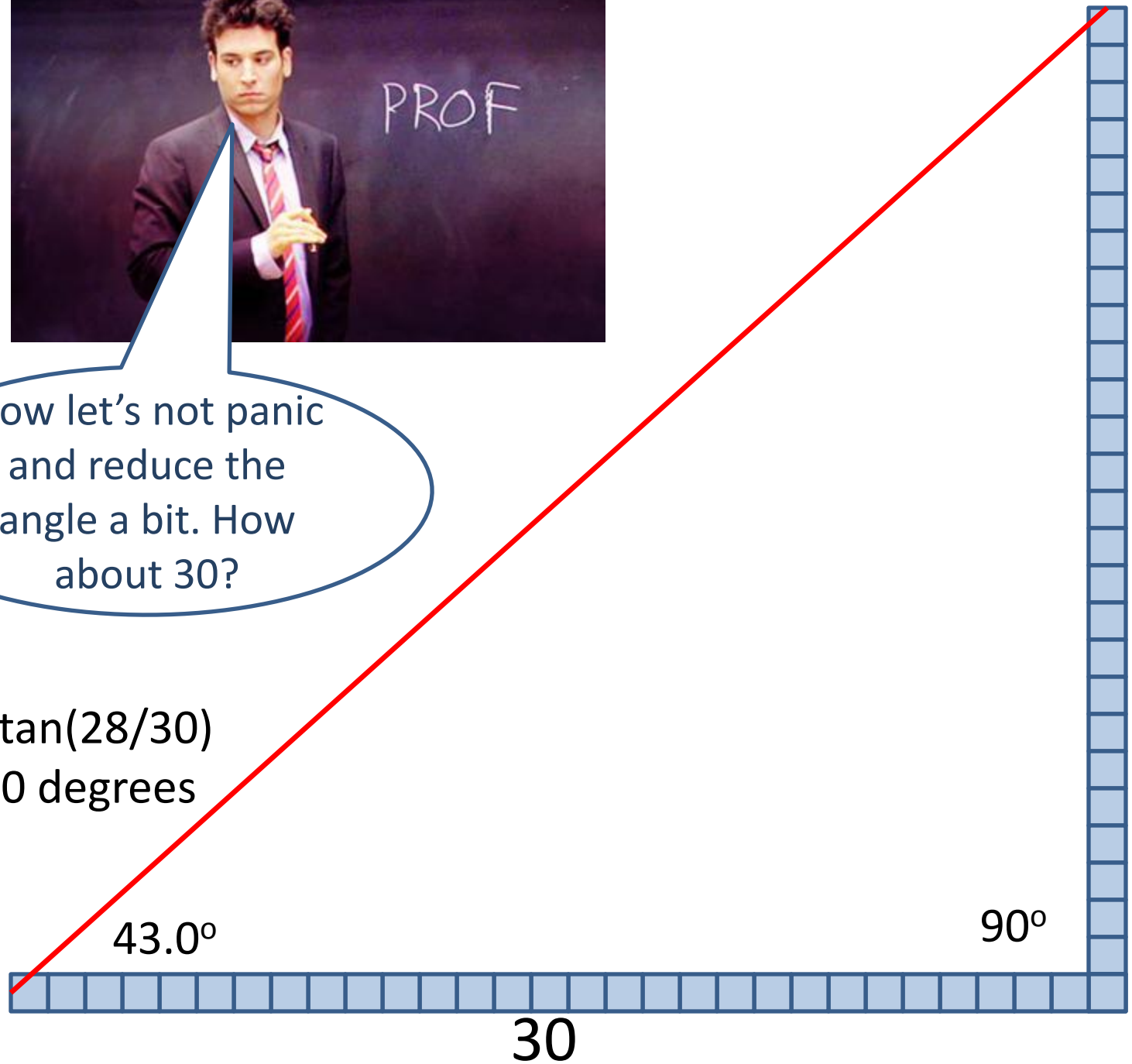
angle=arctan(28/20)=54.5 degrees



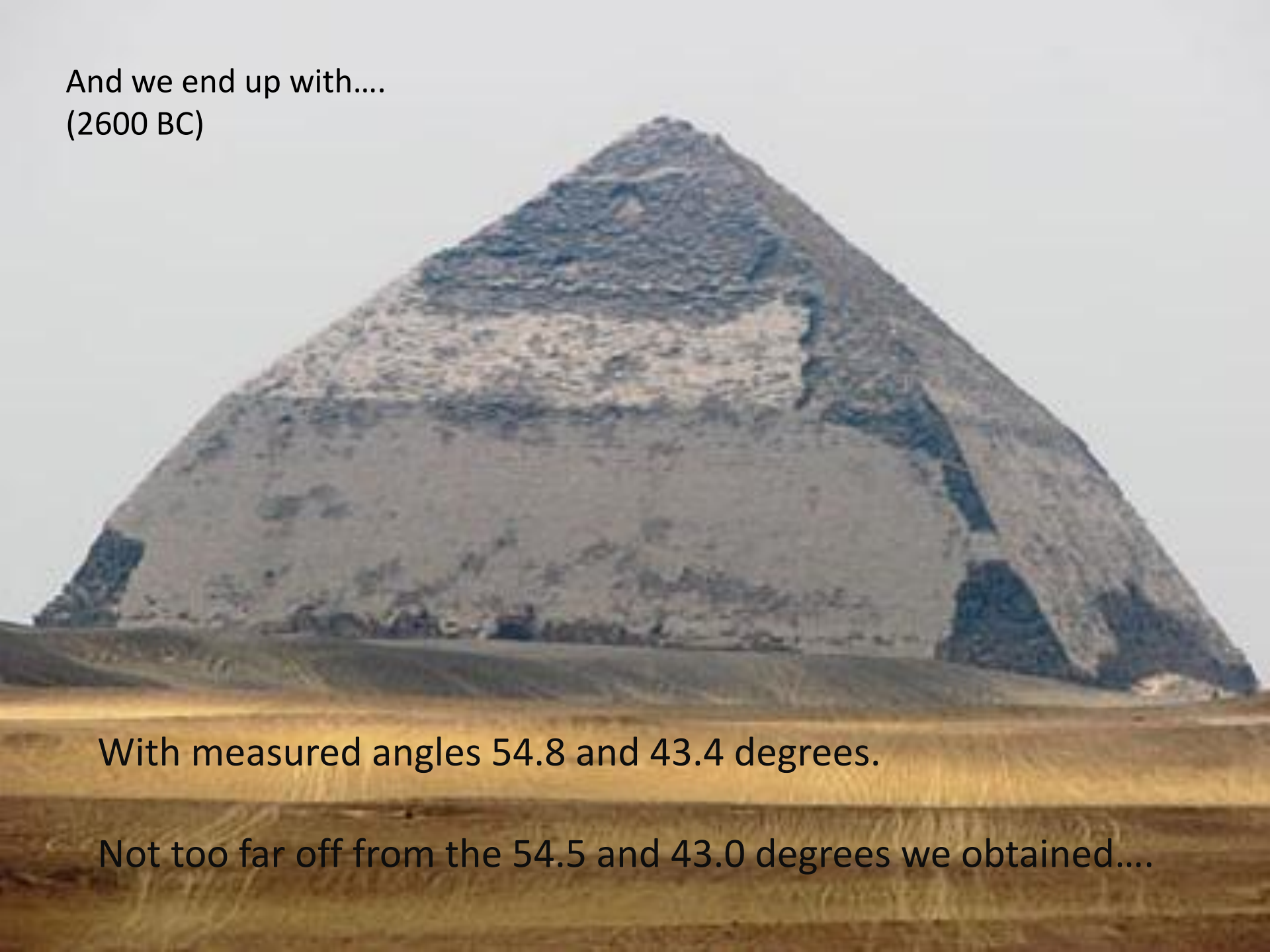
We have a problem! The pyramid is succumbing under its own weight!!

Now let's not panic and reduce the angle a bit. How about 30?

angle=arctan(28/30)
=43.0 degrees



And we end up with….
(2600 BC)



With measured angles 54.8 and 43.4 degrees.

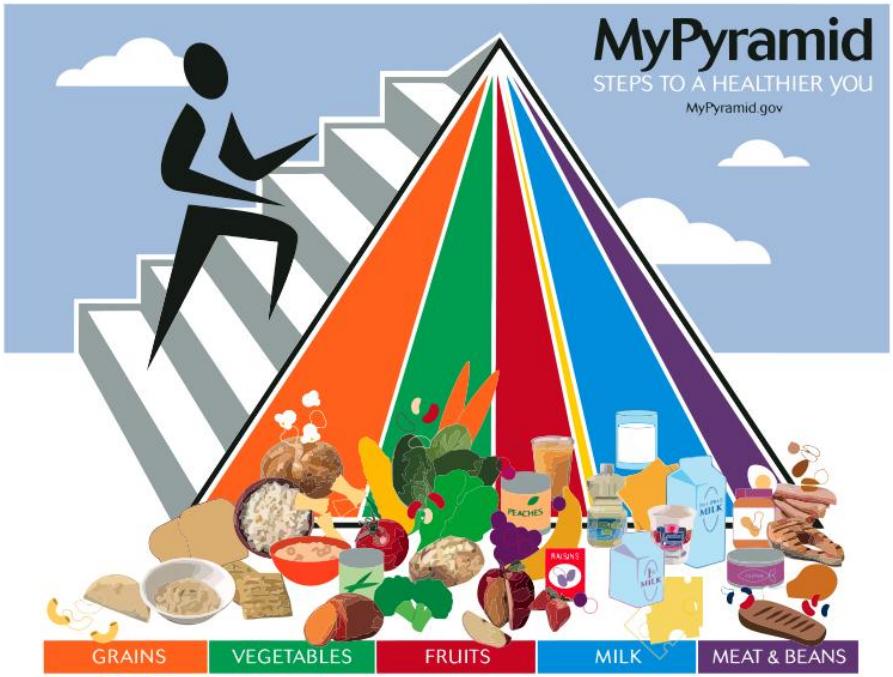
Not too far off from the 54.5 and 43.0 degrees we obtained….

One generation later:

Make me a pyramid and none of that bent crap that you did to my father!!

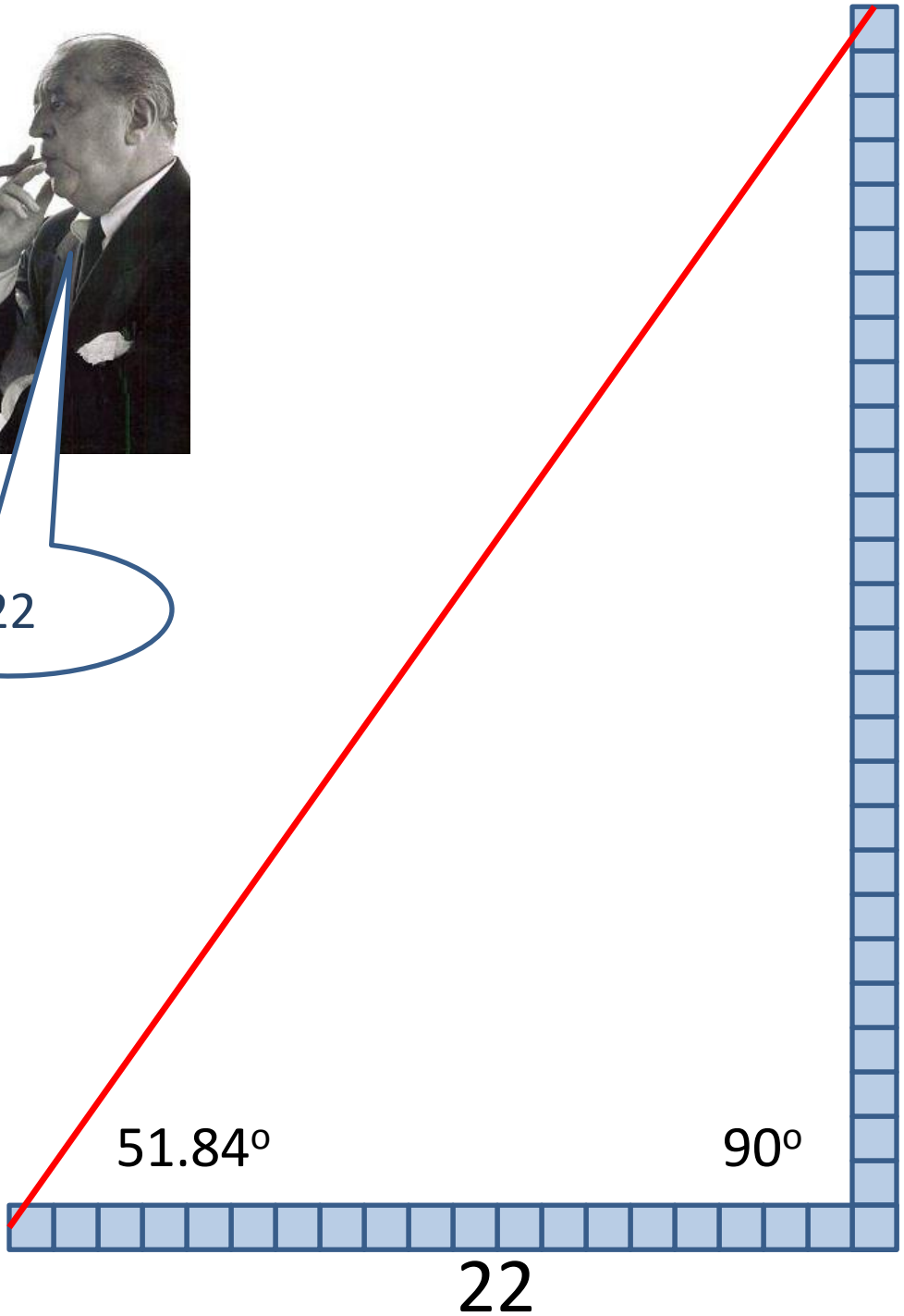
Great family resemblance

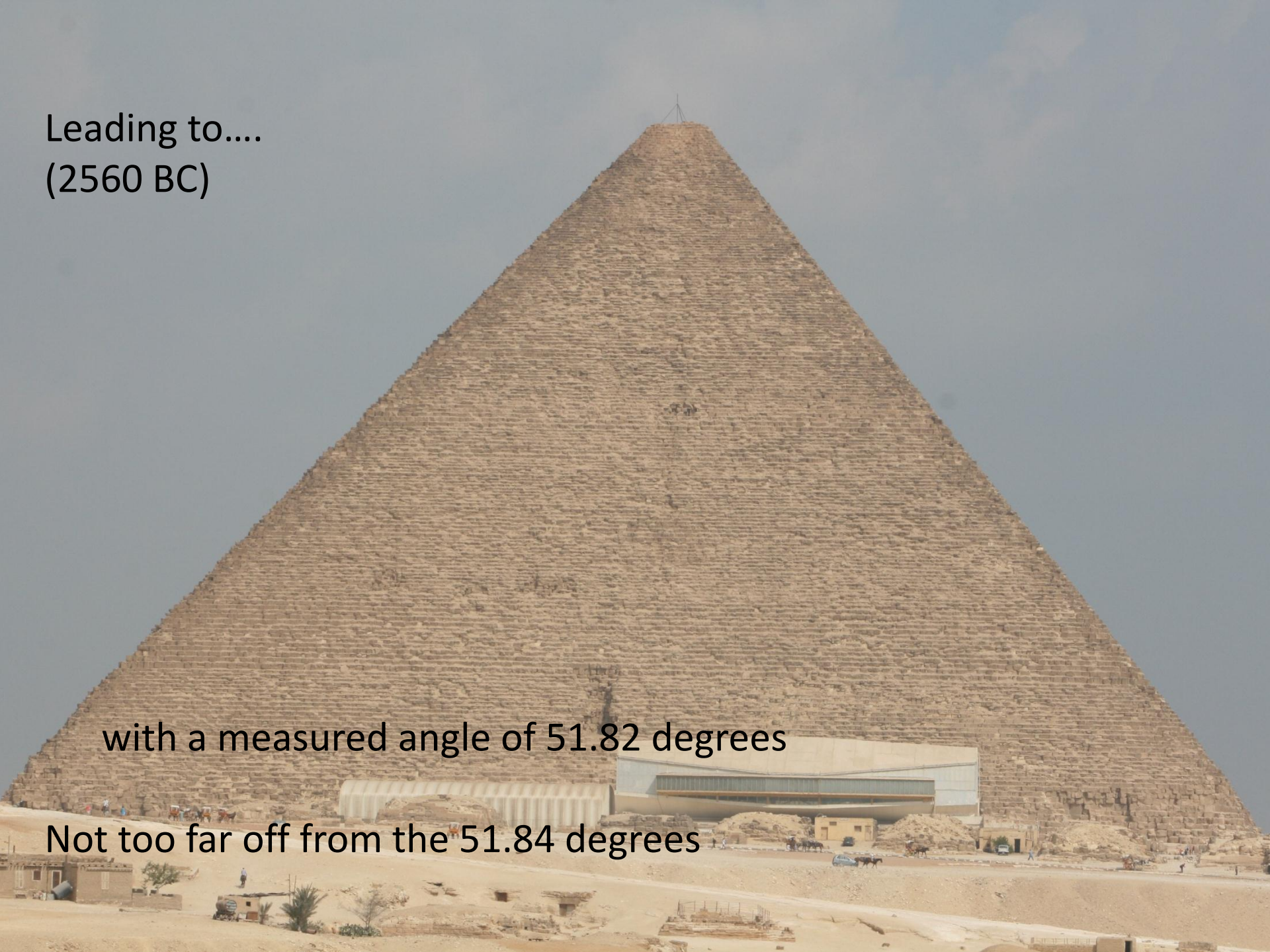
Khufu/Cheops approximation



Last time they tried 20 and that did not go very well

22





Leading to….
(2560 BC)

with a measured angle of 51.82 degrees

Not too far off from the 51.84 degrees

One generation later….

Make me a pyramid and it has to be steeper than my dad's!!

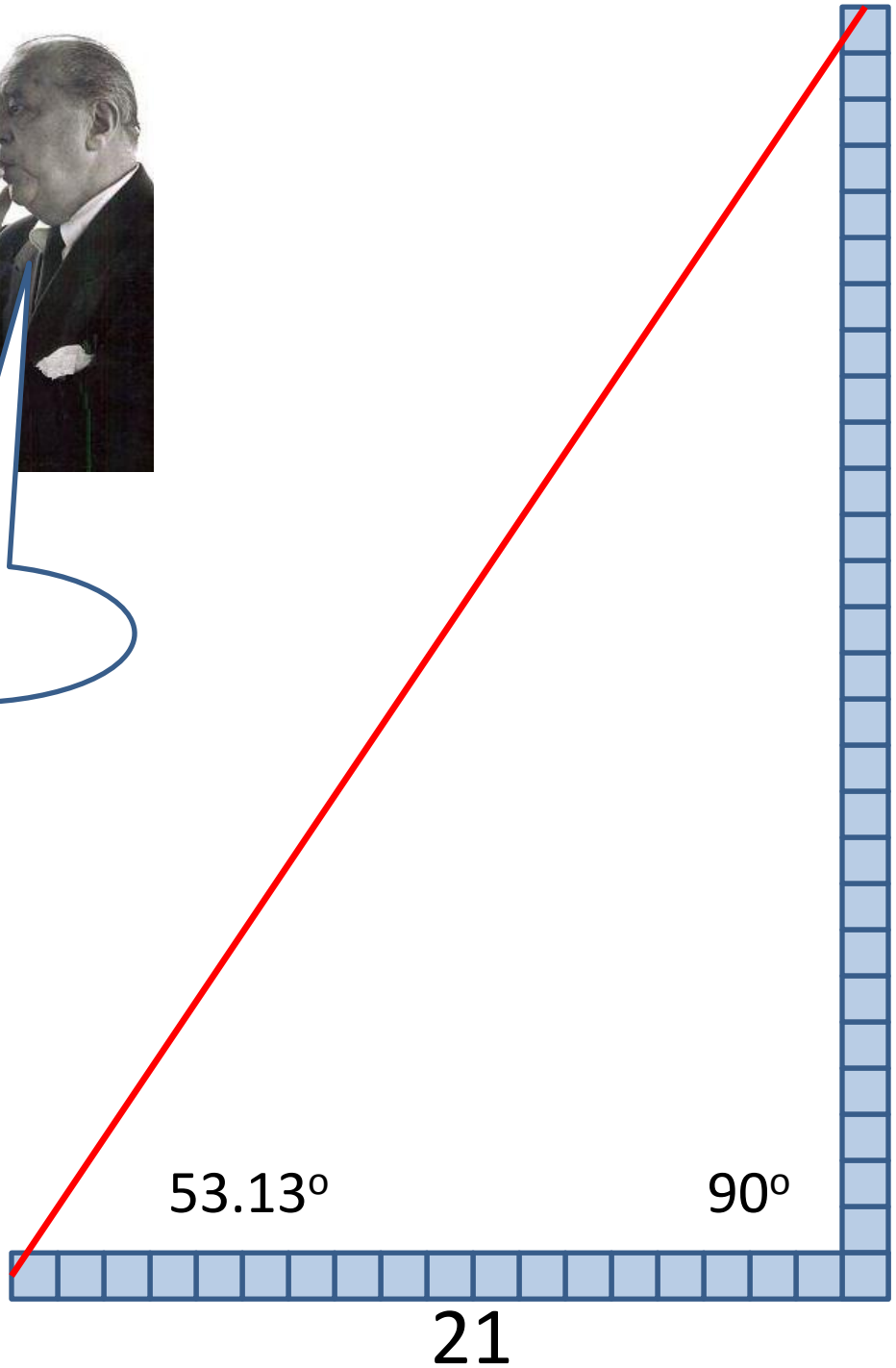
Inbreeding…?

Daddy issues…?
You want to talk about it?

Khafra/Chephren
Approximate image

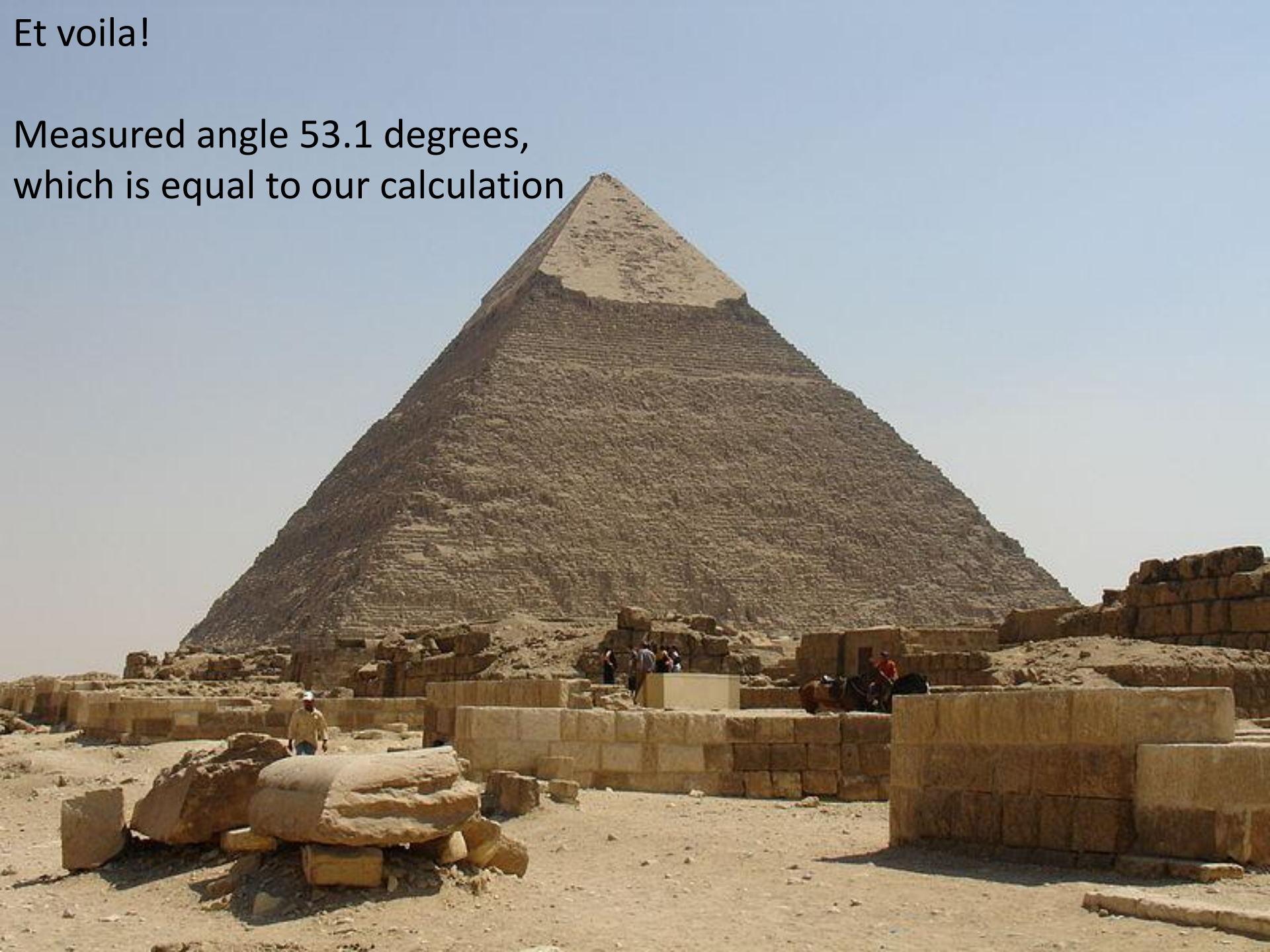
We managed 22, but I still have a bad feeling about 20

21



Et voila!

Measured angle 53.1 degrees,
which is equal to our calculation



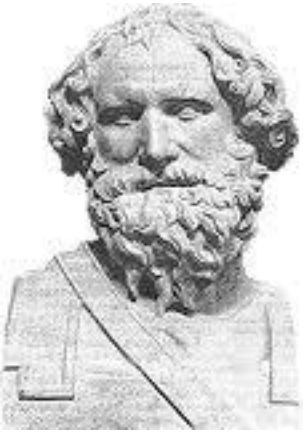
Now what about π?

4 B/H=4 x 22/28=22/7 $\approx$ 3.1428

Which is not too far off from
$\pi \approx$ 3.1415
But this is a coincidence

Although 22/7 is also the upper bound for
π found by Archimedes (287-212 BC)

But maybe…



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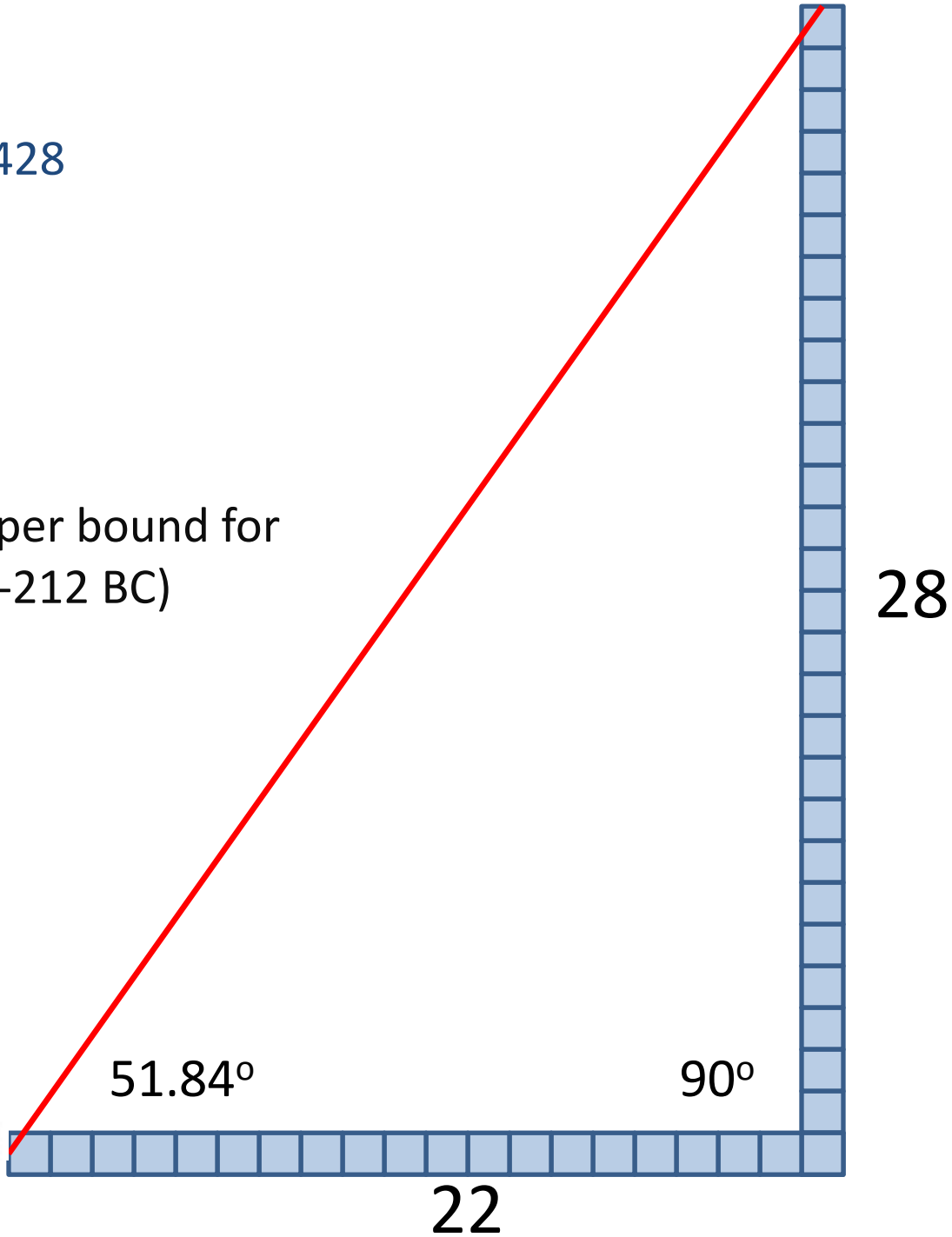
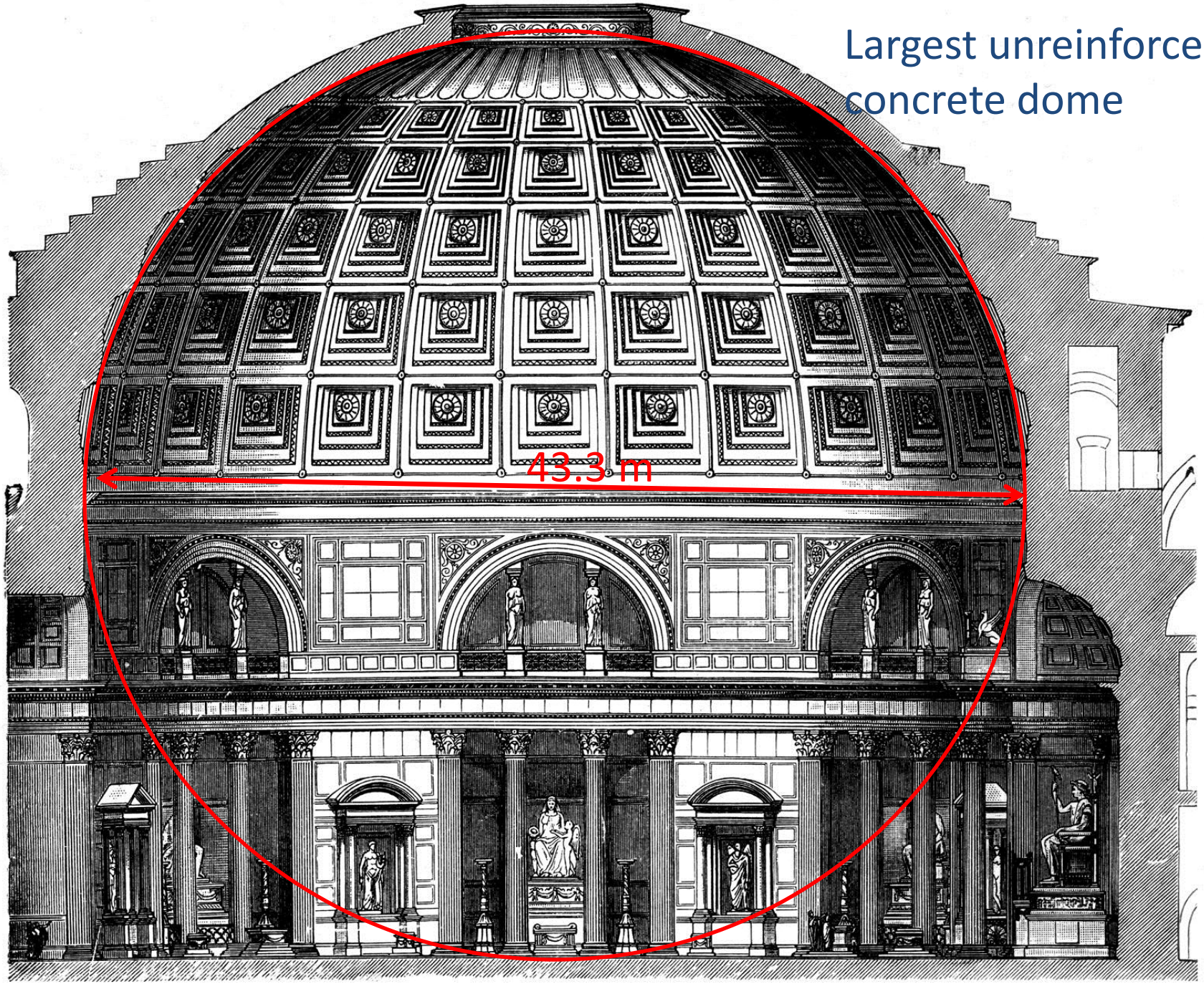


The moral of the story:

- Do not get fooled by coincidences
- Keep thinking
- Failing to understand something is never a proof of something else!

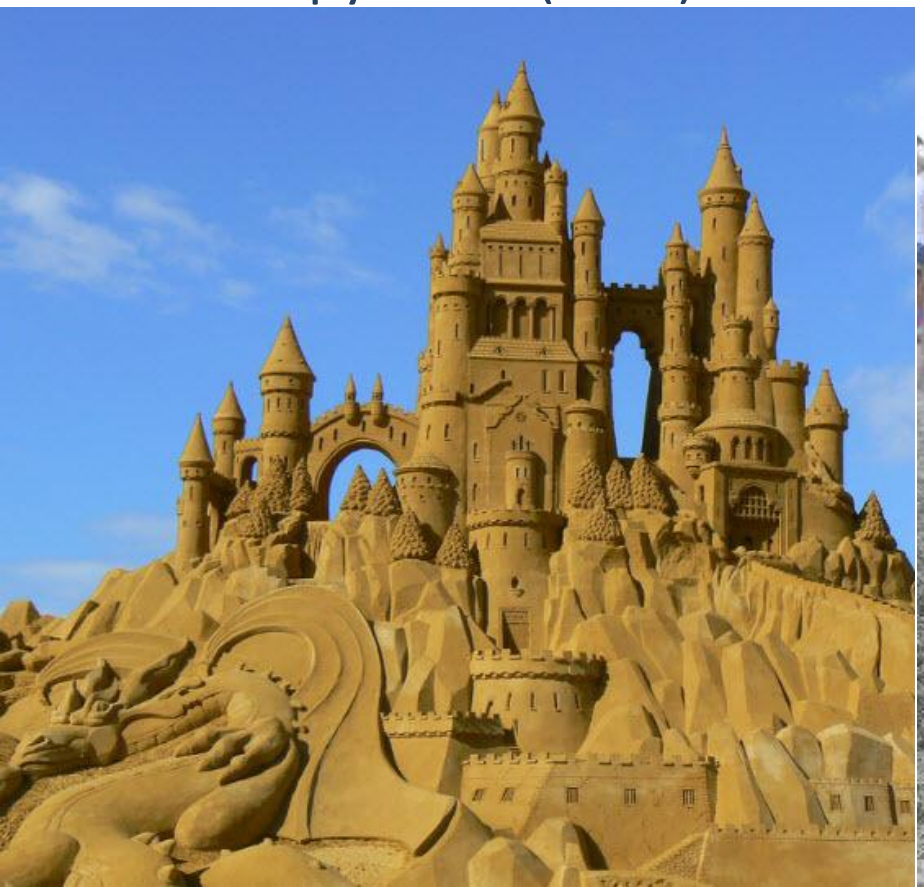
(just because you don't understand 3.14 does not proof the existence of aliens)

And yes those pyramids are impressive….



The Romans must have known π

Try to build that in sand and you see the difference in complexity between a pyramid (solid) and a real building (hollow)



Look at the inner spaces

Great passage pyramid of Gizeh

Pantheon

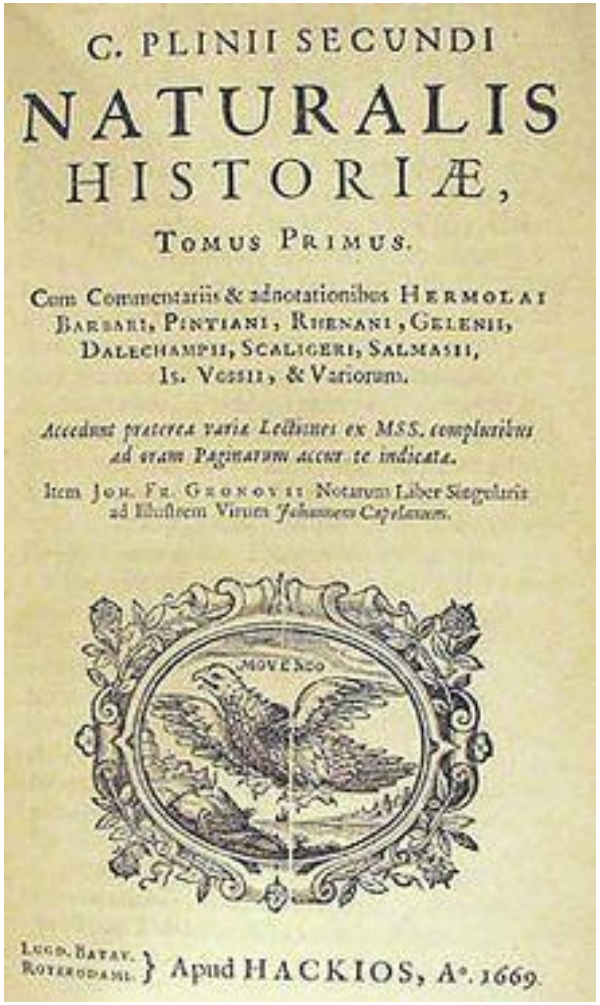
And yes: concrete

Lost in 400 AD after the fall of the Roman empire

Only to be reinvented in the early 19th century

What else happened in science?

Well, not too much… Pliny the Elder (23-79) wrote a book on just about everything

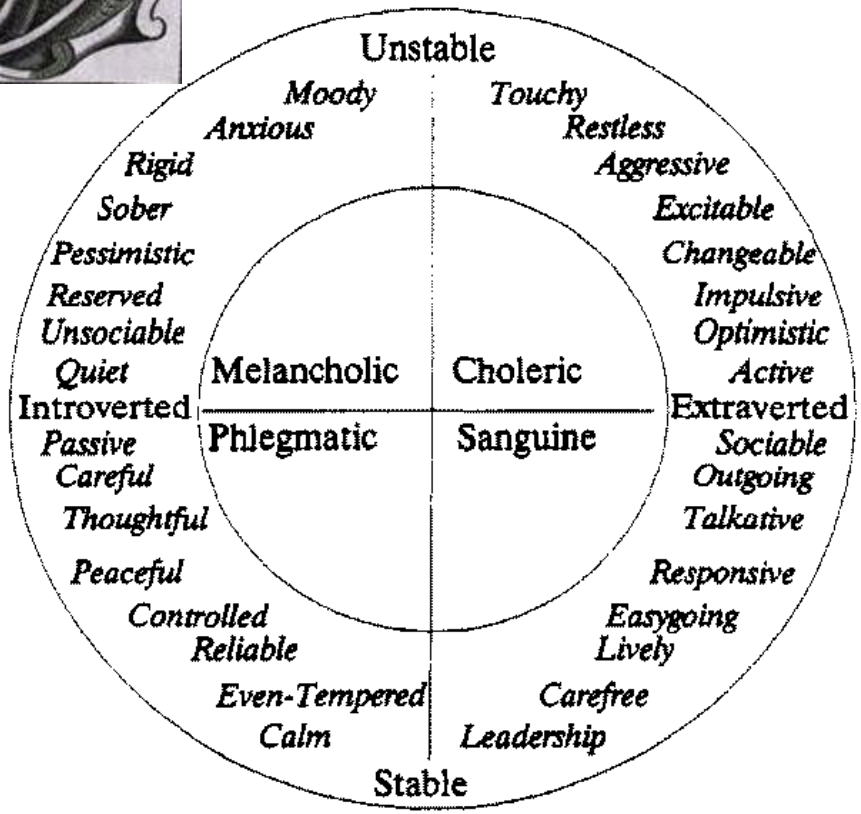

C. PLINII SECUNDI
NATURALIS HISTORIÆ,
TOMUS PRIMUS.
Cum Commentariis & adnotationibus HERMOLAI BARBARI, PINTIANI, RHENANI, GELENII, DALECHAMPII, SCALIGERI, SALMASII, IS. VOSSII, & Variorum.
Accedunt praterea varia Lectiones ex MSS. compluribus ad oram Paginarum accurate indicata.
Item JOH. FR. GRONOVII Notarum Liber Singularis ad Illustrem Virum *Johannem Capelanum.*
MOVENDO
LUGD. BATAV. ROTERODAMI. } Apud HACKIOS, A°. 1669.

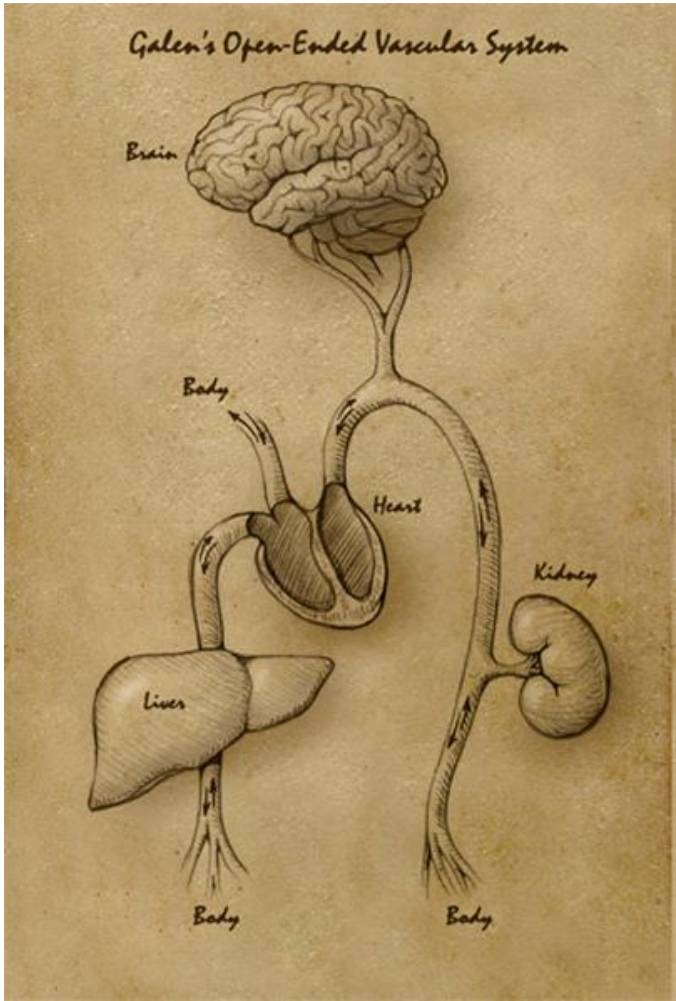
Medicine

Galen (129-200) Roman, but of Greek descent (again…)

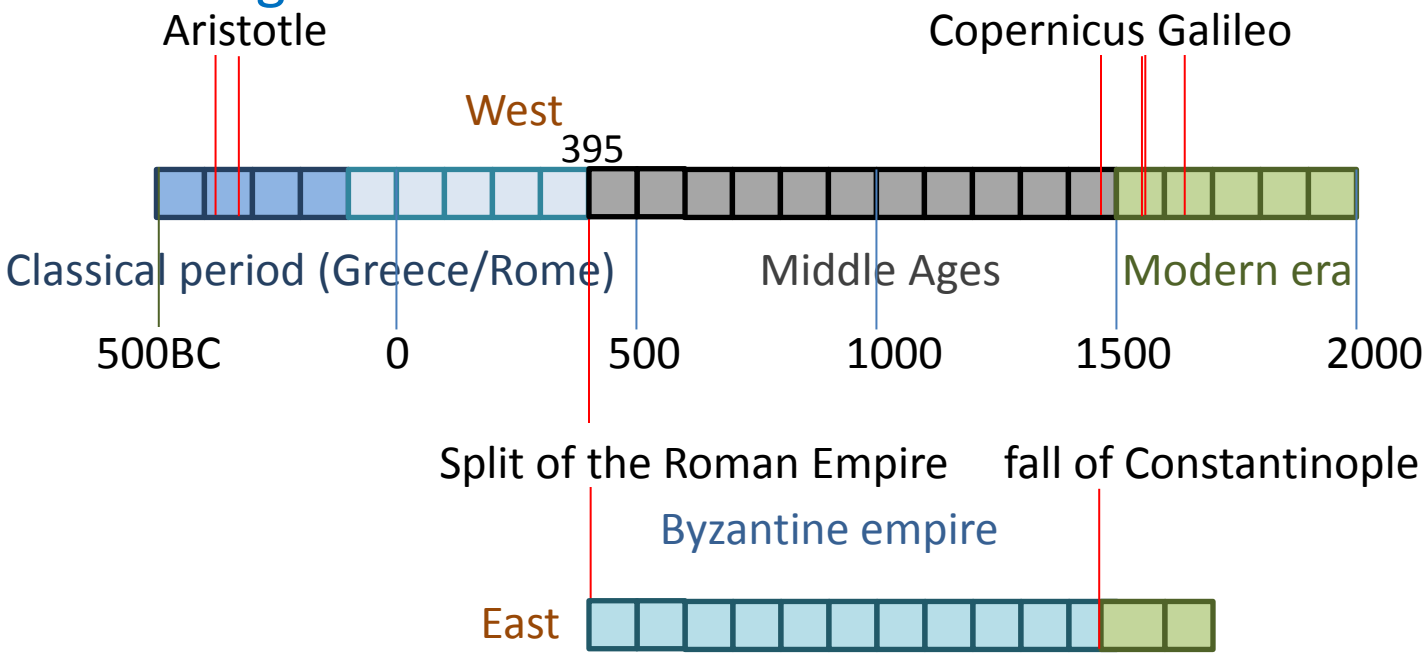
Tried to understand the human body in terms of temperament

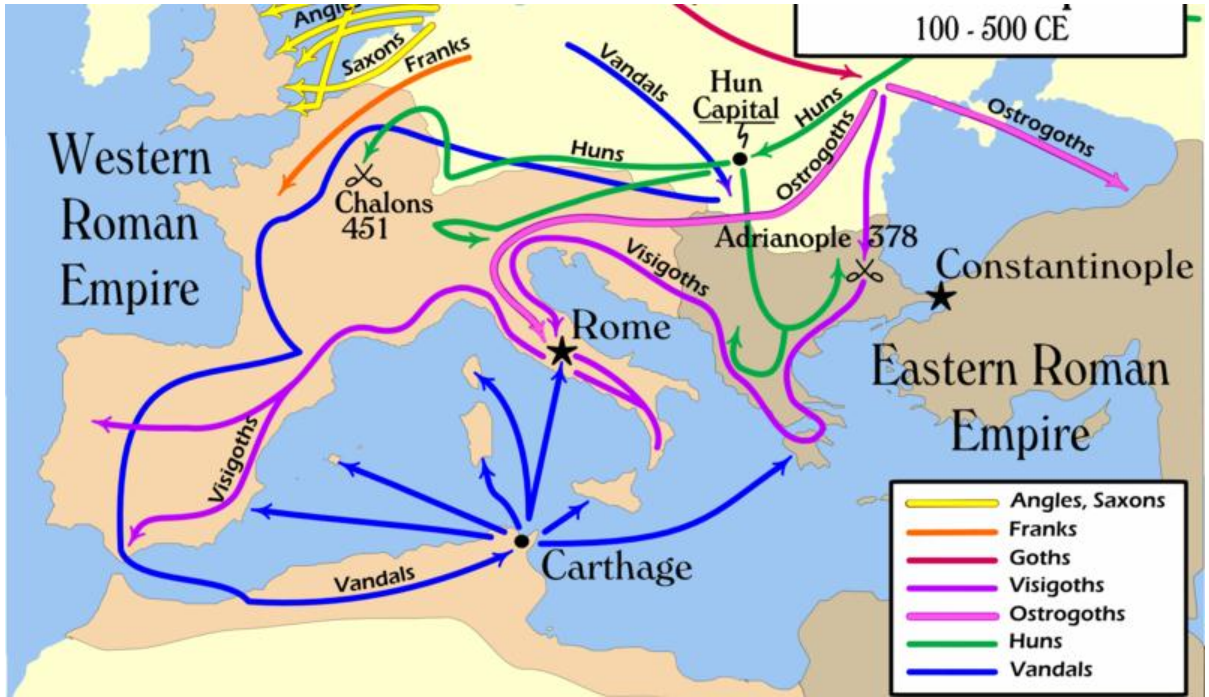
Recognized the difference between arteries and veins
(slightly wrong interpretation….)





The middle ages





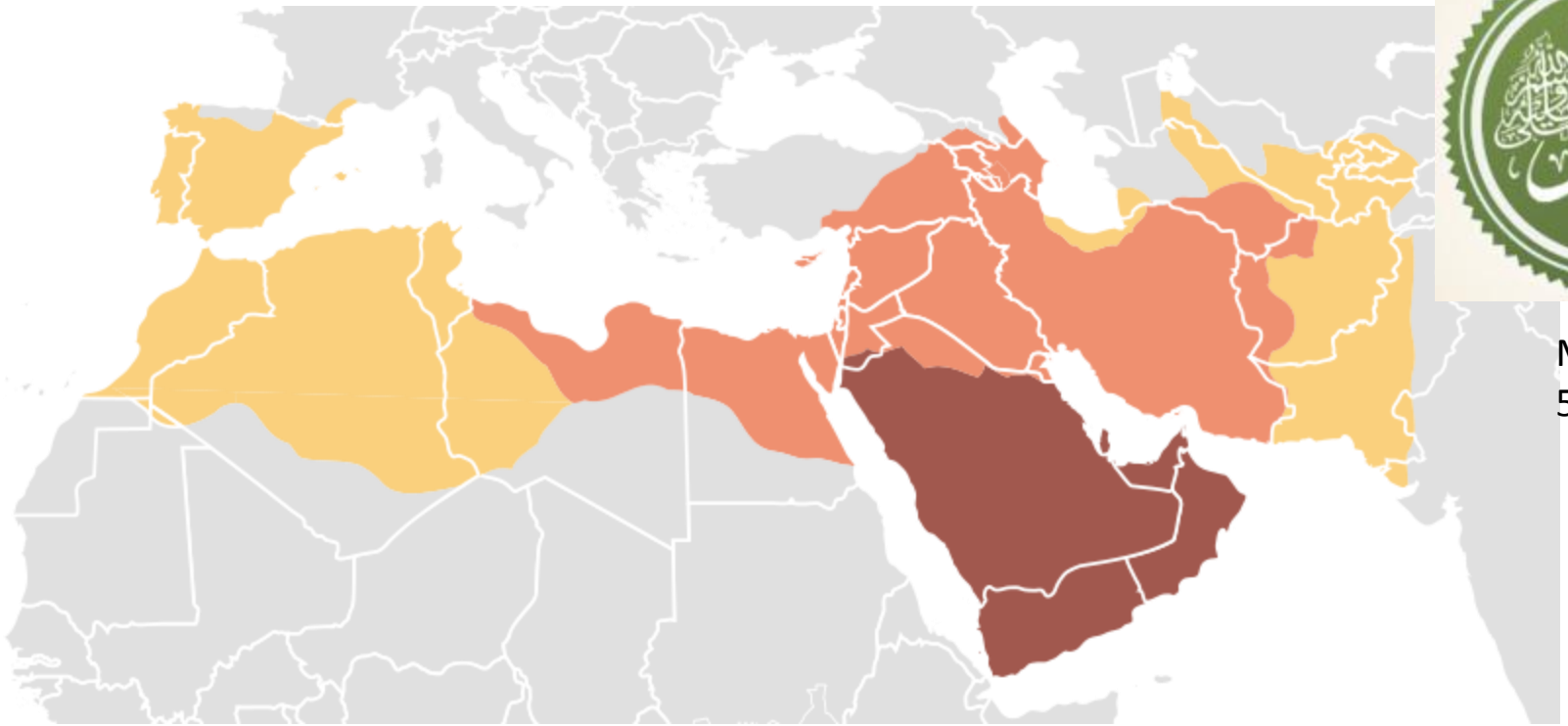
Byzantine empire

Justinian II

Transmitted classical knowledge to Islamic world and renaissance Italy

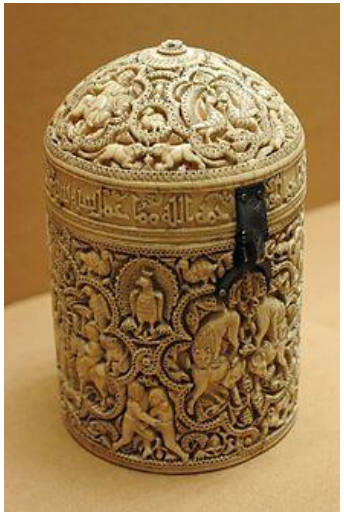
Hagia Sophia (holy wisdom)
530

Rise of the Arab world



Mohammed
570-632

Dome on the Rock, Jerusalem, 690



970

Alhambra, Granada, Spain 1330-50

Innovations coming from the East

Hindu–Arabic numeral system

Roman numerals

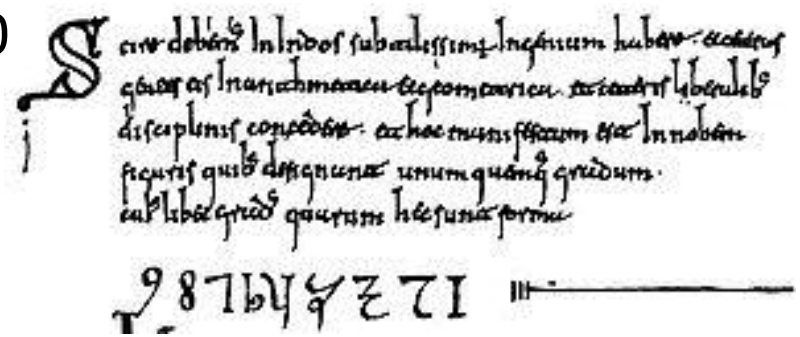
CIII=C+I+I+I=100+1+1+1=103

MCMLIV=M+CM+L+IV=1000+900+50+4=1954

No zero!
Try to add roman numbers
(Why do clocks use IIII instead of IV? …)

Symbol	Value
I	1
V	5
X	10
L	50
C	100
D	500
M	1,000

Arabic numerals moved from India through the Arab world
Appeared in Europe around the year 1000



Irrational numbers π, e, $\sqrt{2}$

Rational number 7/8, 113/435, 90/17

Let's see if we can write the down all the numbers between 0 and 1

1 0.123567443567888999441....
2 0.675433356778889999657....
3 0.644685765323683566786...
4 0.887562727776945445657...
5 0.679497687878975655677....
6 0.253436457688657577888....
7 0.347899879754654575777.....
8 0.234436457587878979789.....
9 ...
. ...
.

Now what if you think you had them all....

But take the numbers in the circles and add one

In that way the number is never equal to any of the numbers in the list

0.28560796....

And you're not done yet, because you can do it again, and again, and...

3. 14159265358979323846264338327950288419716939937510582097494459
2307816406286208998628034825342117067982148086513282306647093844
6095505822317**253594081284811174502841027019385211055**596446
2294895493**038196442881097566593344612847564823378678**31652
7120190914**5648566923460348610454326648213393607260249**14127
3724587**0660631558817488152092096282925409171536436789**2590
360011**3053054882046652138414695194151160943305727036**57595
919530**9218**61173819326**1179**3105118548**7446237**9962749567351885752724**8912**2793818301194**9129**8336733624**4065664**3086021394946395224
73719**07**0217986094370**27705**3921717629**1767523**8467481846766940513
2000**56**8127145263560**8277857**7134275778**9609173**6371787214684409012
2495343014654958537**105079**227968925892**354201**995611212902196086403441815981362977477**13099**605187072113**499999**9837297804995105973173281609631859502**459455**3469083026**4252230**8253344685035261931188171010003137838752**8865**875332083814**2061717**7669147303598253490428755468731159562**8638**82353787593751**957781**857780532171226806613001927876611195909**21642**0198938095**2572010**6548586327886593615338182796823030195203**53018**5296899577**3622594**1389124972177528347913151557485724245**1506**95**9508**29533311**6861727**855889075098381754637464939319255060**4009277**0167113900984**882401**2858361603563707660104710181942955**5961989**46767837449448**2553797**74726847104047534646208046684259069**4912933**13677028989**1521047**52162056966024058038150193511253382**4300355**8764024749647**3263914**199272604269922796782354781636**0934172164**121992458631**5030286182**9745557067**49**838505494588586926995690927210797509302955321165344987202755960236480665499119881834797753566369807426542527862551818417574672890977772793800081647060016145249192173217214772350141441973568548161361157352552133475741849468438523323907394143334547762416862518983569485562099219222184272550254256887671790494601653466804988627232791786085784383827967976681454100953883786360950680064225125205117392984896084128488626945604241965285022210661186306744278622039194945047123713786960956364371917287467 7

and it goes on and on without ever repeating itself….

Astronomy

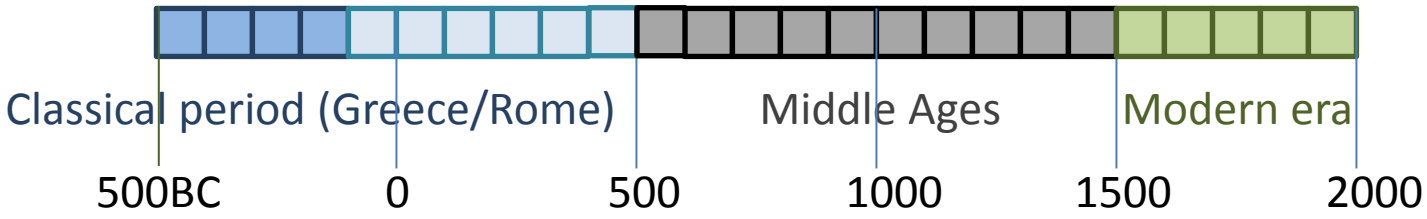
Abū ʿAlī al-Ḥasan ibn al-Ḥasan ibn al-Haytham أبو علي، الحسن بن الحسن بن الهيثم,
Alhacen or Alhazen) (965 -1040)

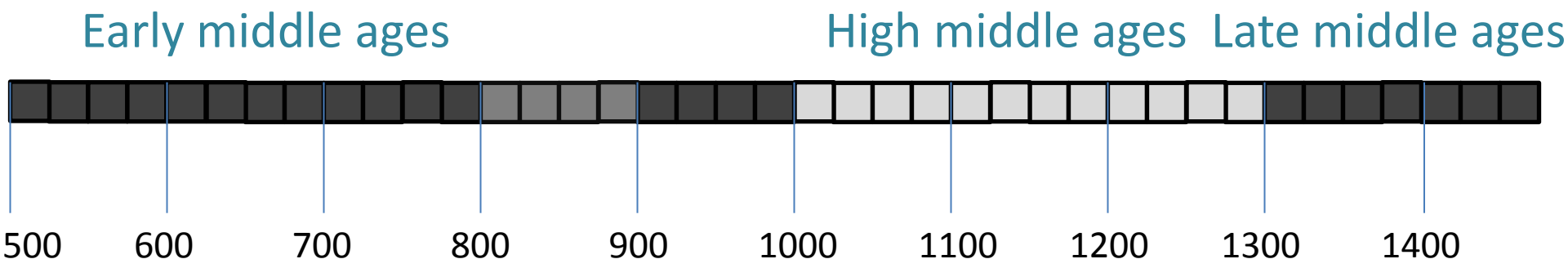
Wrote Al-Shukūk ʿalā Batlamyūs, or Doubts Concerning Ptolemy

Disputed Aristotle's view that the the Milky Way was ignition in the atmosphere of emissions from the stars (no parallax)

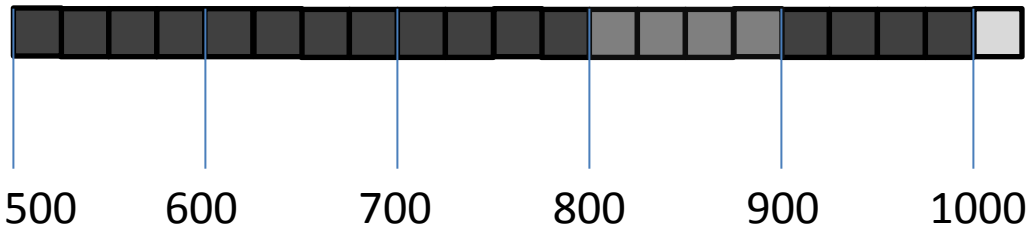
Born in Basra, location of Sumer, birthplace of Sinbad, location of the Garden of Eden (?)

The middle ages

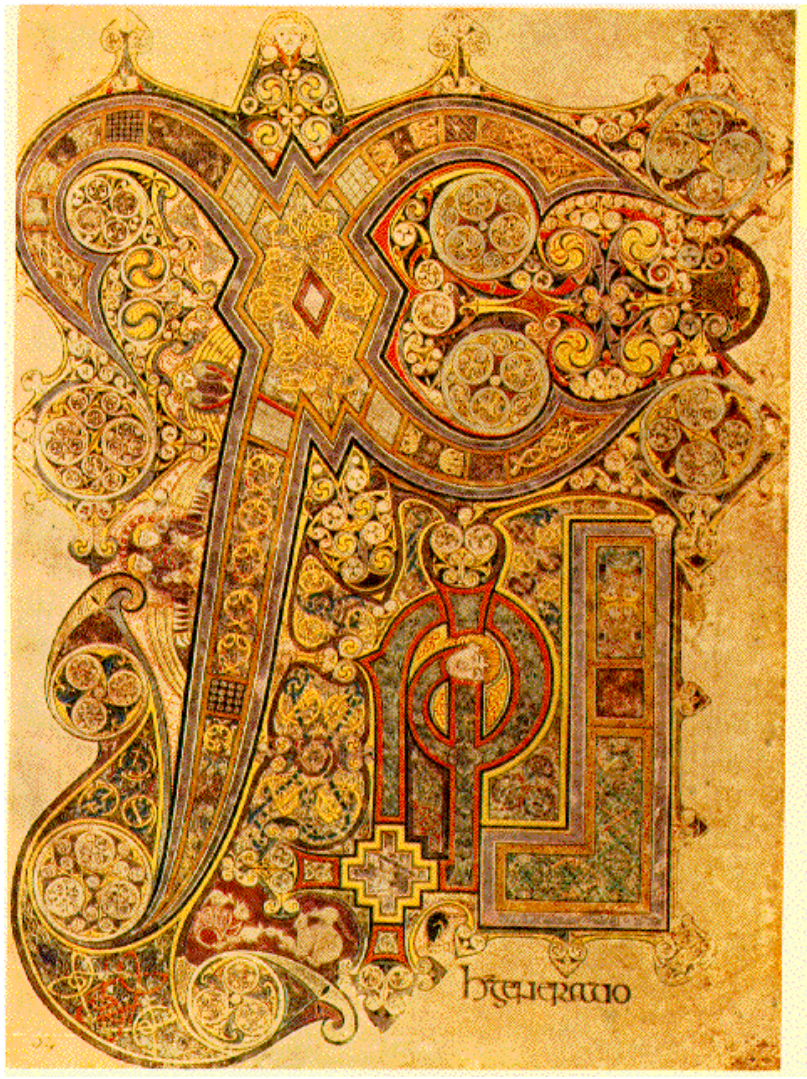




Early middle ages



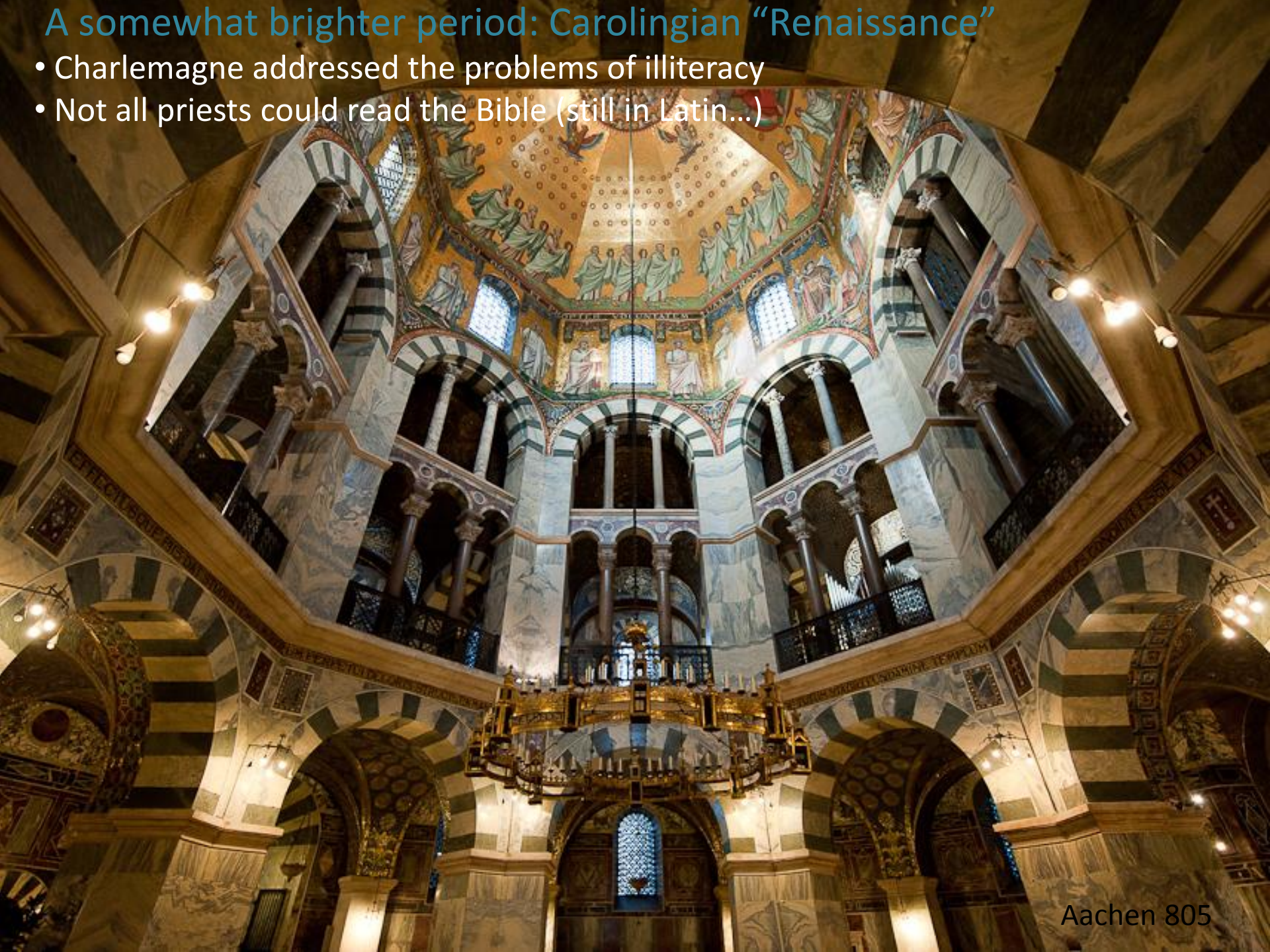
- Western civilization barely surviving
- De-urbanization, only pockets of learning are monasteries
- Science not a primary concern of the clergy



Book of Kells, Ireland 800

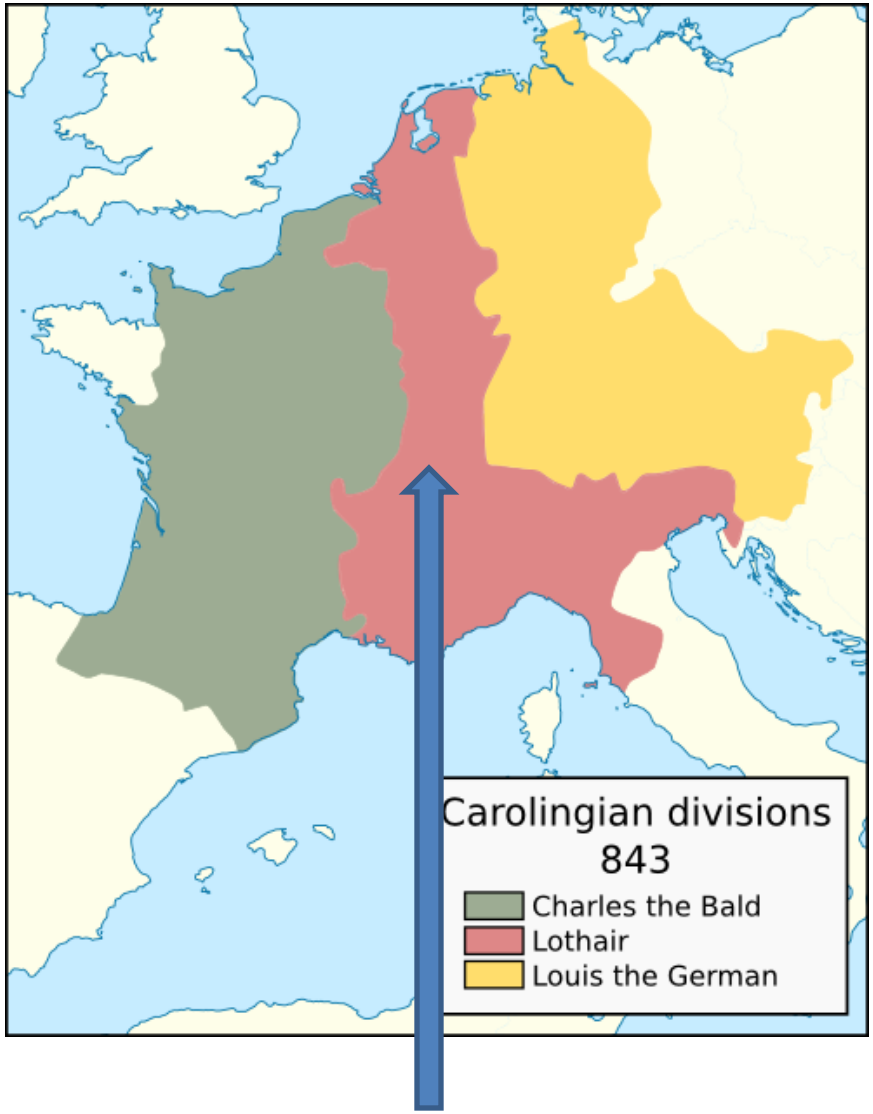
A somewhat brighter period: Carolingian "Renaissance"

- Charlemagne addressed the problems of illiteracy
- Not all priests could read the Bible (still in Latin…)



Aachen 805

But that didn’t last long



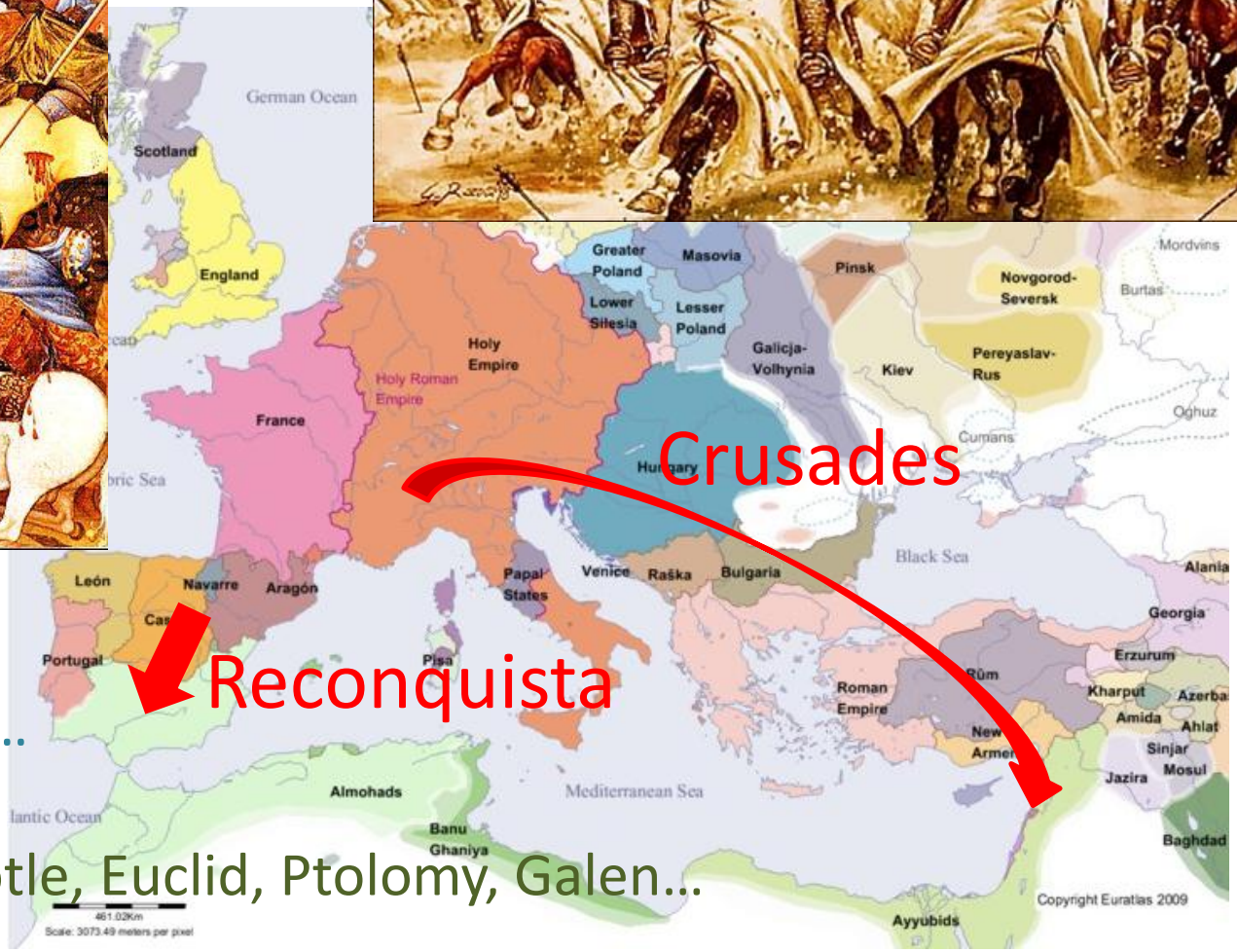
Source of a lot of misery in the coming centuries….

Enter the high Middle Ages

High middle ages

Chartres 1194-1250- No aliens?

Renewed contact with Byzantine empire and muslims

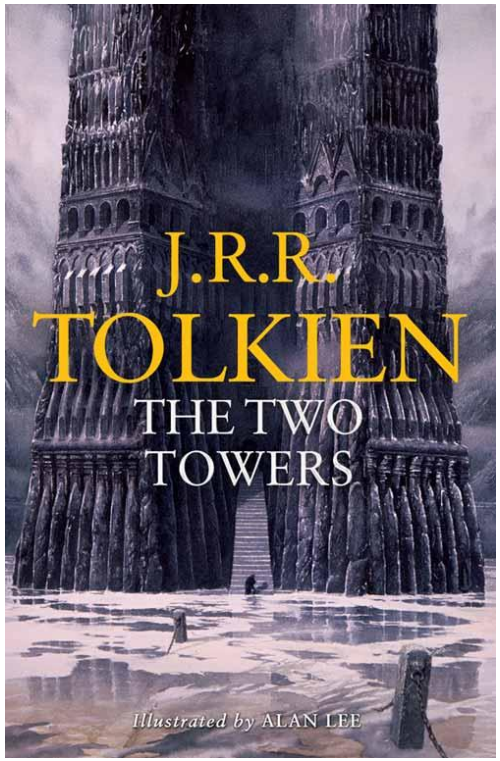


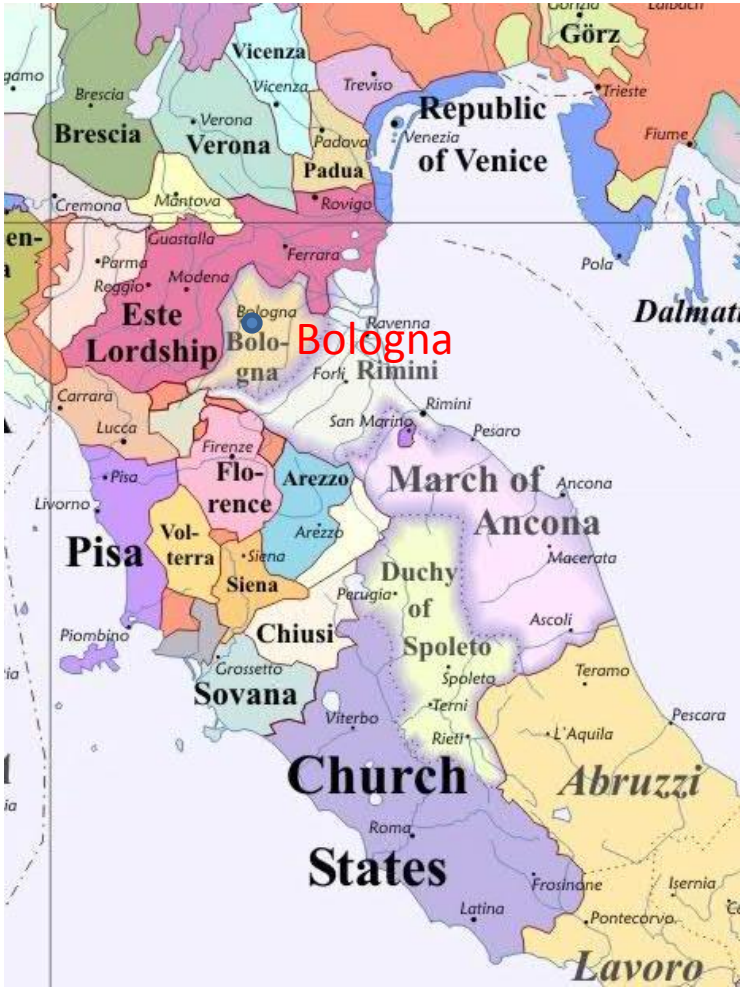
Maybe not entirely
for the right reasons…

Rediscovery of Aristotle, Euclid, Ptolomy, Galen…

Formalization of higher eduation:
Early on: monastic or cathedral schools

Organized in universities granted by the pope
Bologna, Paris, Salerno, Oxford, Cambridge, Salamanca
Coimbra. Montpellier, Modena





~1200-1300

Studium Generale
Arts: philosophy, music, mathematics, natural philosophy, astronomy
Higher faculties: Theology, Law and Medicine

A priest, a doctor, and a lawyer walk into a bar.
The bartender says, “What is this, a joke?”

An elderly man, 82, just returned from the doctors only to find he didn't have long to live. So he summoned the three most important people in his life to tell them of his fate:
1. His Doctor
2. His Priest
3. His Lawyer.

He said, "Well, today I found out I don't have long to live. So, I have summoned you three here, because you are the most important people in my life, and I need to ask a favour. Today, I am going to give each of you an envelope with $50,000 dollars inside. When I die, I would ask that all three of you throw the money into my grave."

After the man passed on, the three people happened to run into each other. The doctor said, "I have to admit I kept $10,000 dollars of his money. He owed me from lots of medical bills. But, I threw the other $40,000 in like he requested. "

The Priest said, "I have to admit also, I kept $25,000 dollars for the church. It’s all going to a good cause. I did, however, throw the other $25,000 in the grave."

Well the Lawyer just couldn't believe what he was hearing! "I am surprised at you two for taking advantage of him like that. I wrote a cheque for the full amount and threw it all in!!!"

Roger Bacon (1214-1294)

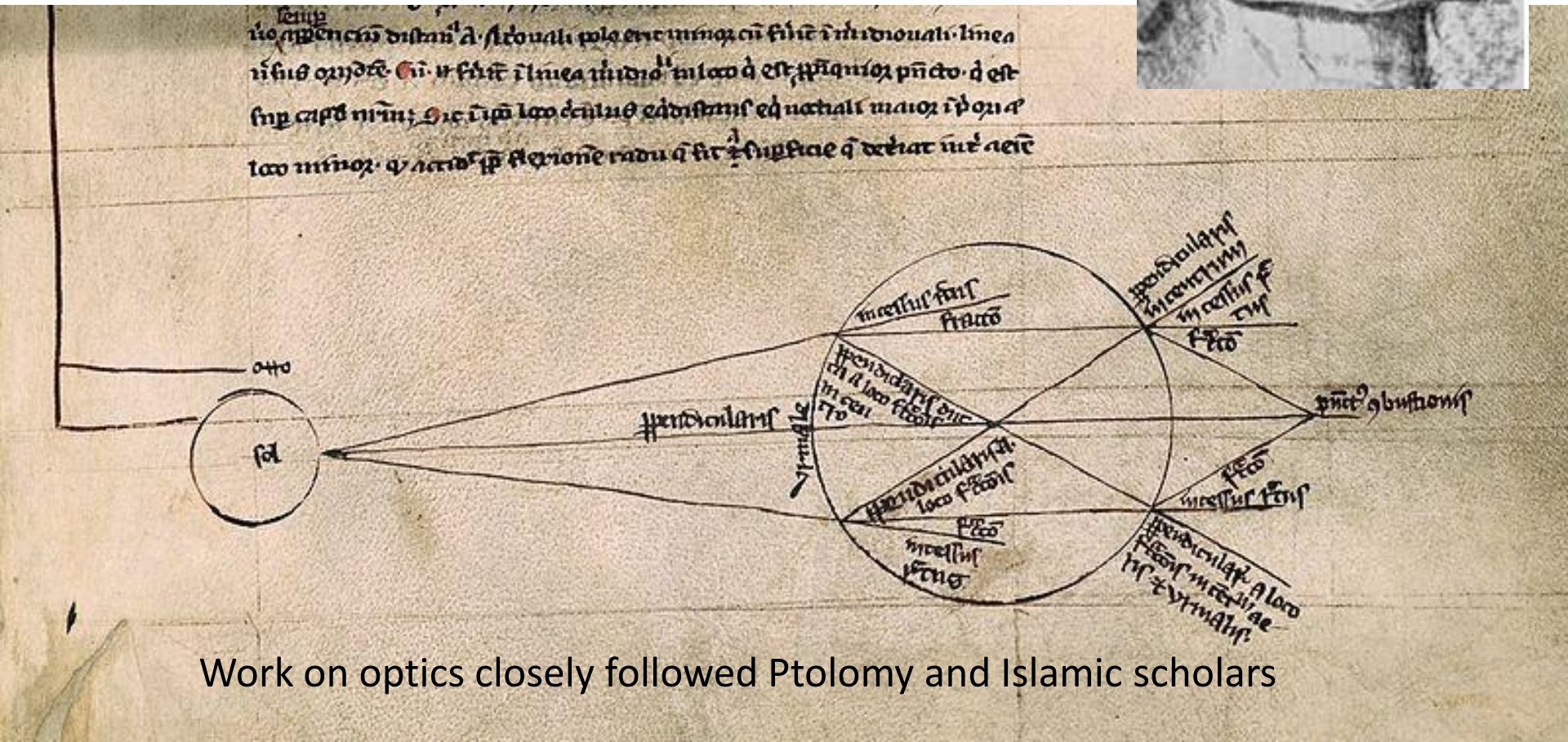
Stressed the need for experimental knowledge

19th century (romanticized interpretation):

First modern scientist, ahead of his time

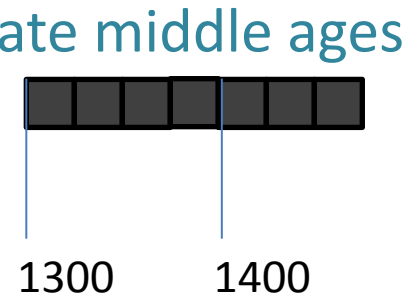
More modern: not too much different (Grosseteste)

too much emphasizing of Middle Ages as Dark Ages

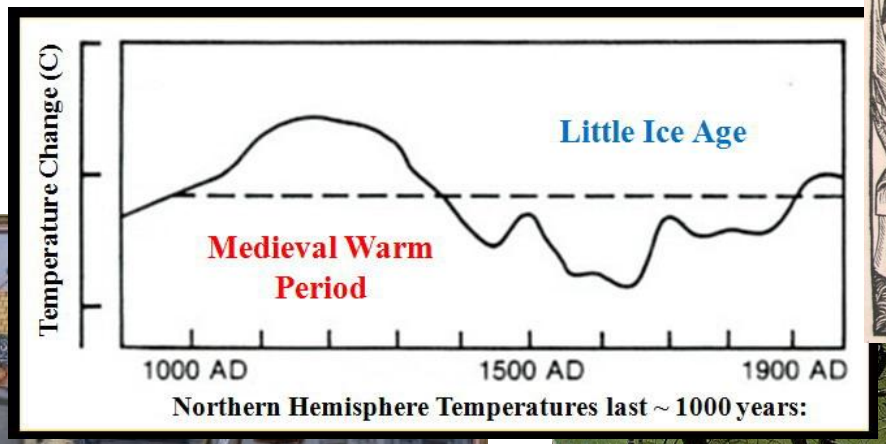


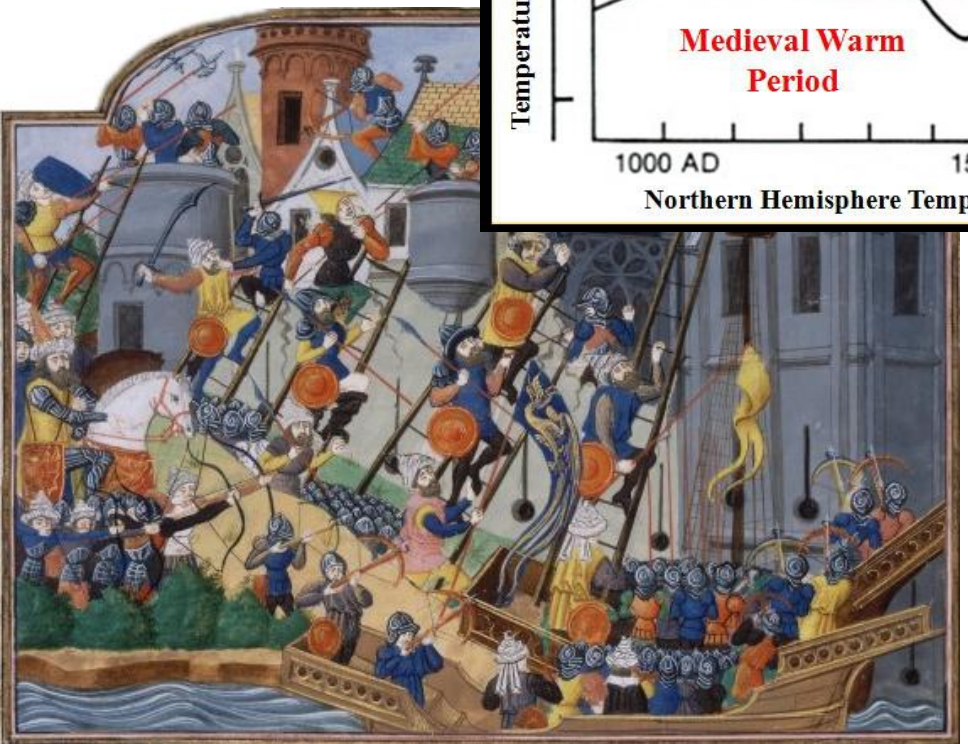
Work on optics closely followed Ptolomy and Islamic scholars

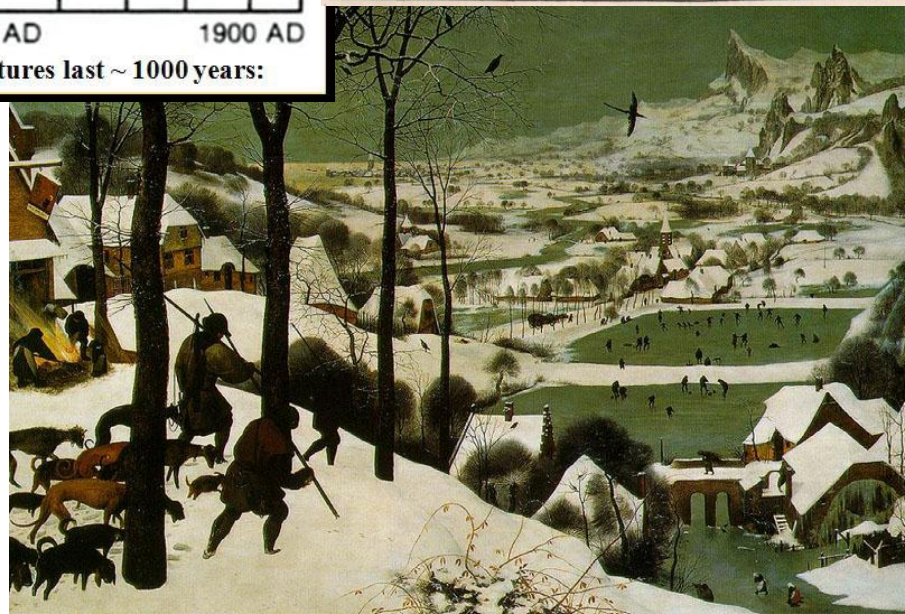
The Late Middle Ages (1300-1500) had some issues….



- 1315-7 the Great Famine, start of little Ice Age
- 1348-50 the Black Death
- 1453 Fall of Constantinople







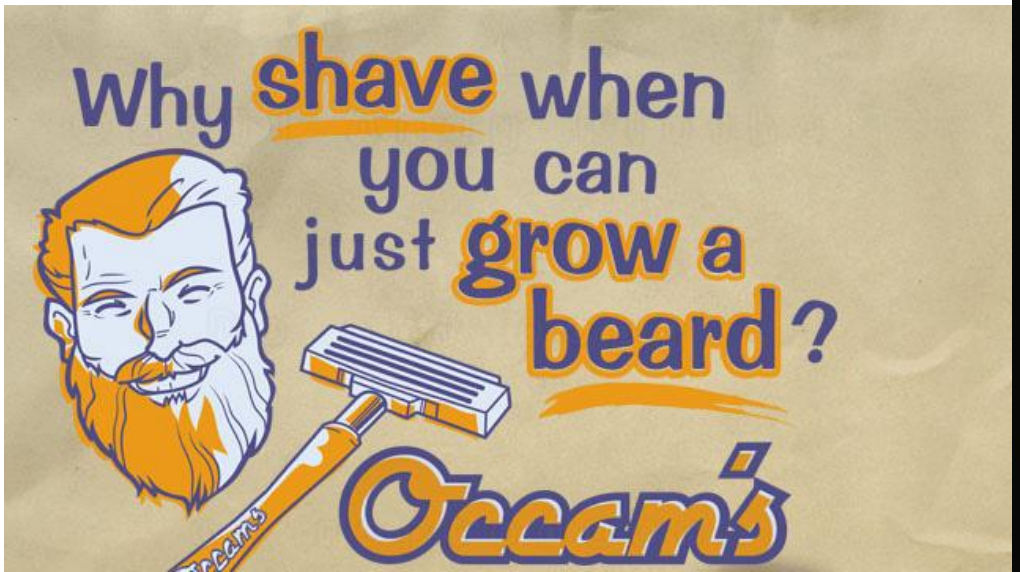
Philosophical developments in the late Middle Ages

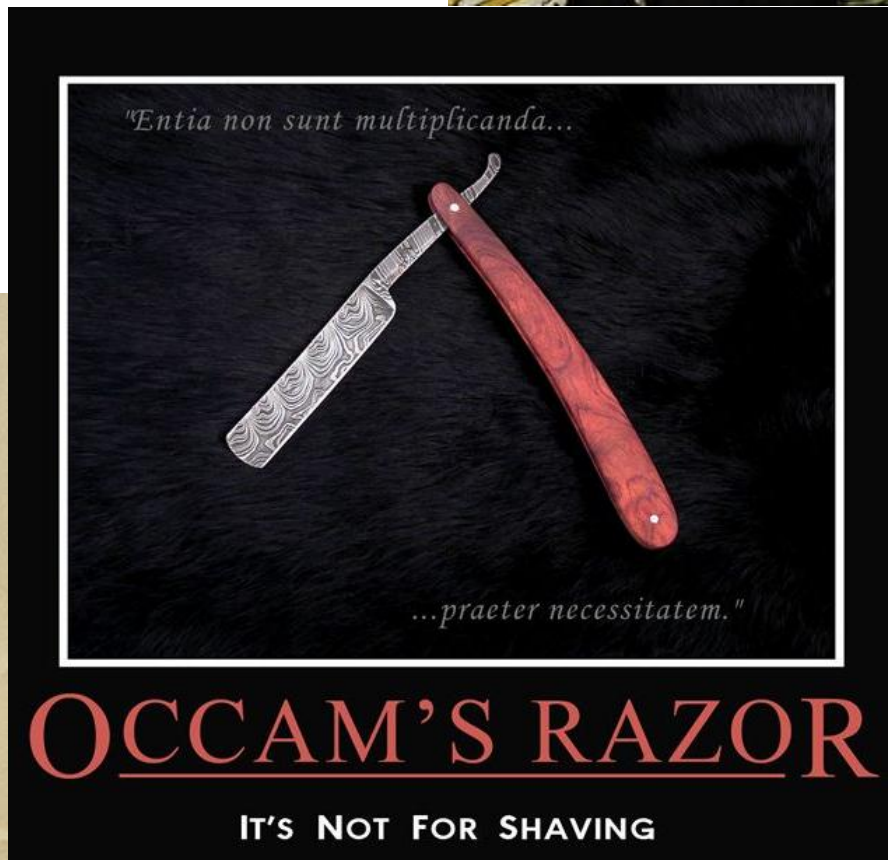
Occam/Ockham's razor
(traceable to John Duns Scotus (1265-1308) or even Aristotle and Ptolomy)

entia non sunt multiplicanda praeter necessitatem (entities must not be multiplied beyond necessity)


William of Ockham
(1288 – 1348)

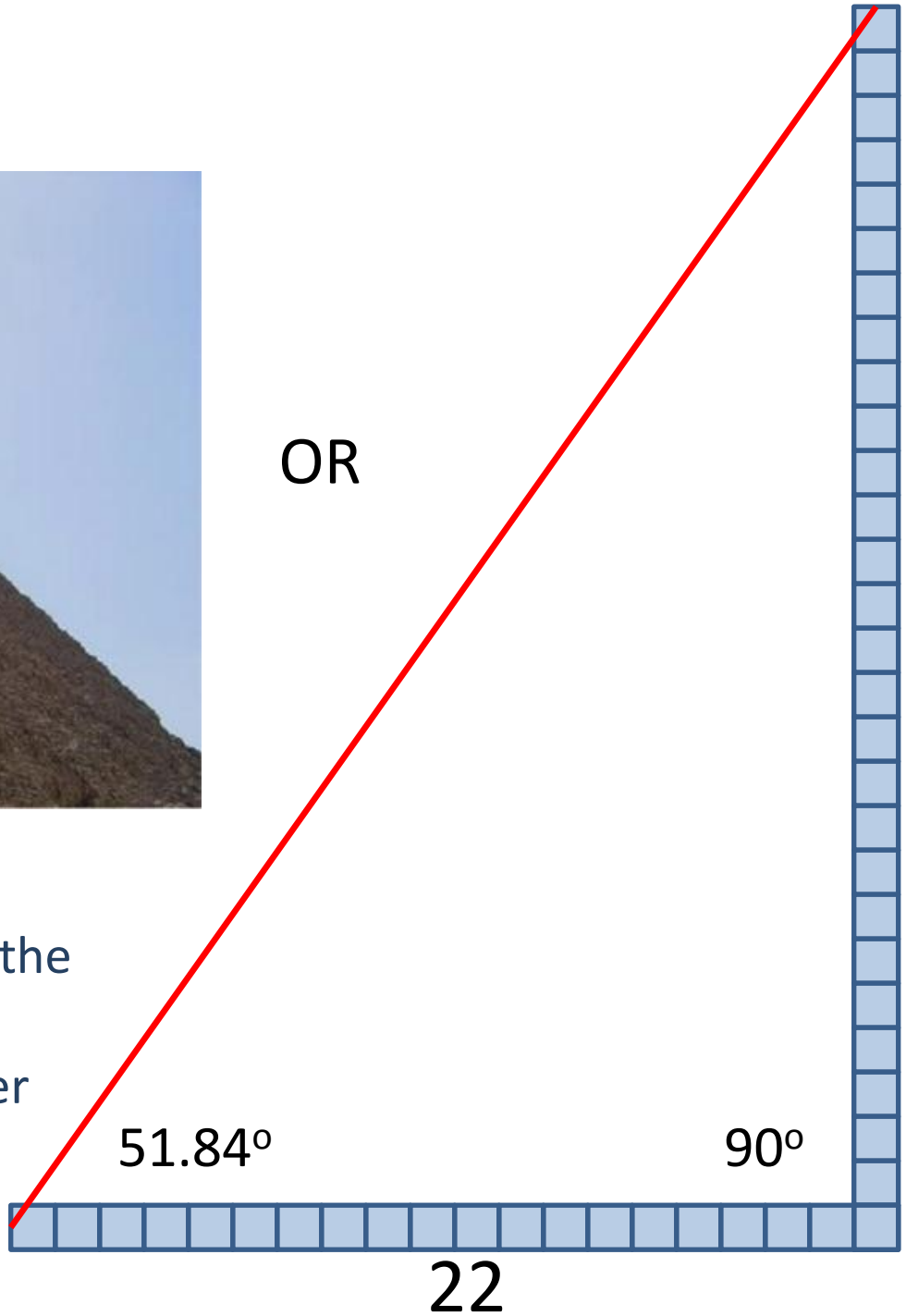
Other things being equal, a simpler explanation is better than a more complex one
In science:
Not really scientific logic, but certainly helpful





We used a similar principle

OR



We never proved that one is right and the other is wrong, but appealed to the argument: Which solution looks simpler and more likely?

Thomas Bradwardine (1290-1349) and the Oxford calculators :

William Swineshead

John Dumbleton

William Heytesbury

a body moving with constant velocity travels distance and time equal to an accelerated body whose velocity is half the final speed of the accelerated body

Constant velocity: $x = \frac{1}{2} v t$

Accelerated body: $v = a t$ or $a = v/t$

$x = \frac{1}{2} a t^2 = \frac{1}{2} (v/t) t^2 = \frac{1}{2} v t$

By jolly, that is indeed the same

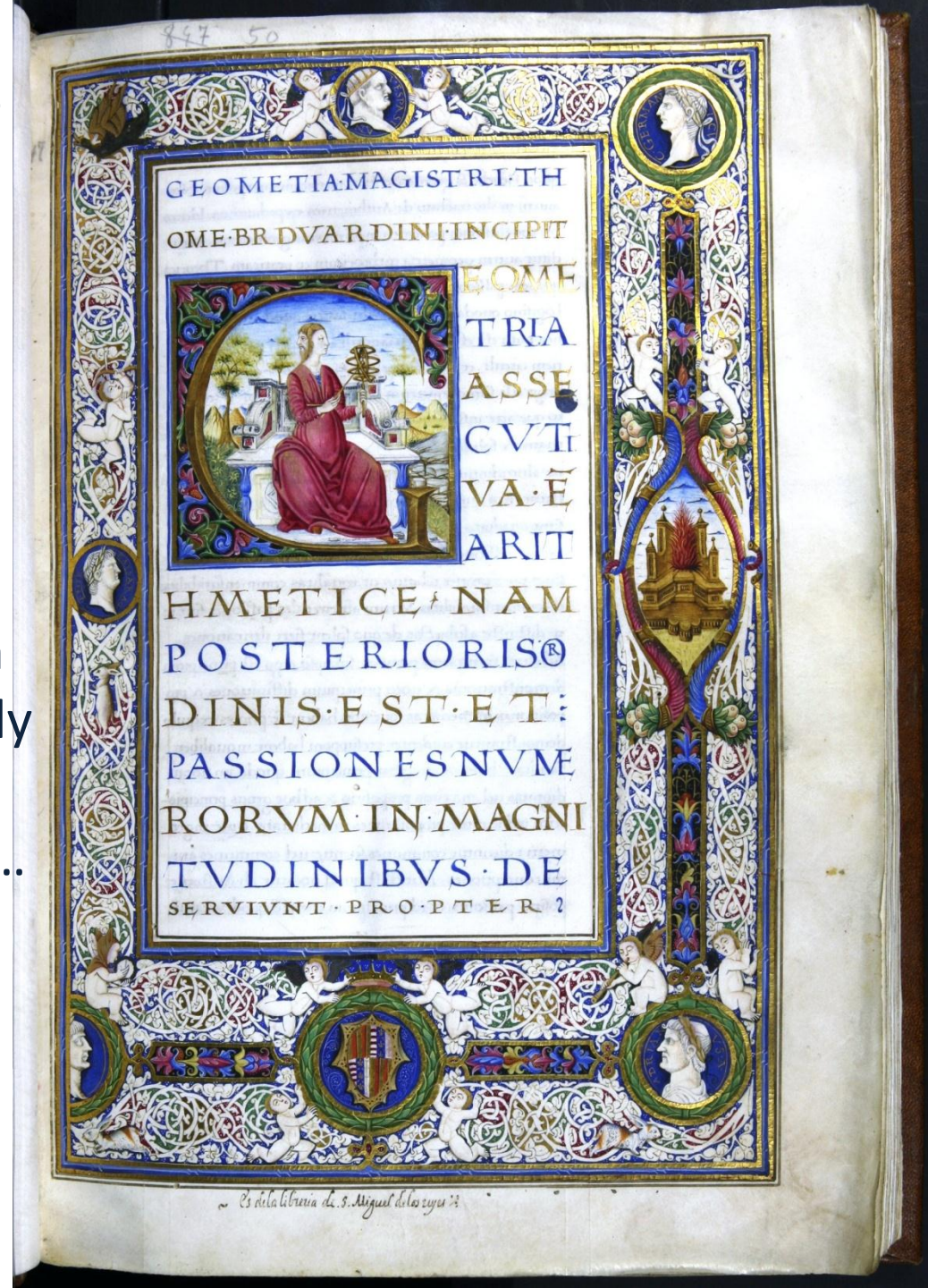
Approximate image of a medieval Oxford calculator

So that's Galileo, more than two centuries before Galileo

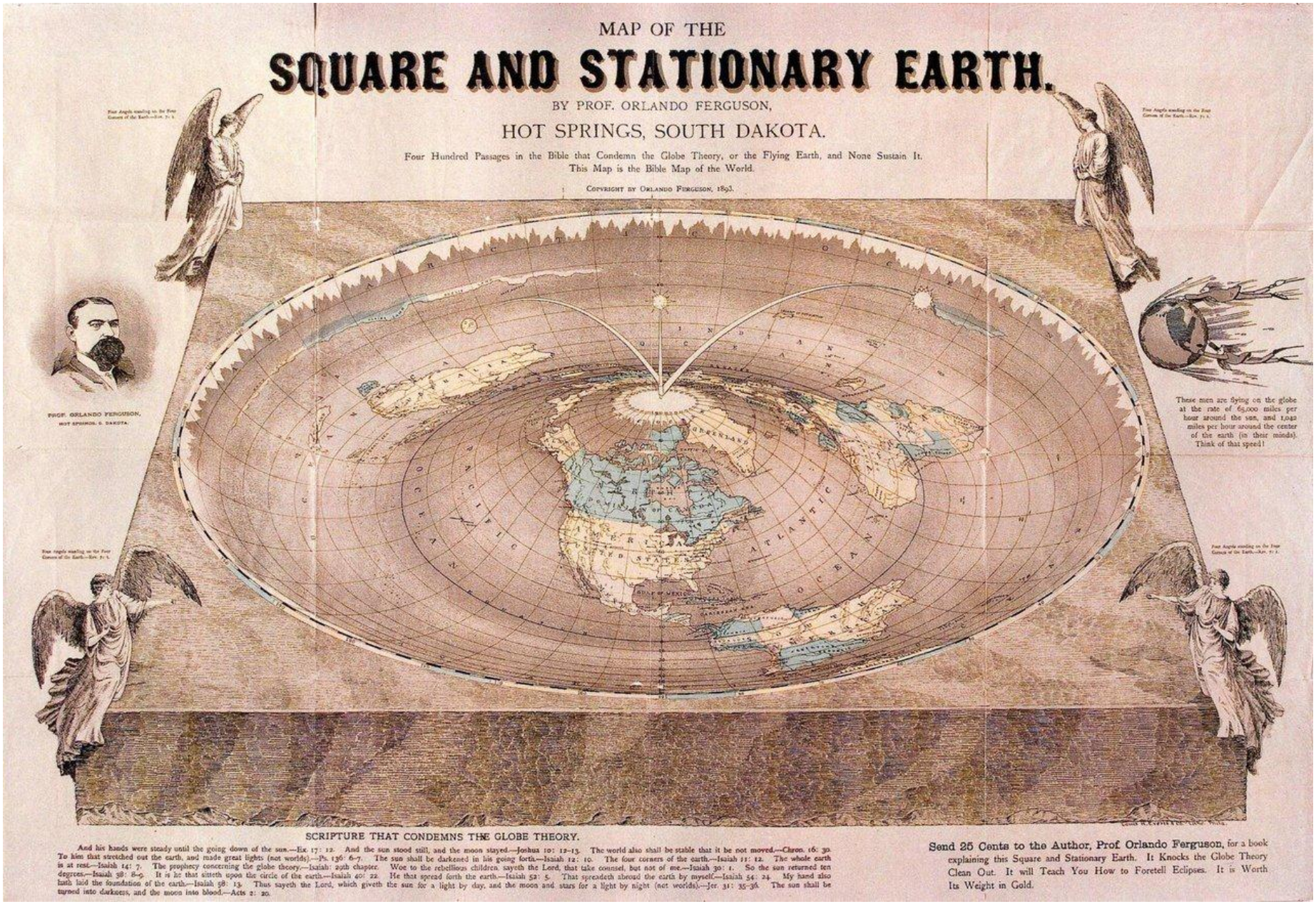
It diffused to the continent: France, Italy, and other parts

Why don't we hear about it?

- It's good, but not good enough
- It lacks algebra, to make it really general
- So in the end, it kind of fizzled…

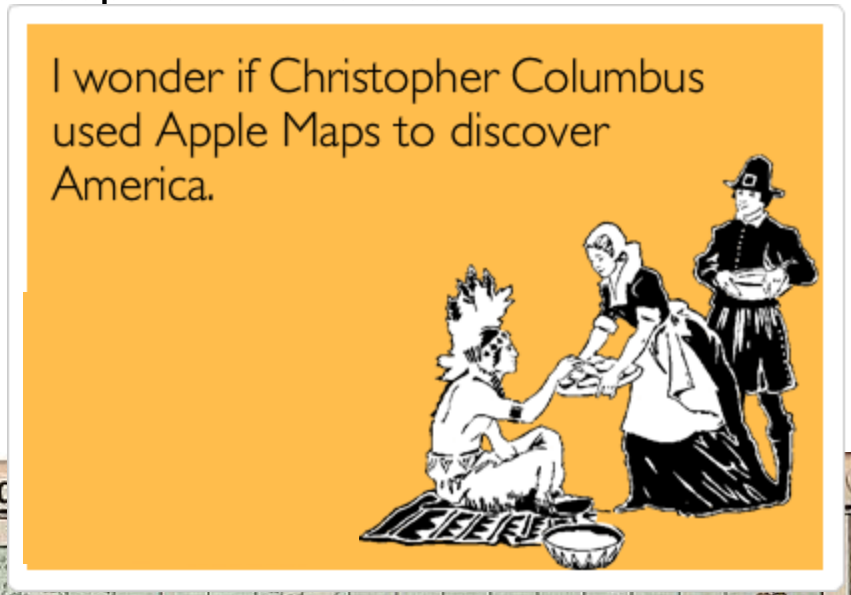


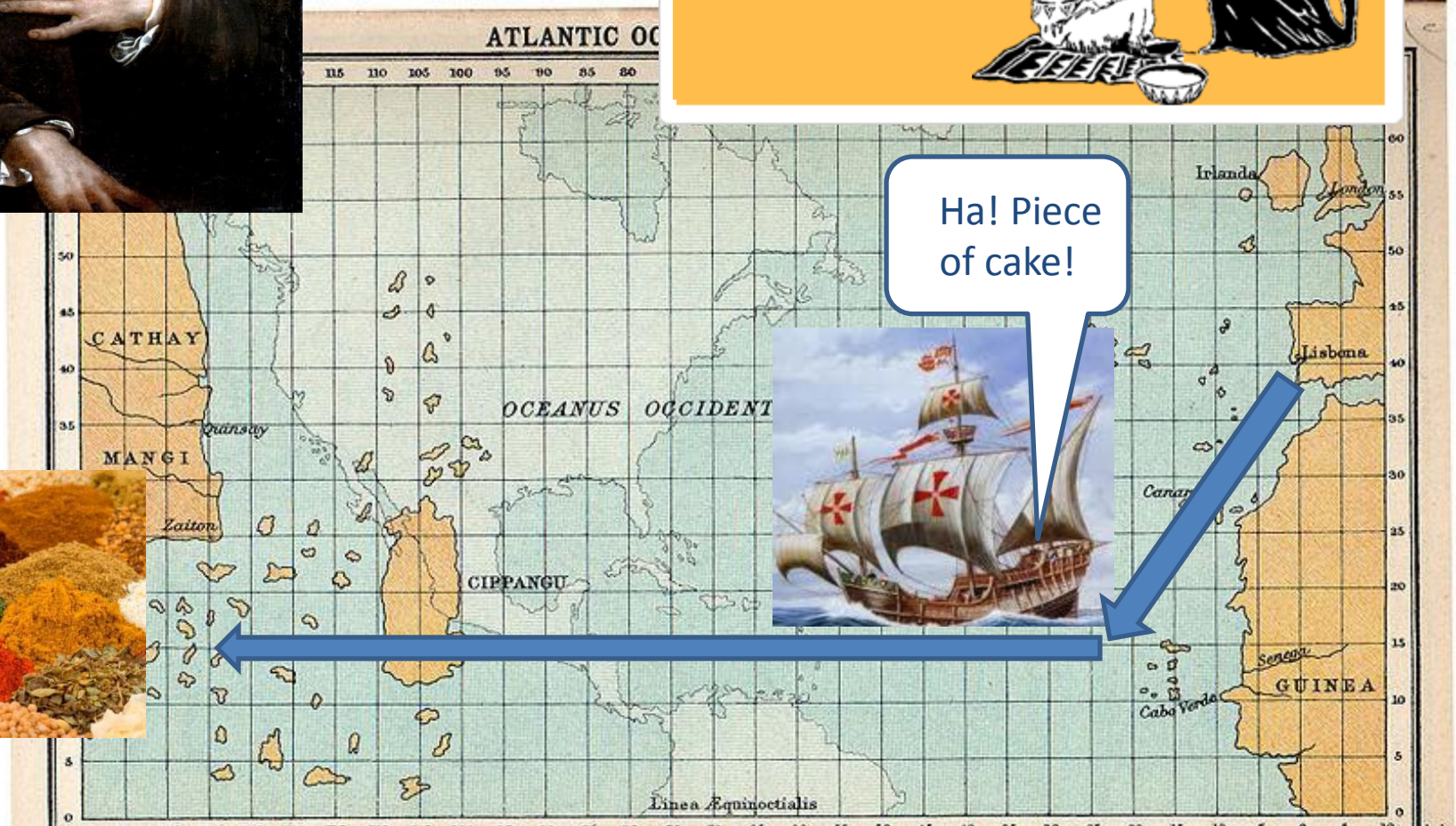
So here we are at the end of the Middle Ages, and the Earth is still flat….



Ok, most people accepted that the Earth was round

Well, some misconceptions remained….





Ha! Piece of cake!

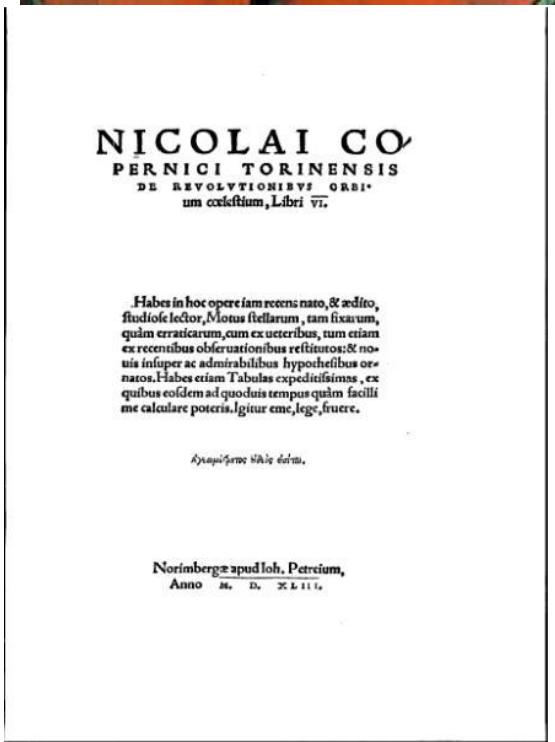
DISCOVERED AMERICA AND GAVE US:

Copernicus

And we still don’t have a simple (remember Ockham…) for the weird motion of the atoms

In 1543 (the year he died), Copernicus published his theory that the Earth rotated around the Sun

De revolutionibus orbium coelestium (*On the Revolutions of the Celestial Spheres*)



NICOLAI CO
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI-
um cœlestium, Libri VI.

Habes in hoc opere iam recens nato, & ædito, studiose lector, Motus stellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obseruationibus restitutos: & nouis insuper ac admirabilibus hypothesibus ornatos. Habes etiam Tabulas expeditissimas, ex quibus eosdem ad quoduis tempus quàm facillime calculare poteris. Igitur eme, lege, fruere.

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

How did we get there?
Why now?
Why circles?


Largest cities
125,000 and over
100,000 to 125,000
50,000 to 100,000
25,000 to 50,000
NORWAY
SWEDEN
MUSCOVY
SCOTLAND
North Sea
DENMARK
Baltic Sea
Königsberg/
Kaliningrad
Danzig/Gdansk
Warmia 1503-1543
Torun
LITHUANIA
HOLY ROMAN EMPIRE
POLAND
Ghent
Antwerp
Rouen
Kraków 1491-1495
BOHEMIA
ATLANTIC OCEAN
Paris
AUSTRIA
FRANCE
HUNGARY
Verona
Brescia
Lyon
Padua
1501-1503
Milan
Cremona
Genoa
Bologna
1496-1501
Florence
NAVARRE
PAPAL STATES
SPAIN
Corsica (Genoa)
Rome
Naples
Sardinia (Spain)
KINGDOM OF THE TWO SICILIES
Palermo
Mediterranean Sea
500 Miles
500 Kilometers
Cyprus (Venice)


IRELAND
St. Andrews 1413
Sea
Rostock 1419
WALES
ENGLAND
Cambride 1209/1231
Oxford 1167/1254
London
Ghent
Antwerp
HOLY
ROMAN
EMPIRE
Leipzig 1409
POLAND
Krakow 1364
BOHEMIA
Prague 1348
Rouen
Heidelberg 1386
ATLANTIC
OCEAN
Paris
1150
AUSTRIA
FRANCE
HUNGARY
Verona
Brescia
Lyon
Padua 1222
Milan
Venice
Cremona
Rhone R.
Toulouse 1224
Genoa 1481
Pisa 1341
Bologna
1088
Florence 1321
Sienna 1240
NAVARRE
Montpellier 1289
Coimbra 1290
PAPAL
STATES
Salamanca 1218
Corsica
(Genoa)
SPAIN
Madrid 1293
Barcelona 1450
Rome
1303
Naples
1224
PORTUGAL
Sardinia
(Spain)
KINGDOM
OF THE
TWO
SICILIES
Valencia
Seville
Granada
Palermo

We often simplify the constrast between the Middle Ages and the Renaissance as:

Memento Mori=Remember you will die

Carpe Diem=Seize the day

Town hall Leuven, Belgium, 1448-1469
Several architects

Palazzo Farnese, Rome, Italy, 1517-1541
Antonio de Sangallo


Reims 1230


Notre Dame, Paris


Verrocchio 1467-1483


Lombardo 1494-5


Michelangelo 1501-04


Naumburg cathedral 1250

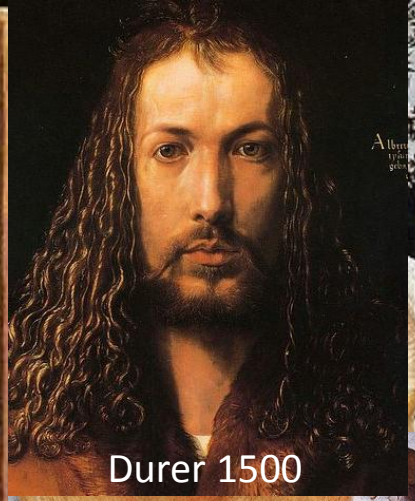

Chartres


Donatello 1453

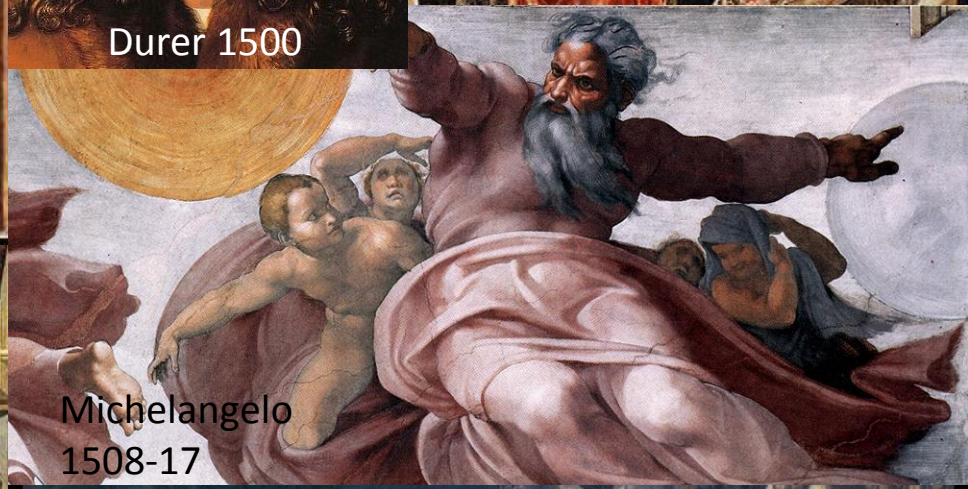

1517


Cimabue 1290


Byzanthine


Durer 1500

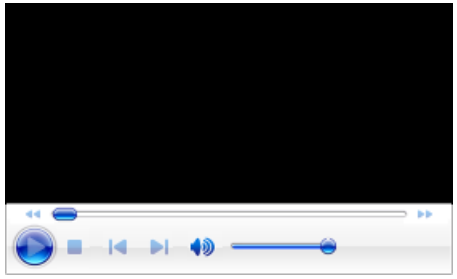

Botticelli 1482


Michelangelo
1508-17

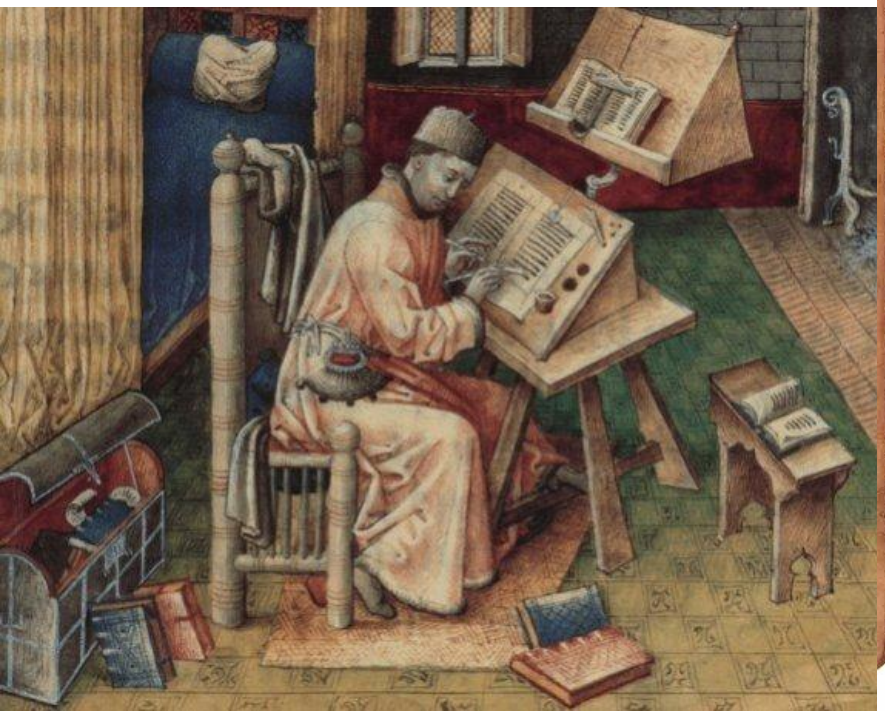

Lorenzetti 1338-40


Titian 1538

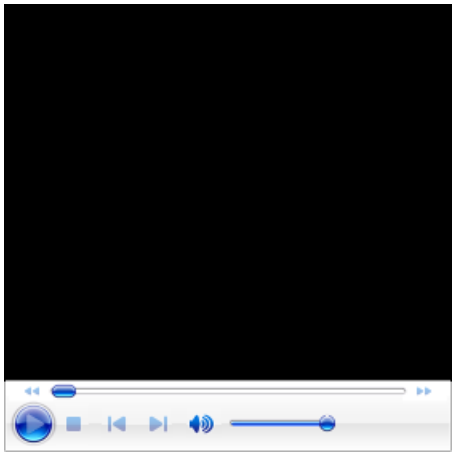
Music in the middle ages:

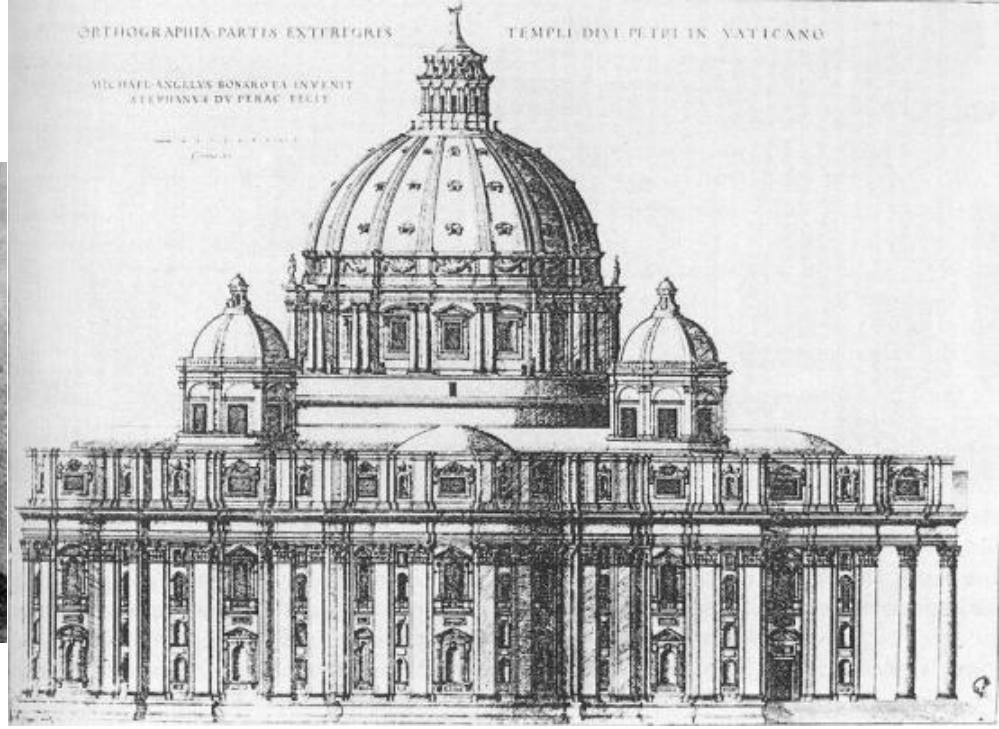


Composer by Anonymous
(most prolific composer ever!)



Music in the renaissance





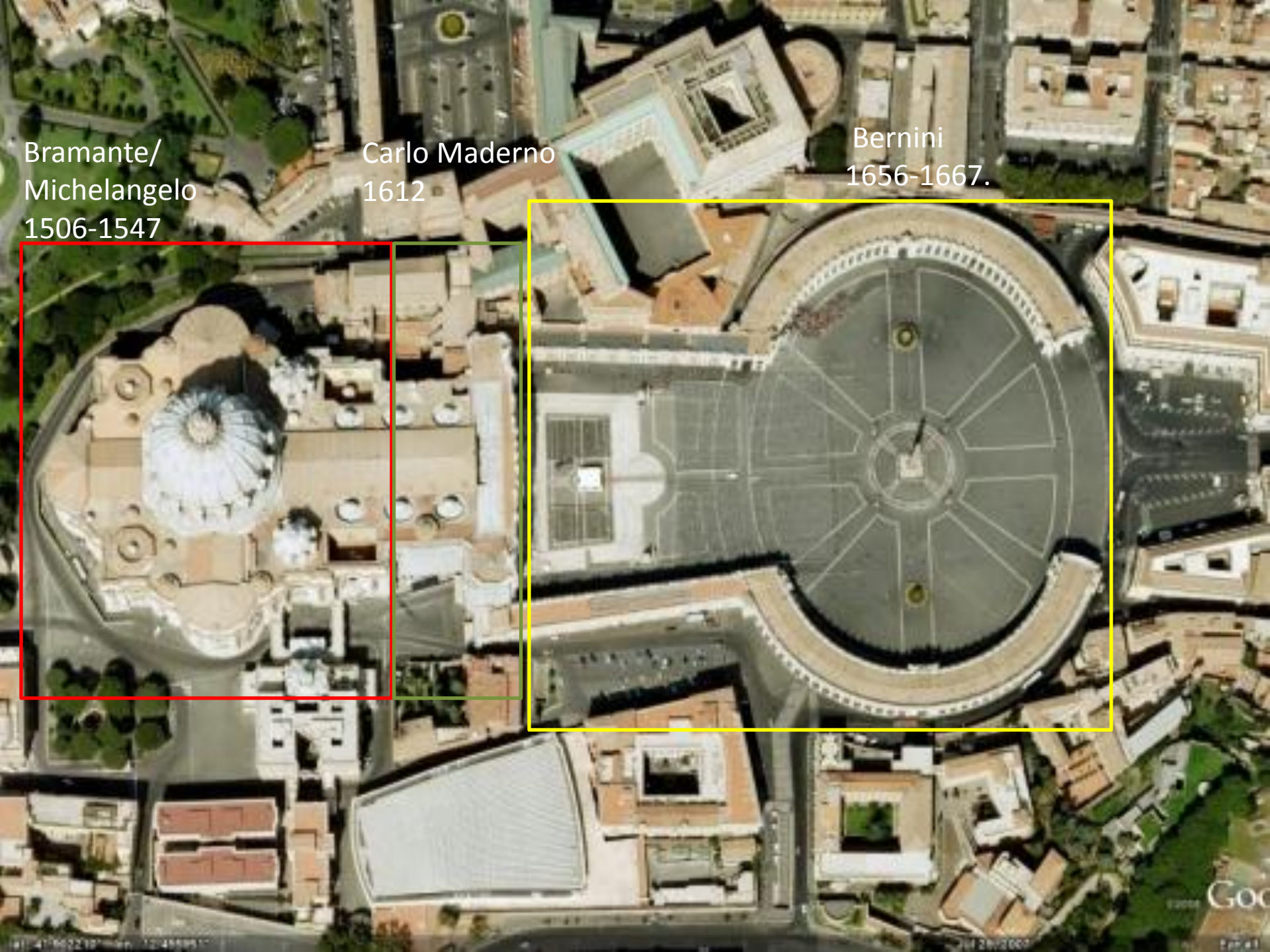
Giovanni Pierluigi da Palestrina (1525 -1594)

St. Peter's basilica

Shortest-reigning popes

Urban VII (15–27 September 1590): reigned for 13 calendar days, died before coronation.
Boniface VI (April 896): reigned for 16 calendar days
Celestine IV (25 October – 10 November 1241): reigned for 17 calendar days
Theodore II (December 897): reigned for 20 calendar days
Sisinnius (15 January – 4 February 708): reigned for 21 calendar days
Marcellus II (9 April – 1 May 1555): reigned for 22 calendar days
Damasus II (17 July – 9 August 1048): reigned for 24 calendar days
Pius III (22 September – 18 October 1503): reigned for 27 calendar days
Leo XI (1–27 April 1605): reigned for 27 calendar days
Benedict V (22 May – 23 June 964): reigned for 33 calendar days
John Paul I (26 August – 28 September 1978): reigned for 33 calendar days.

After his death, it would be 415 years before another Pope would choose a name with an ordinal number less than IV (John Paul I).


Bramante/
Michelangelo
1506-1547
Carlo Maderno
1612
Bernini
1656-1667.

Michelangelo’s St. Peter


1630, Viviano Codazzi

Modern image:

Shows the tremendous wealth and power of the Roman Catholic church!

This will come back and haunt 16th Century scientists

However, just because the people in the renaissance thought that the Middle Ages (in the middle between the classical period and the renaissance) were the dark ages

In fact, the high Middle Ages were pretty spectacular:

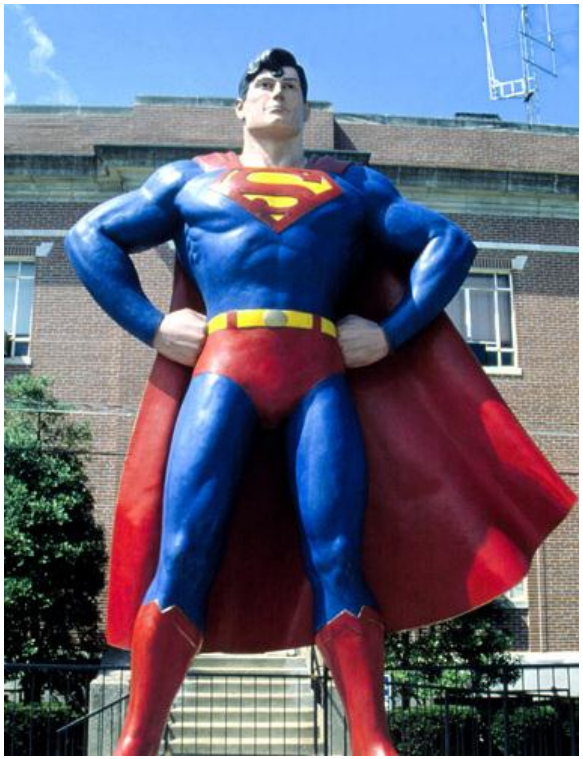
Notre Dame, Paris, 1163-1345

And has been an inspiration throughout the centuries

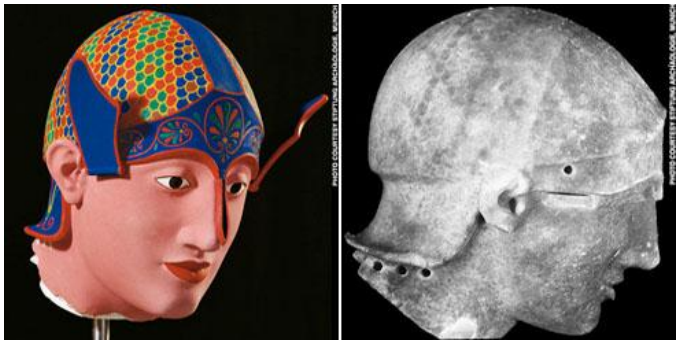
And the way people in the Renaissance (and now!) look at the ancient Greeks is often wrong!

Which to us (indoctrinated by those renaissance guys) looks often pretty tacky

Really, Augustus…?



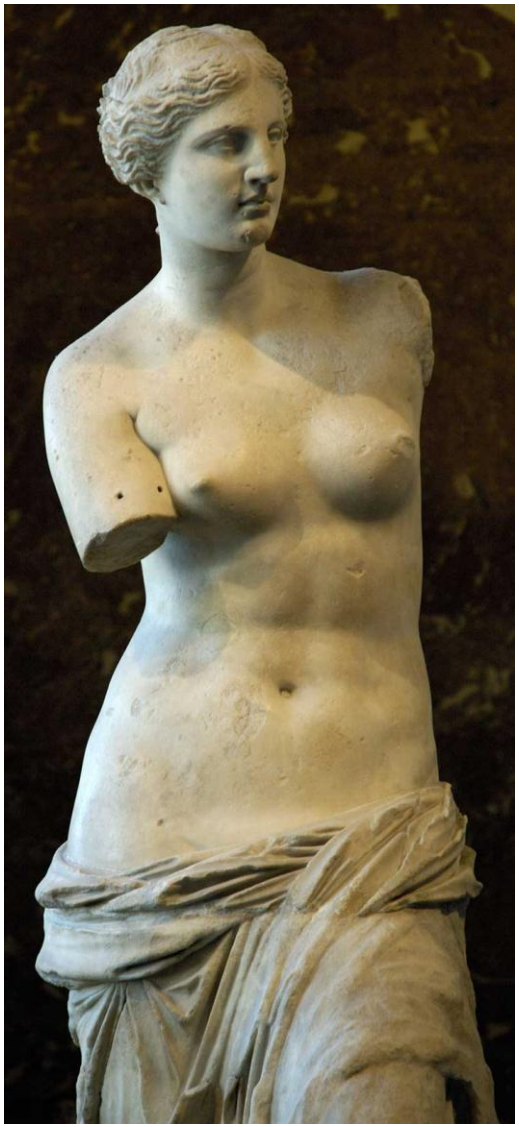
Classic Greek statue of caped Adonis in Metropolis, IL [sic]



Dude!!

Already noticed in the 18th, but ignored/denied, because it didn't really fit into their view of ancient Rome/Greece (period of enlightenment)

Johann Joachim Winckelmann
1717 –1768

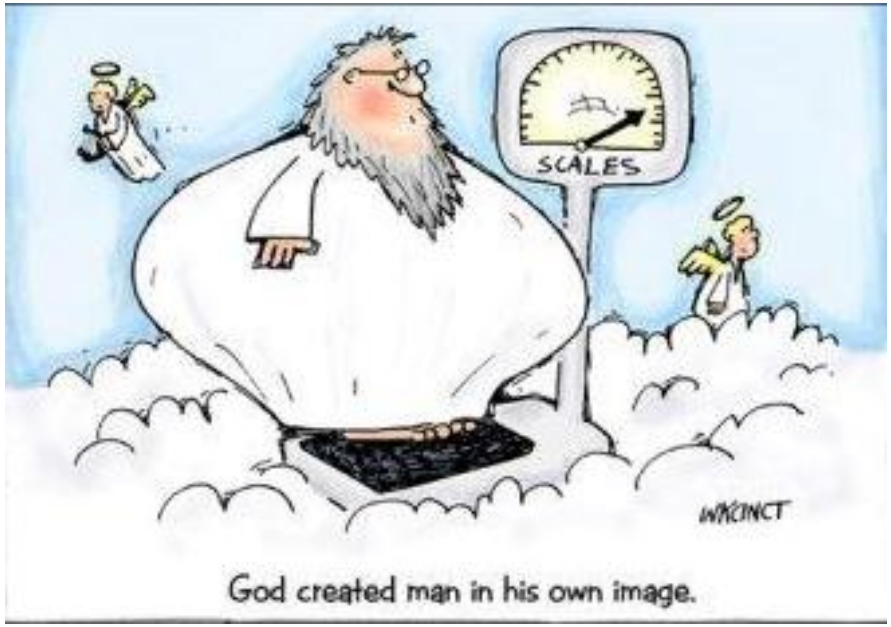


No self-respecting Greek would keep this in his palazzo

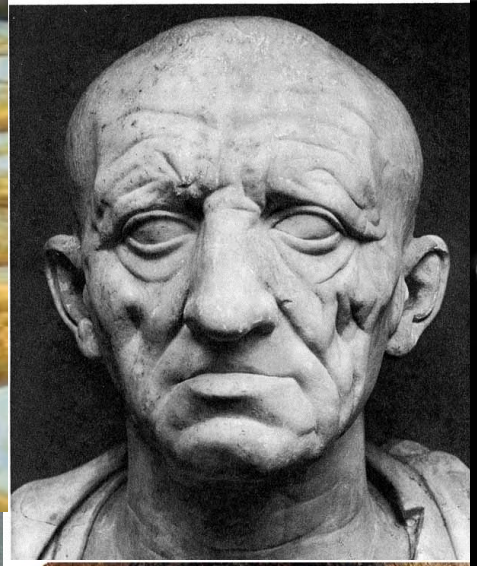
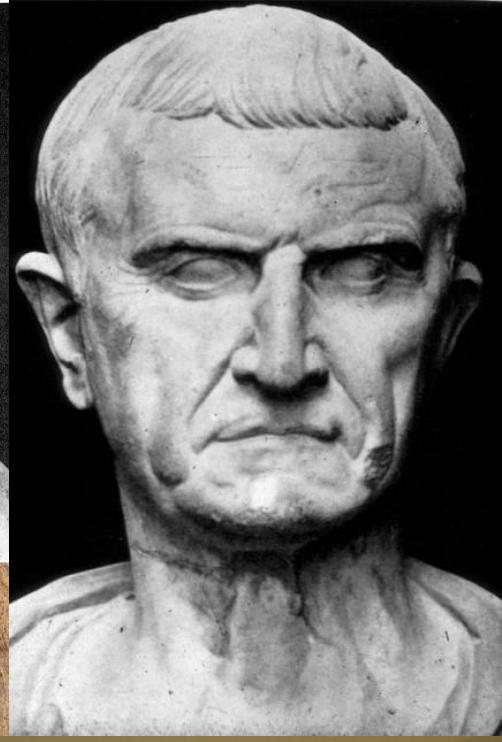
Some of the conceptions in the renaissance were maybe too idealistic

- It was a time where one was going back to classical ideals
- Focus back on men as opposed to God
- Men created in the image of God

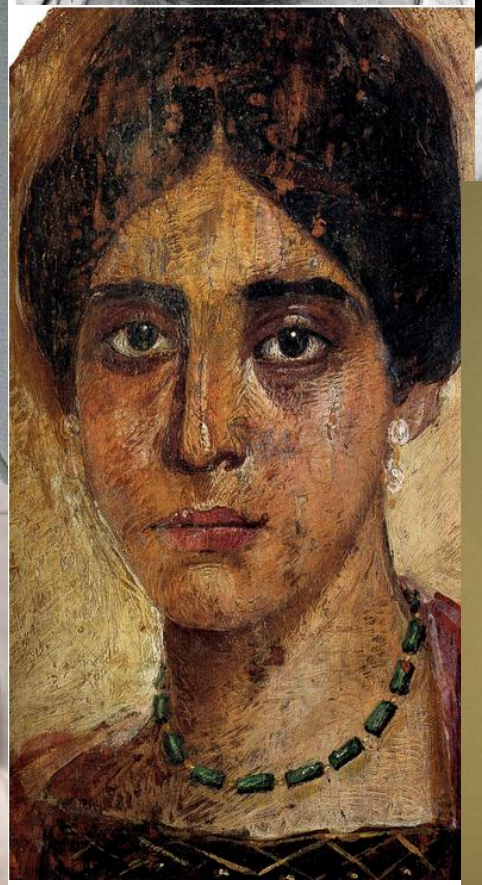
- Let’s compare some Roman portraits with renaissance ones





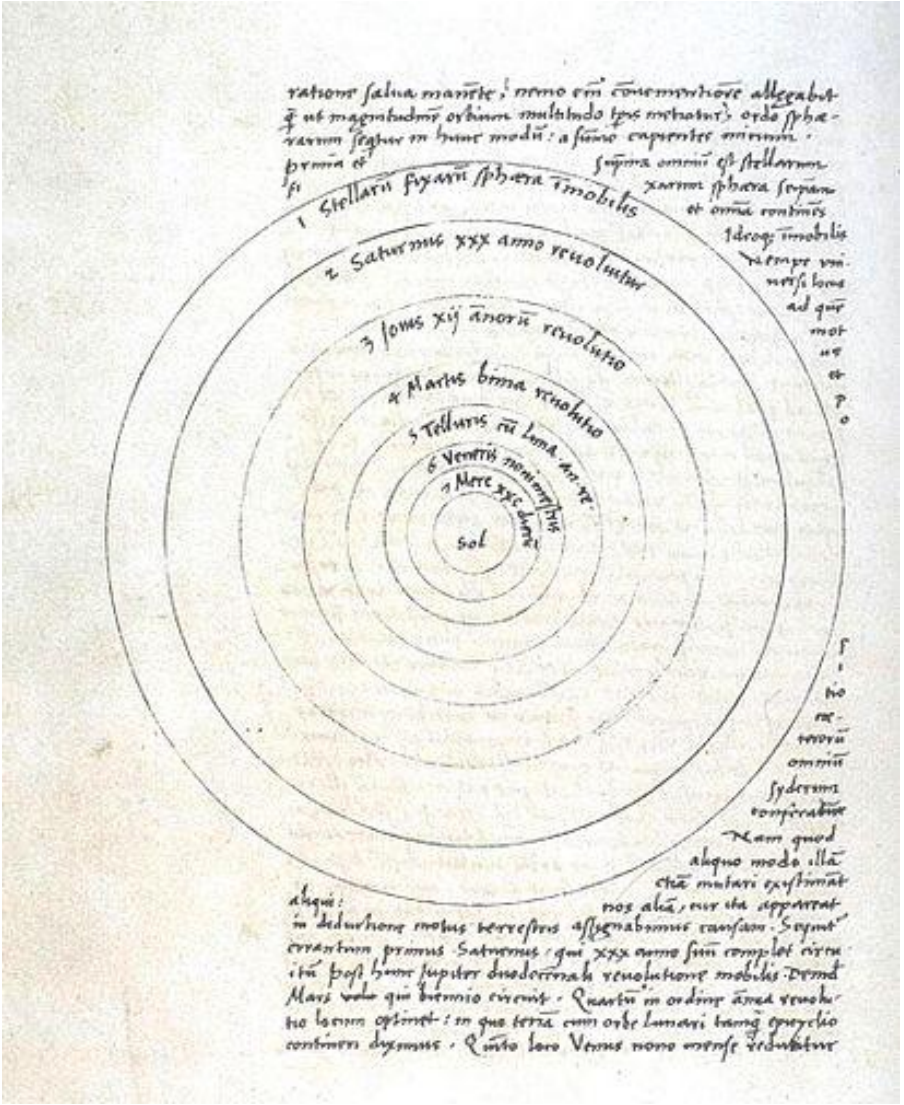








Maybe Michelangelo could have used some Roman realism

With all this striving for perfection, circles seems to be the only option

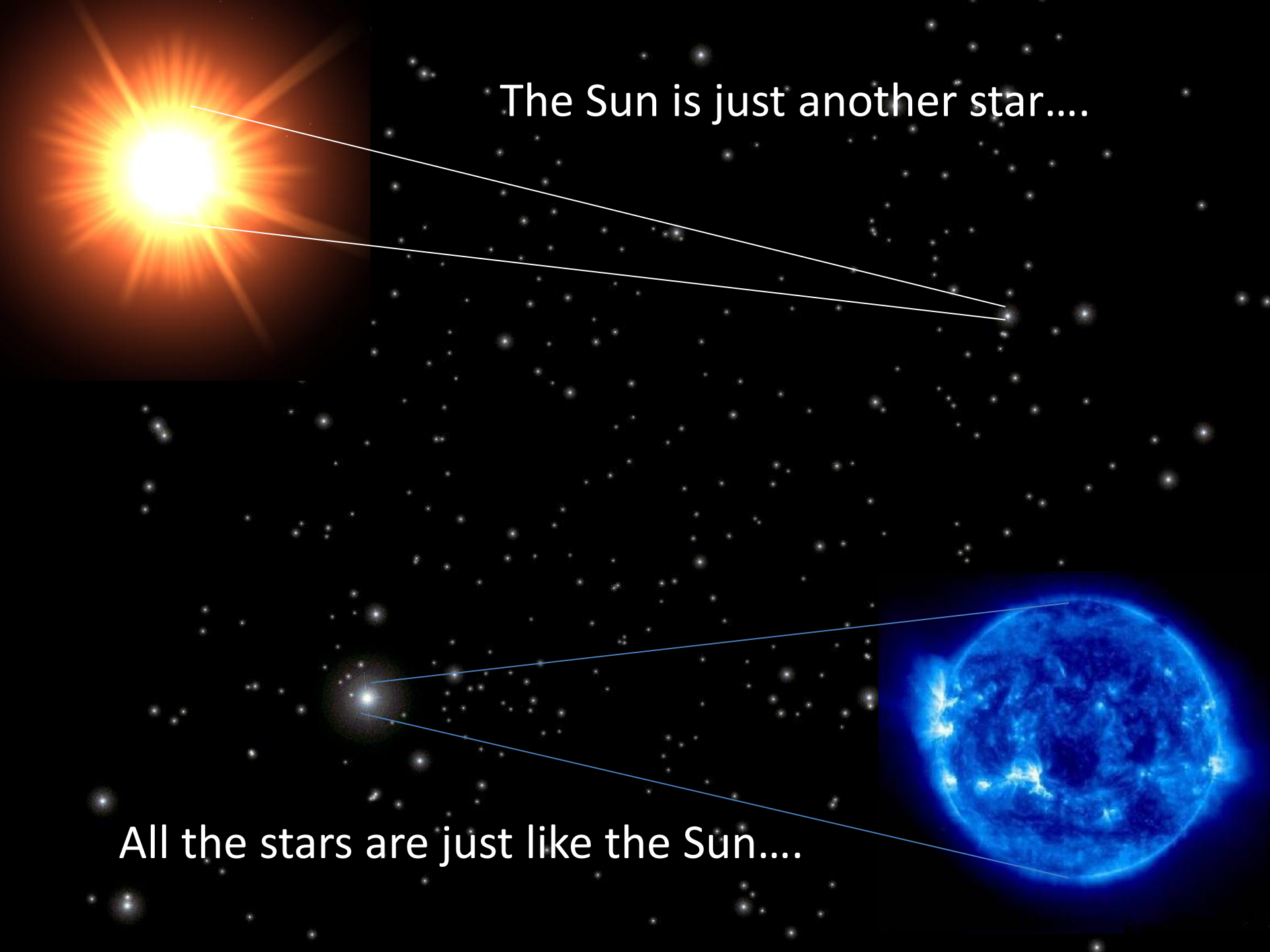


Giordano Bruno

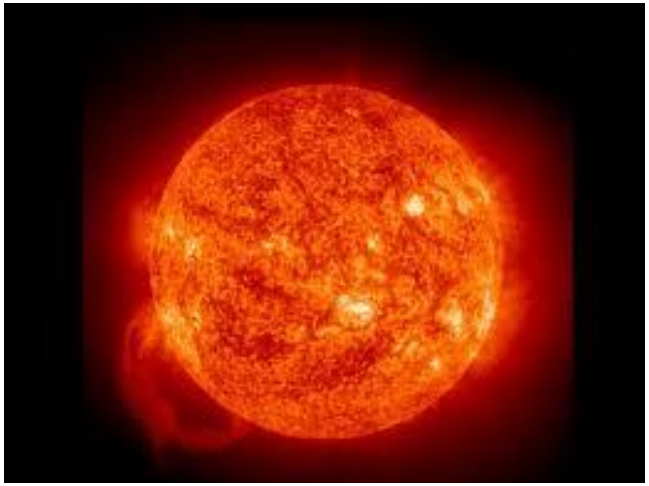
Some went even several steps further than Copernicus: One of those was Giordano Bruno (1548 –1600)

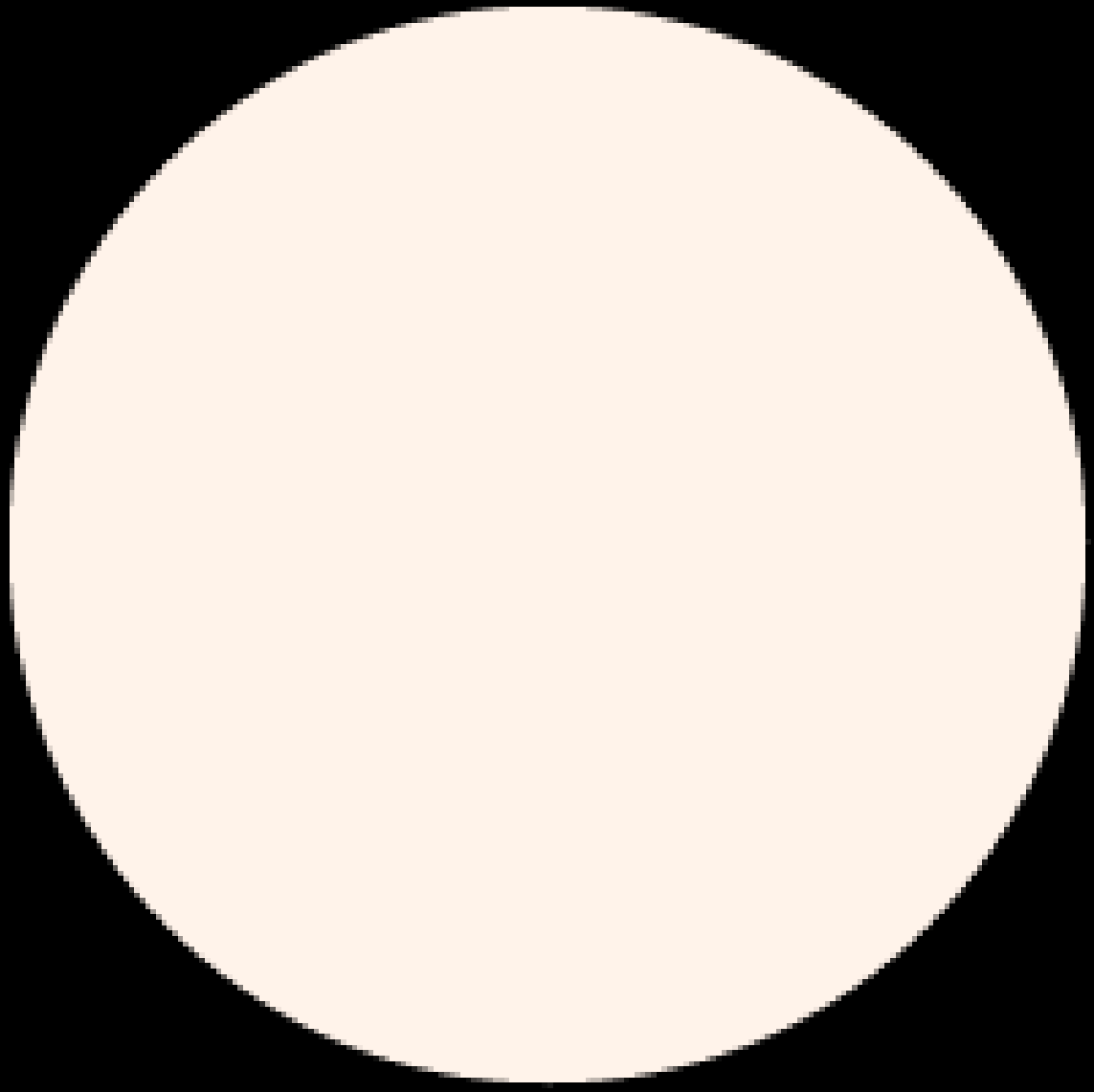
The universe is then one, infinite, immobile....
It is not capable of comprehension and
therefore is endless and limitless,
and to that extent infinite and indeterminable,
and consequently immobile

The universe is infinite!


The Sun is just another star….
All the stars are just like the Sun….

Speaking of the Sun. What color is the Sun?





Yup, it is white, close to the color above
Not yellow, red, or whatever….

Of course looking at the Sun, when it is white is something you don’t want to do…
When we can look at it, it’s usually yellow or red.

And speaking of the Moon…. (which we were not…)

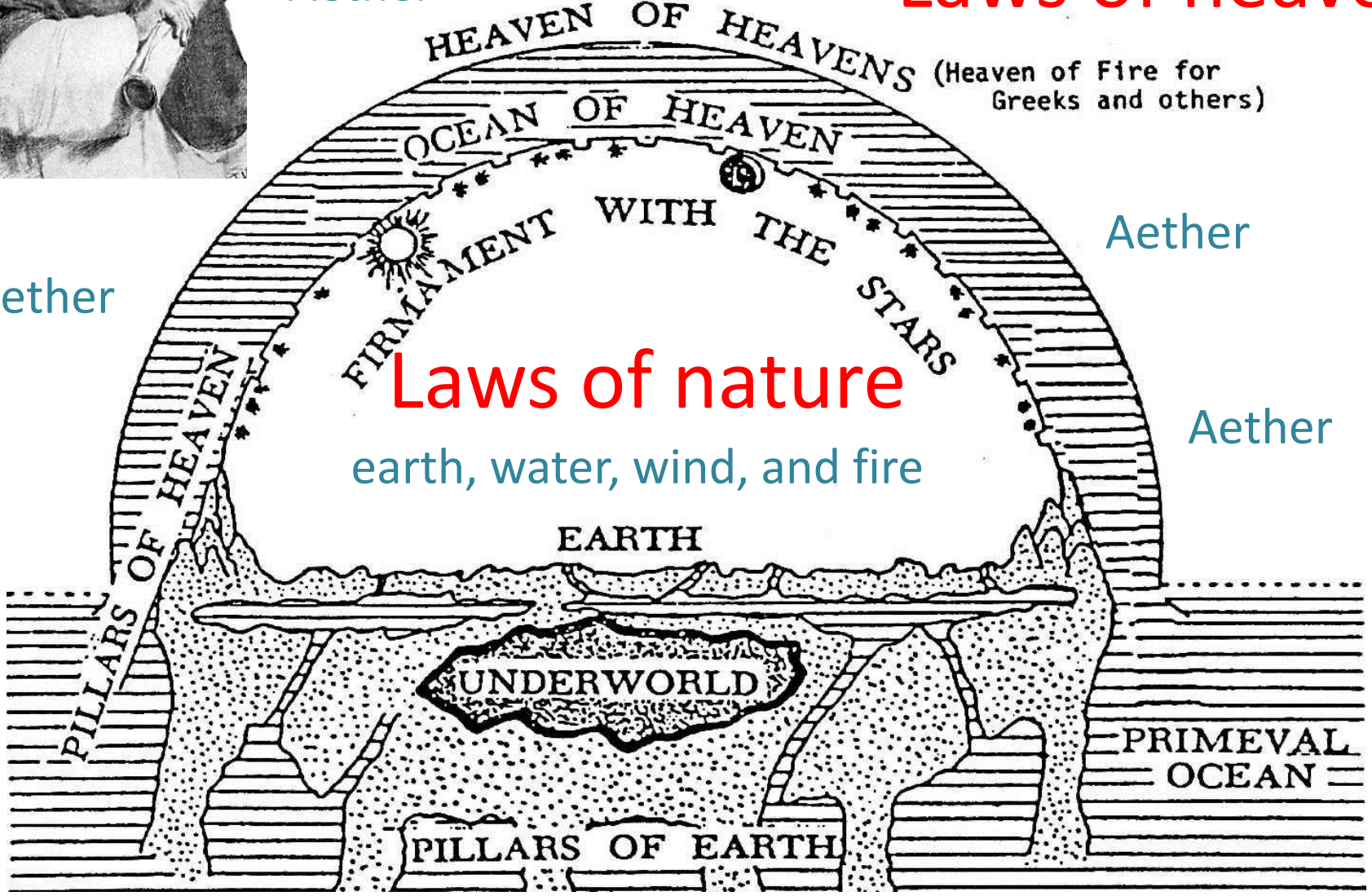
What’s wrong with this picture?


The Moon is not transparent!

What else did Giordano Bruno think of?
The universe is not finite and divided into different space with different laws

Aether

Laws of heaven



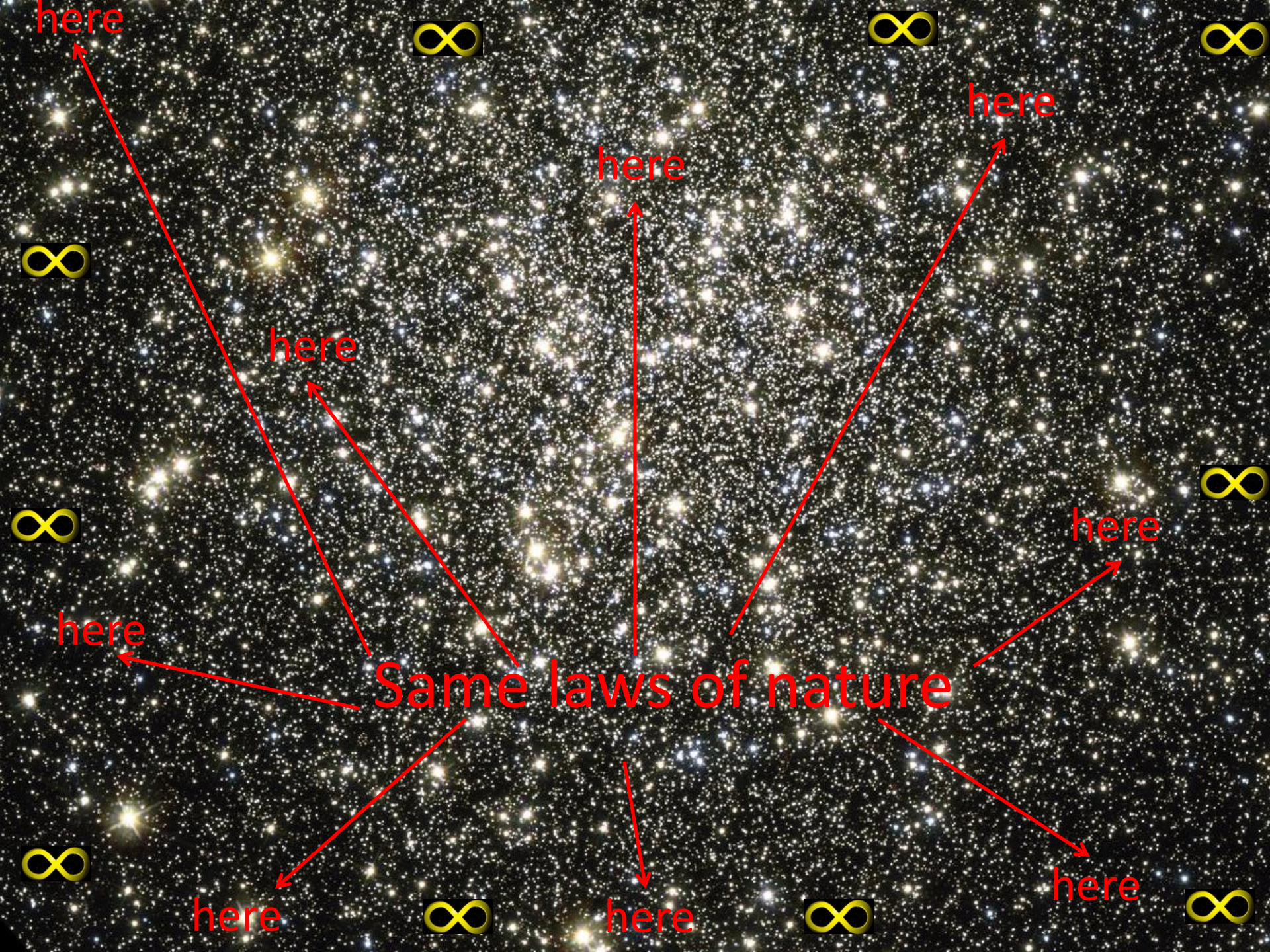
Aether

Aether

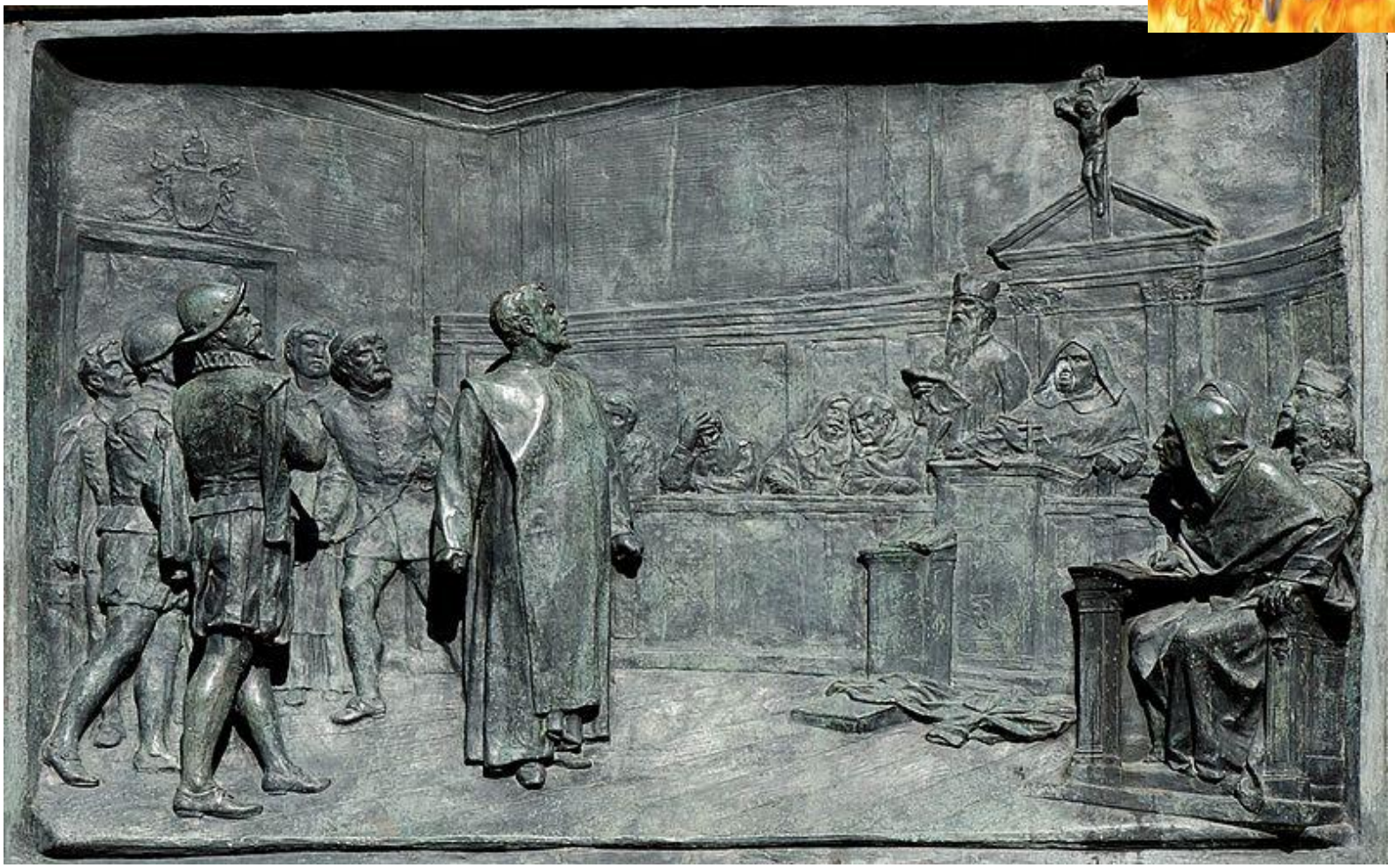
Laws of nature

earth, water, wind, and fire

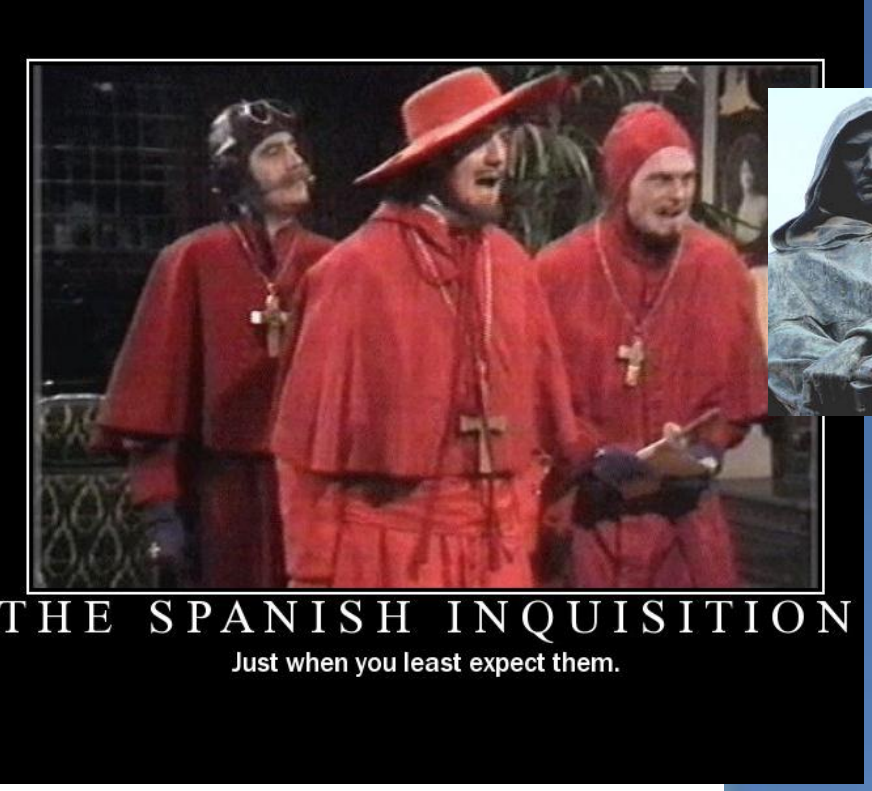
Aether


here
here
here
here
here
here
here
here
here
Same laws of nature

It is often asserted that Bruno died at the stake for supporting Copernicus' heliocentric views



1600



However, the church had a whole laundry list of acts of heresy against him

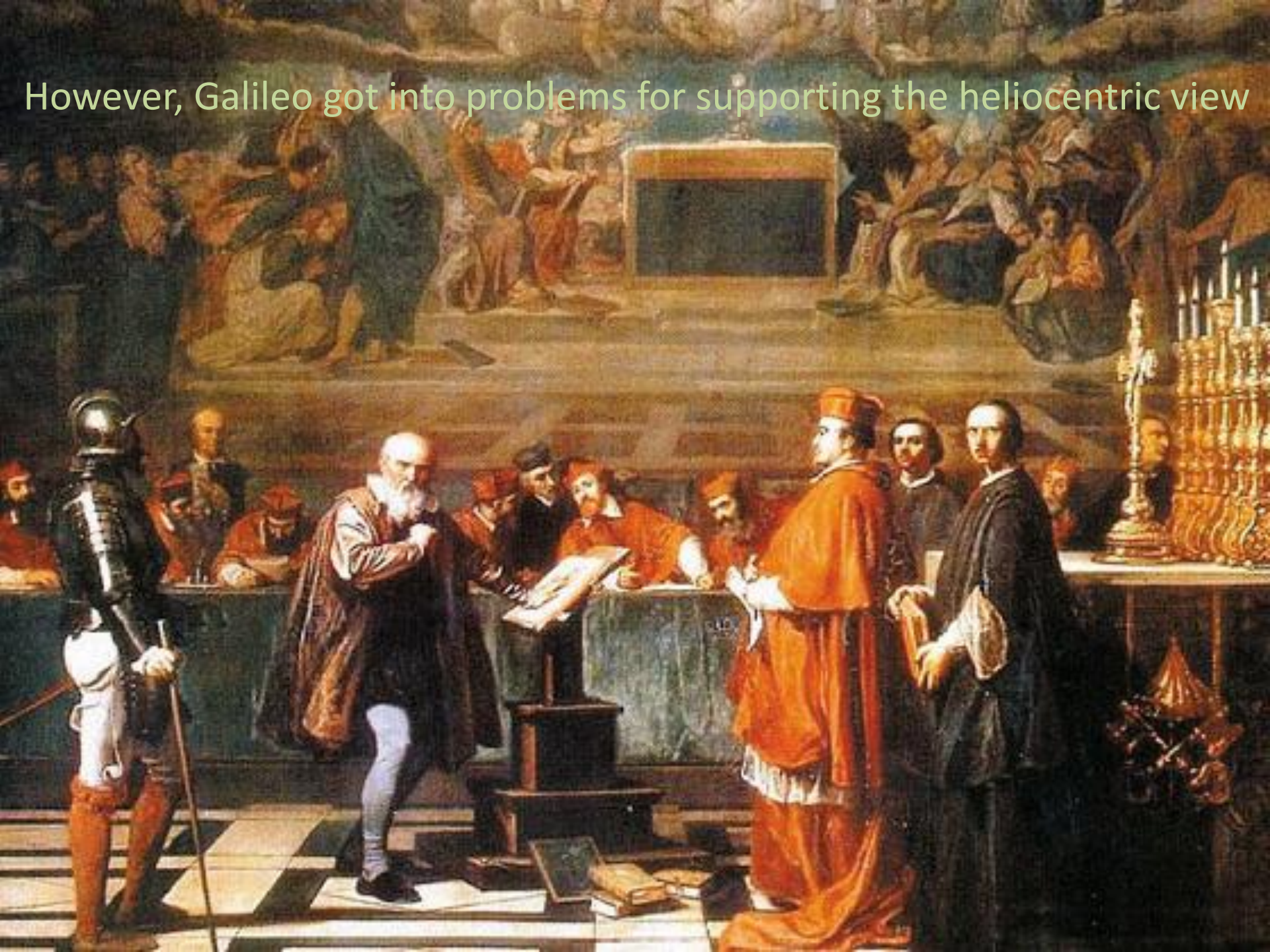
Laundry list

- holding opinions contrary to the Catholic faith and speaking against it and its ministers;
- holding opinions contrary to the Catholic faith about the Trinity, divinity of Christ, and Incarnation;
- holding opinions contrary to the Catholic faith pertaining to Jesus as Christ;
- holding opinions contrary to the Catholic faith regarding the virginity of Mary, mother of Jesus;
- holding opinions contrary to the Catholic faith about both Transubstantiation and Mass;
- claiming the existence of a plurality of worlds and their eternity;
- believing in metempsychosis and in the transmigration of the human soul into brutes, and;
- dealing in magics and divination.

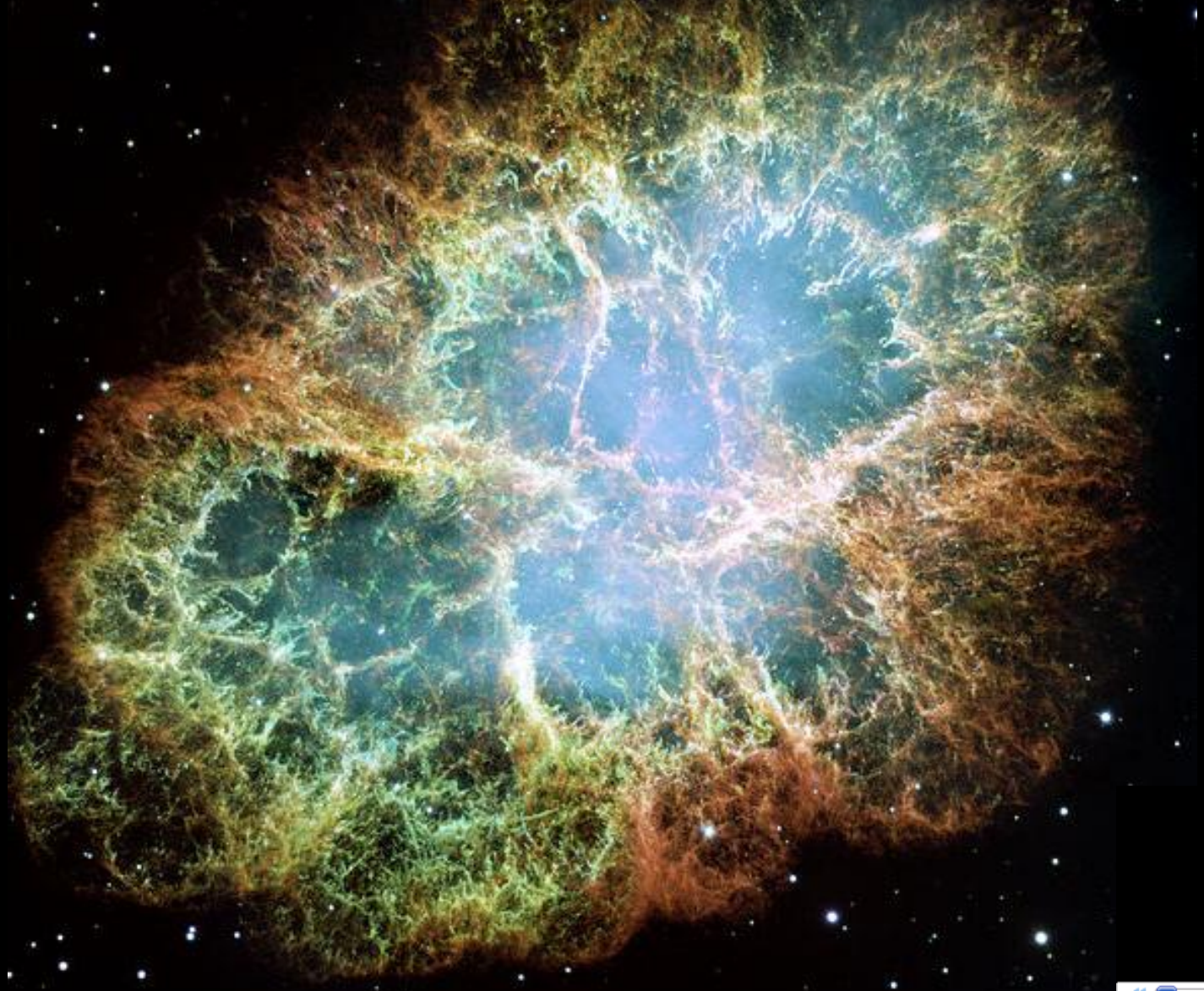
etc., etc., etc., etc., etc., etc., etc., etc.,

Galileo Galilei

However, Galileo got into problems for supporting the heliocentric view



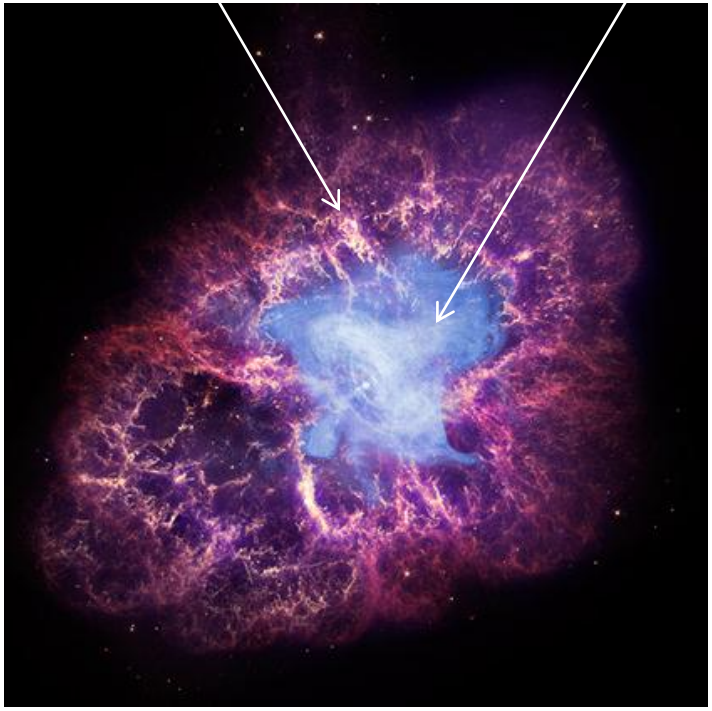
Galileo discussed the remains of the a superonova, stating that the universe does change, contrary to Aristotle's position

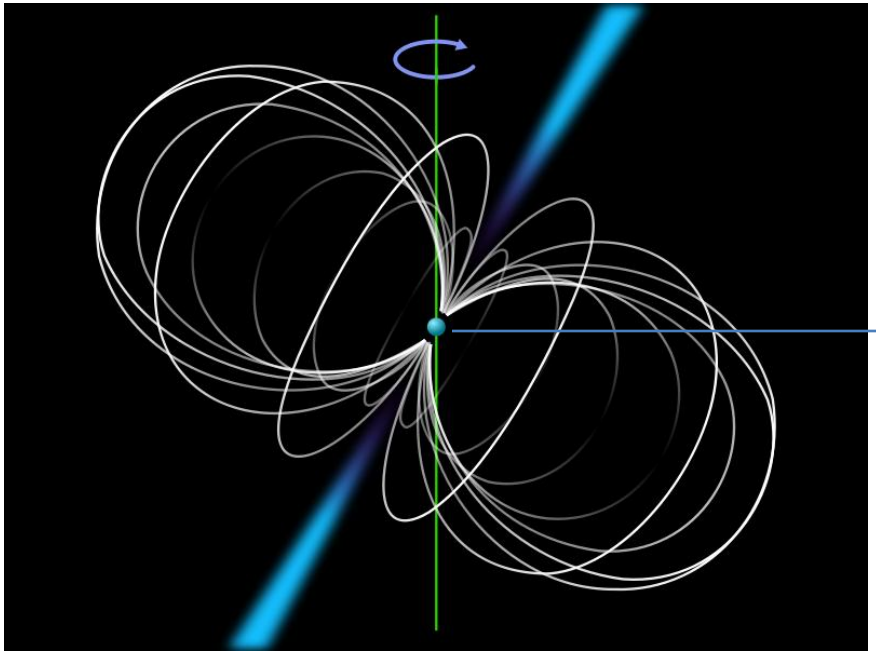


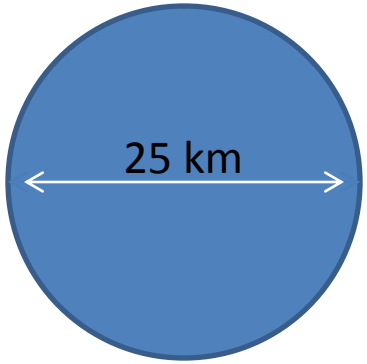
Previous page: Crab nebula

- Exploded in 1054 AD
- Explosion observed by Indian, Arabic, Chinese, and Japanese astronomers (Hey, Europeans, what were you doing?)

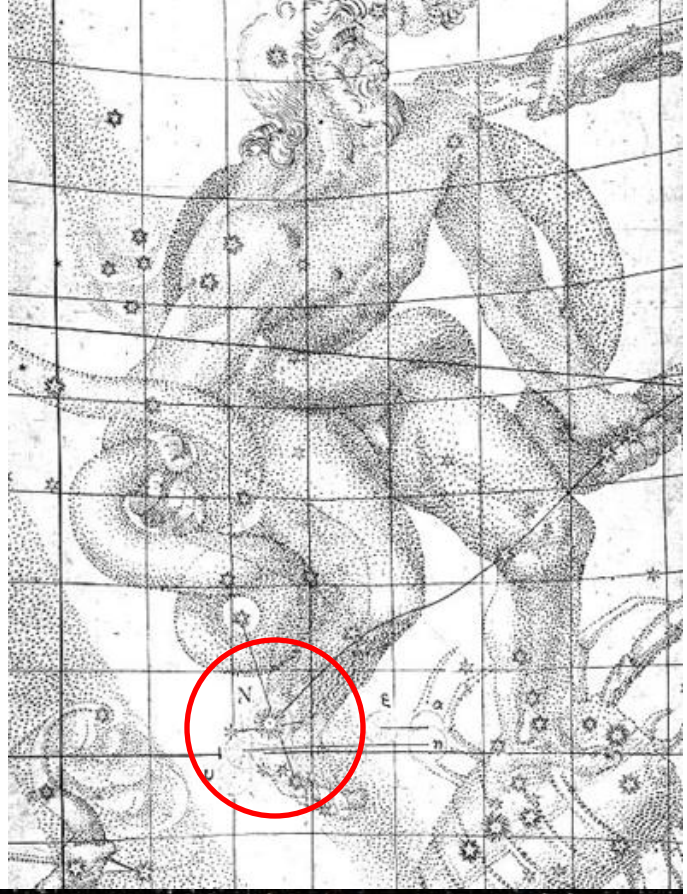
Optical image X-ray image





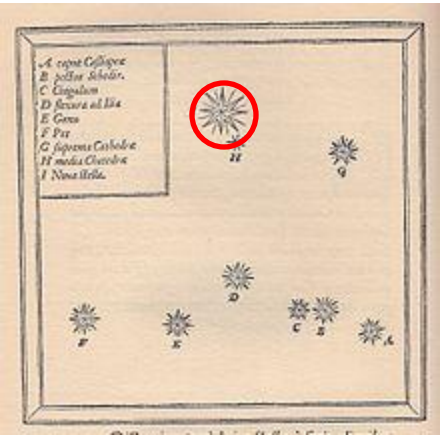


Turns 30 times per second

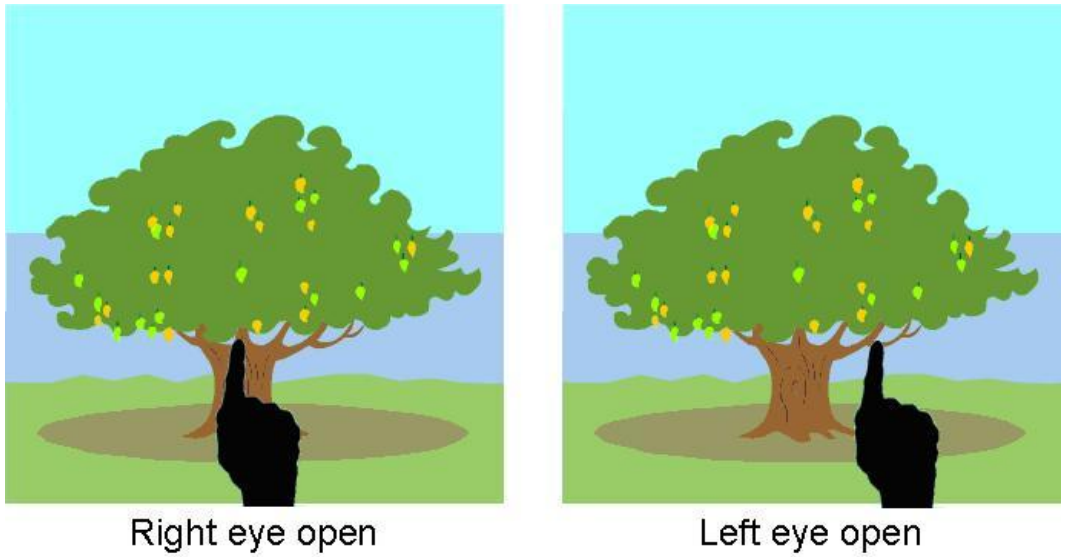


Remnant of
Kepler's supernova

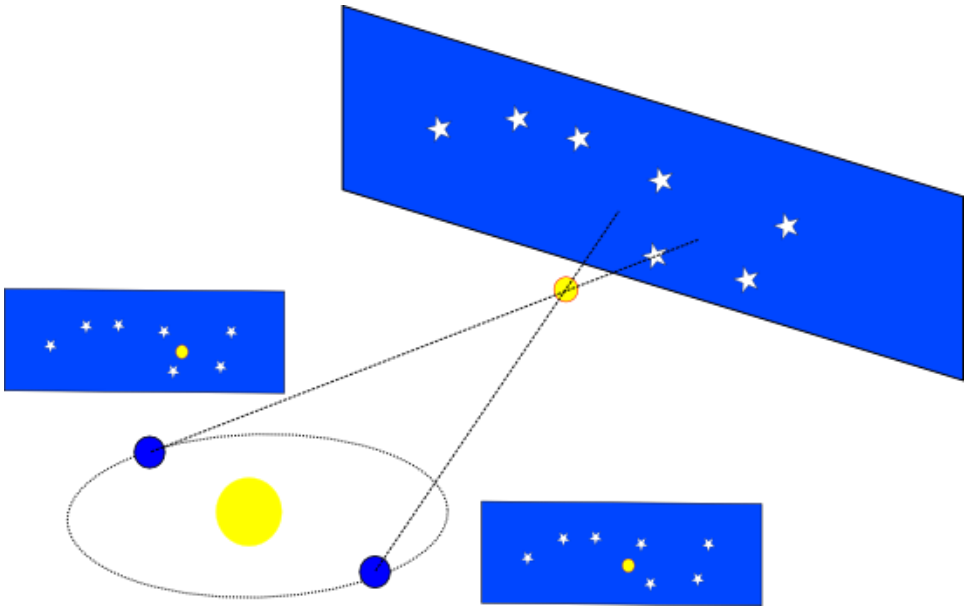
- Occurred in the Milky-way in 1604
- 20,000 light years from Earth (1.9 10^{17} km)
- Brighter than all stars and planets, except Venus
- Visible during the day for three weeks
- Lucky: Tycho Brahe's supernova happened in 1572



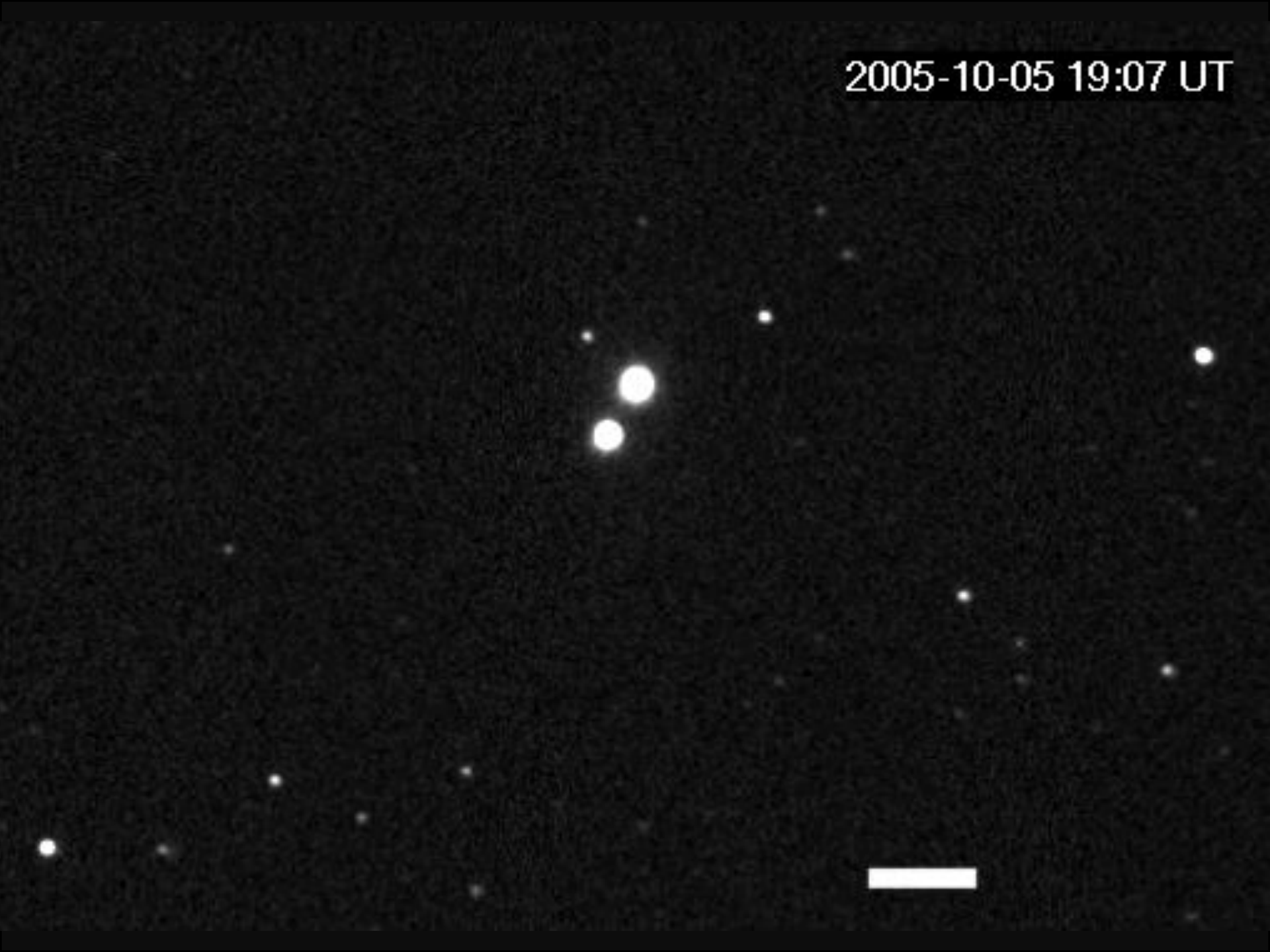
Galileo studied the parallax with respect to distant stars



Presence of parallax (the movement of the finger) with respect to the distant object indicates finger is close to your eyes



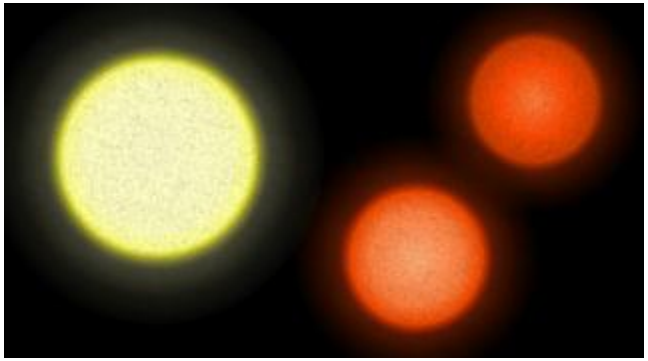
Same can be done with stars


2005-10-05 19:07 UT

First distance determination using parallax

Motion first observed in 1804
by Giuseppe Piazzi

61 Cygni is a double star system



Sun (left), 61 Cygni A (bottom) and 61 Cygni B (upper right).

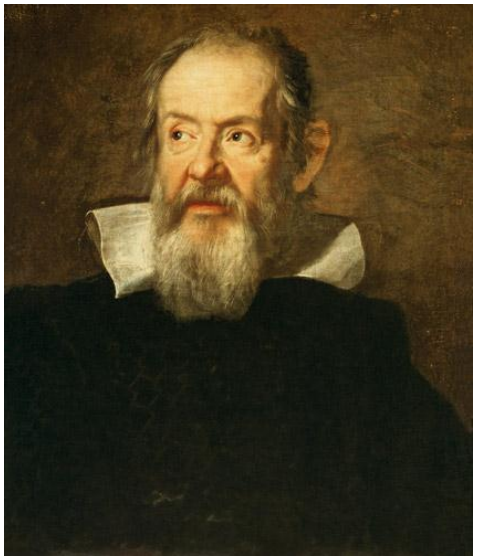
Period 659 years

15th nearest known star system

Calculation of distance from parallax by Friedrich Bessel (1784 –1846)

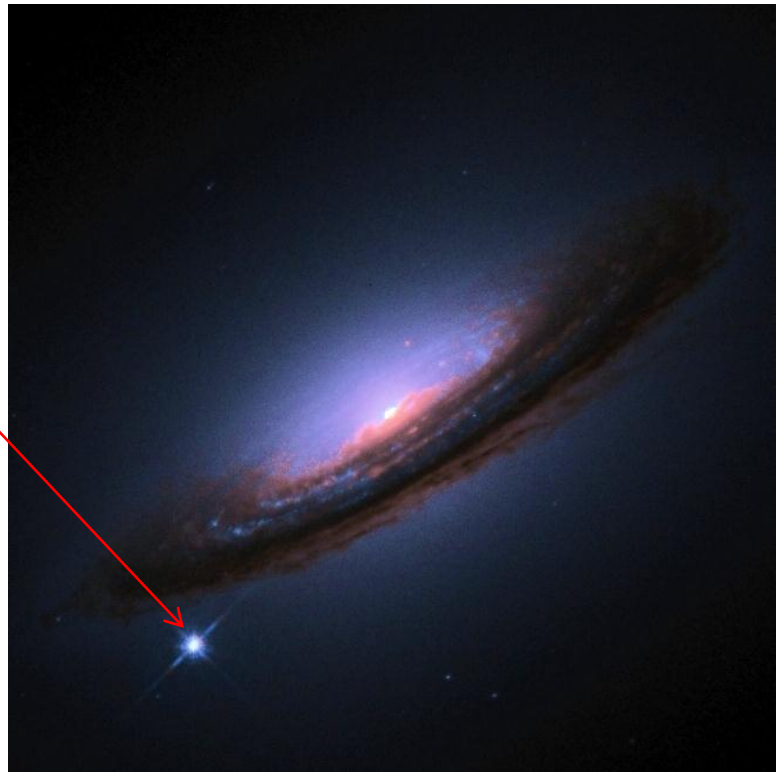
Determined 10.4 light years, actual distance 11.4 light years=1.07 10^{14} km

Galileo did no such thing, but he noticed that there was no parallax



This shit was happening really far away and not in our solar system

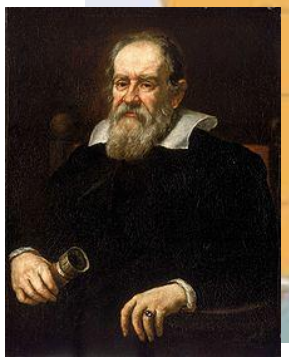
Supernovae in different galaxies



Invention of the telescope:

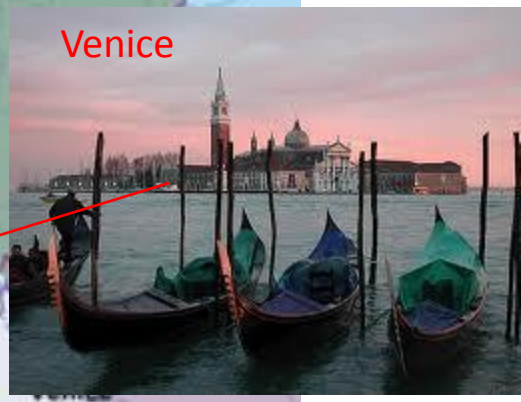
Hans Lippershey
1608

Galileo heard of this
in Venice in 1609



Middelburg town hall
1452-1520

1592-1610



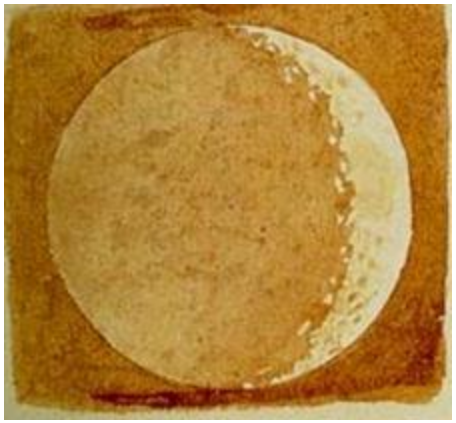
Venice

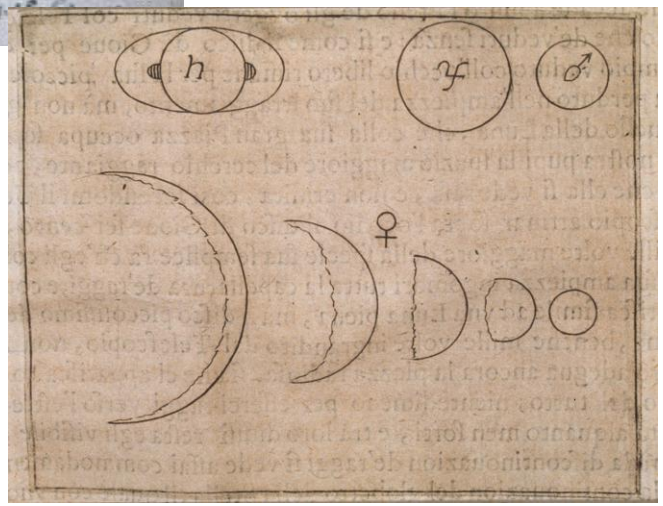
1564-1592

Pisa

Padua Basilica of
St. Anthony 1232-1301

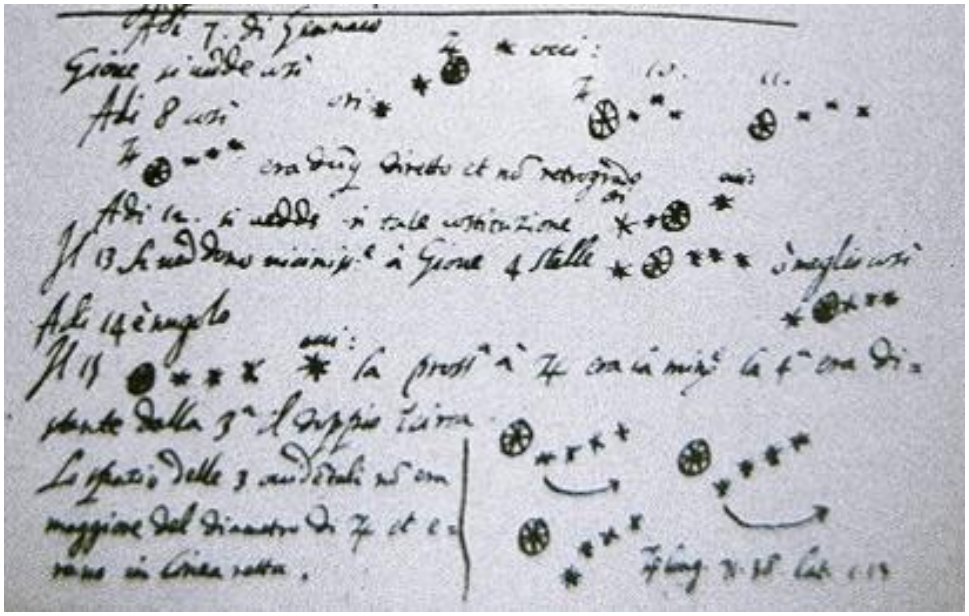
Galileo's telescope 20x magnification

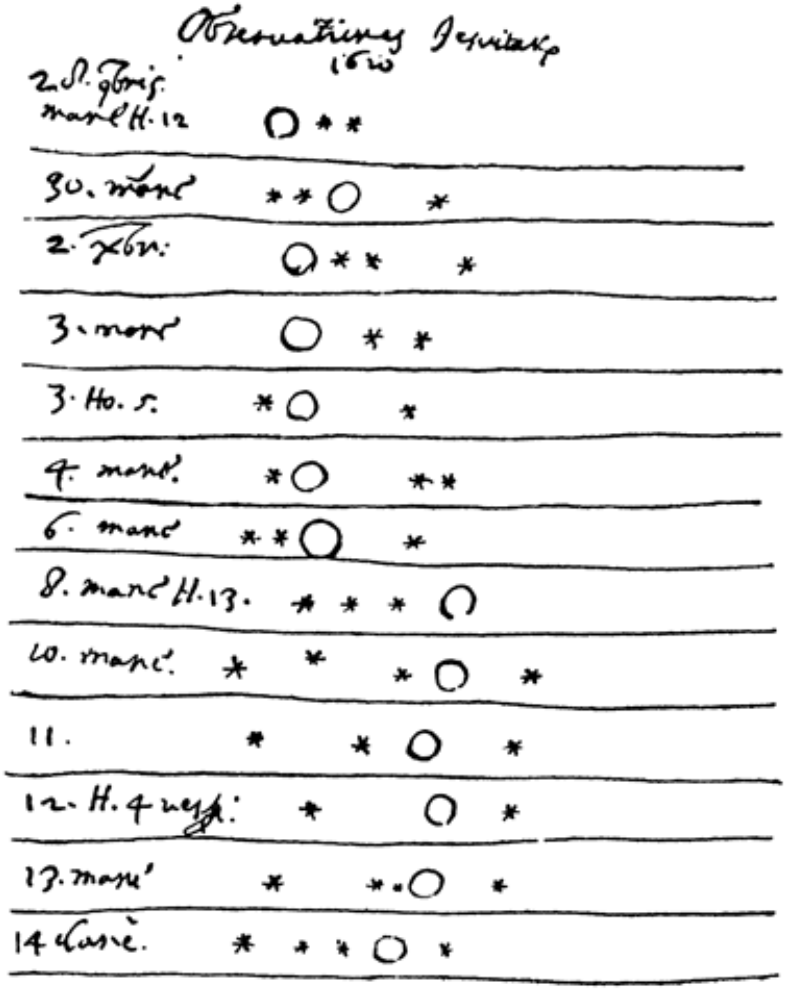




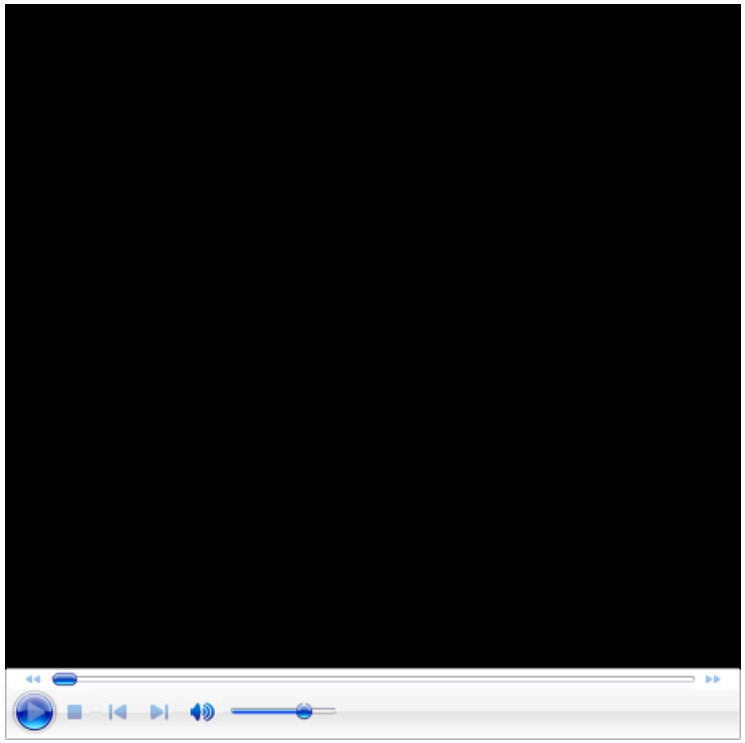
Obviously, he directly turned his telescope to the sky!

He made detailed observations of Jupiter and saw something orbiting the planet

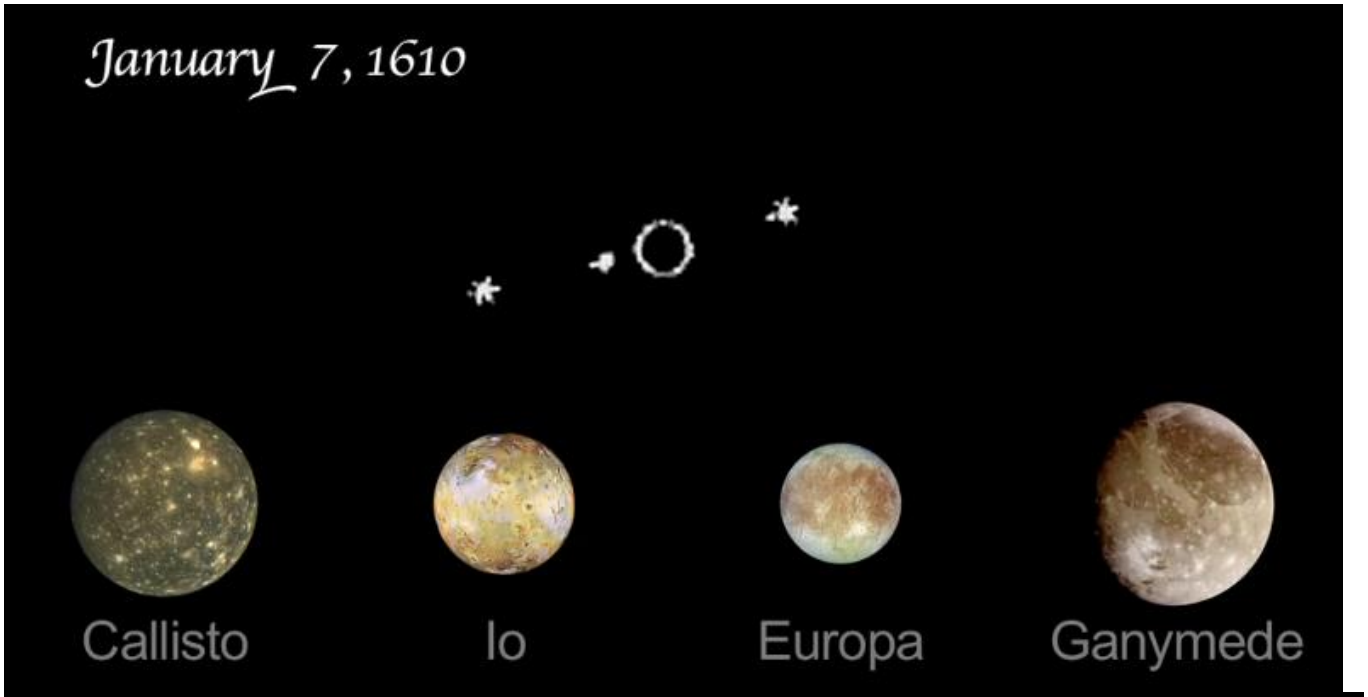




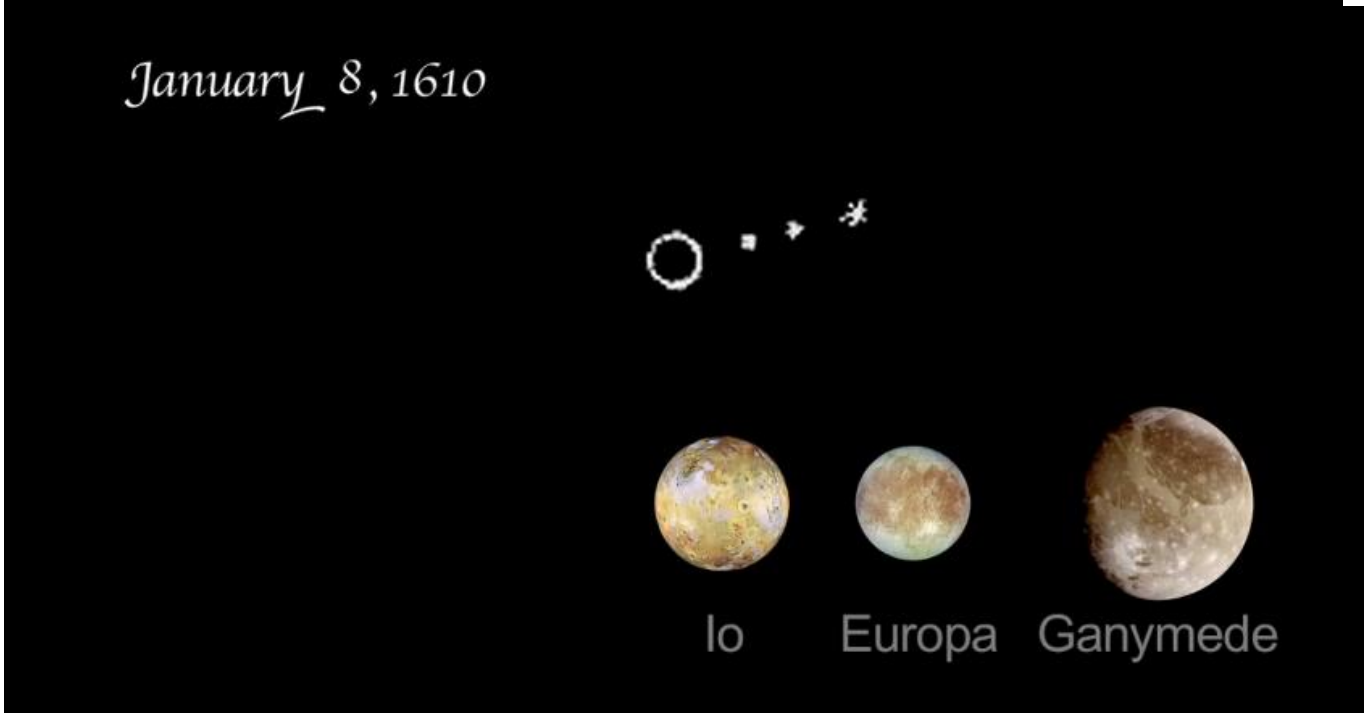
This is what one can do with a modern telescope



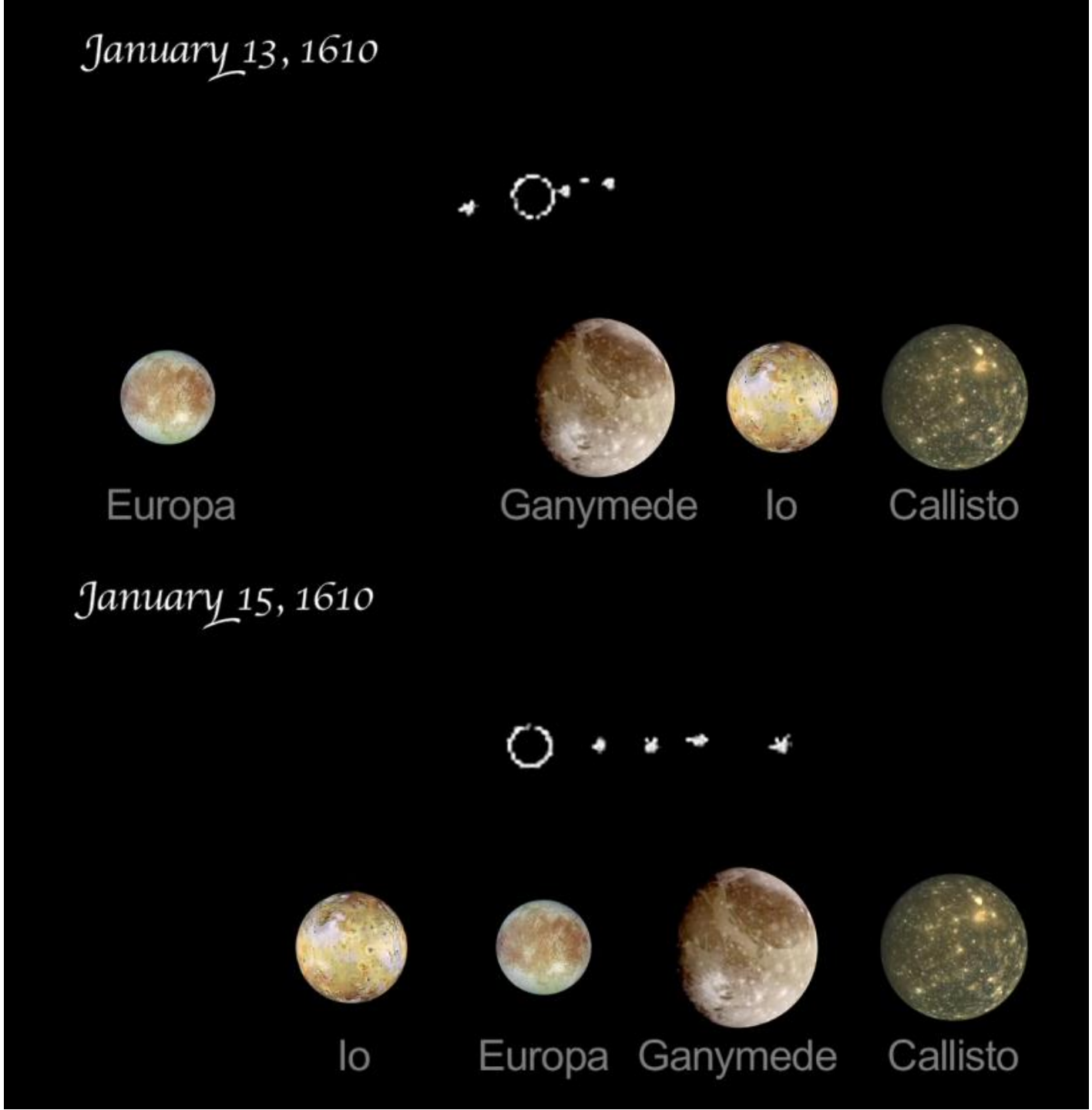
total time 3-4 hours



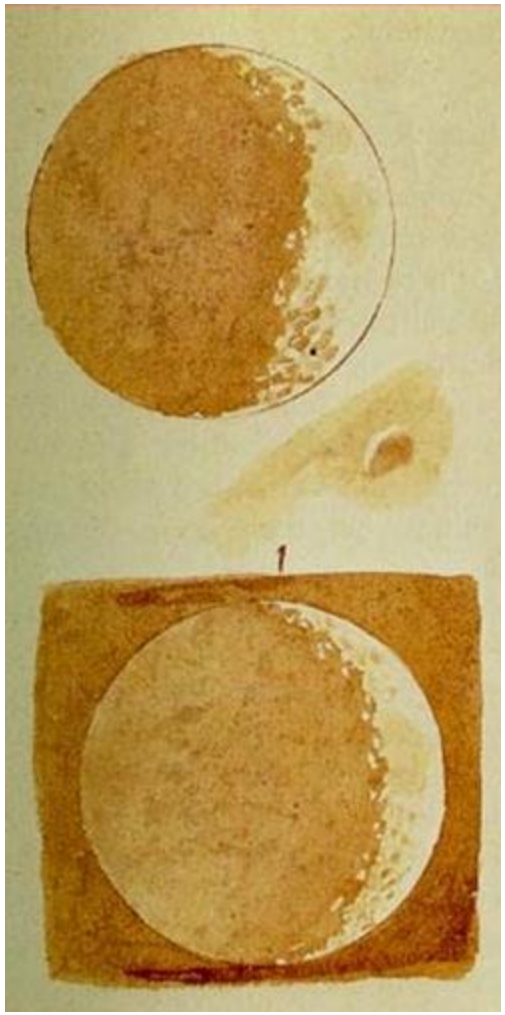
Galileo's notes 1610

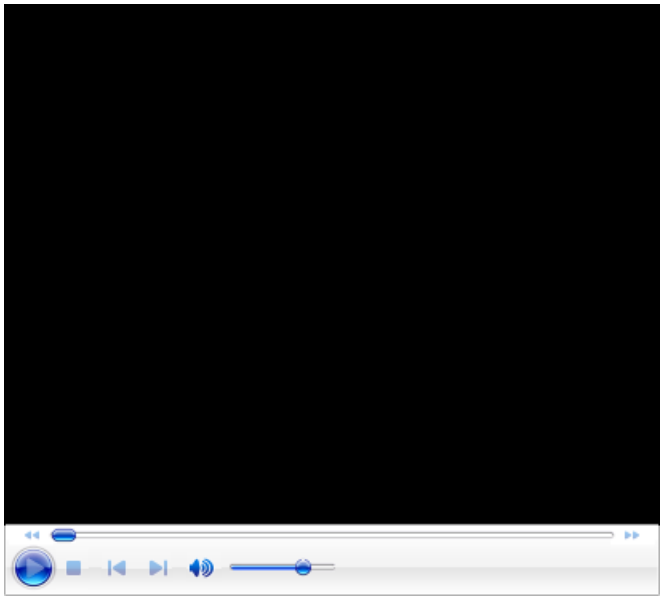


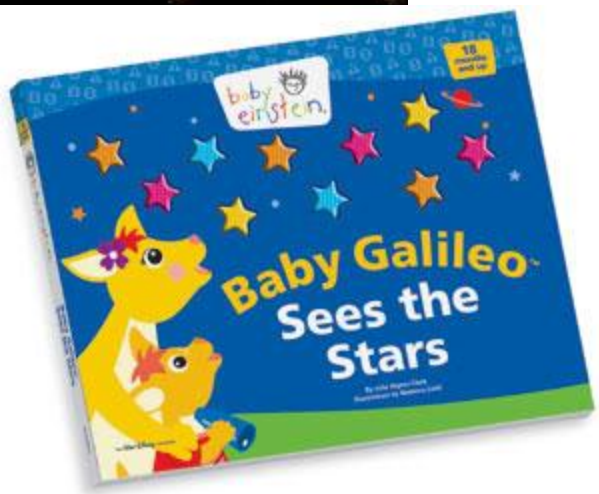
Modern interpretation


January 13, 1610
Europa
Ganymede
Io
Callisto
January 15, 1610
Io
Europa
Ganymede
Callisto

There are mountains on The Moon

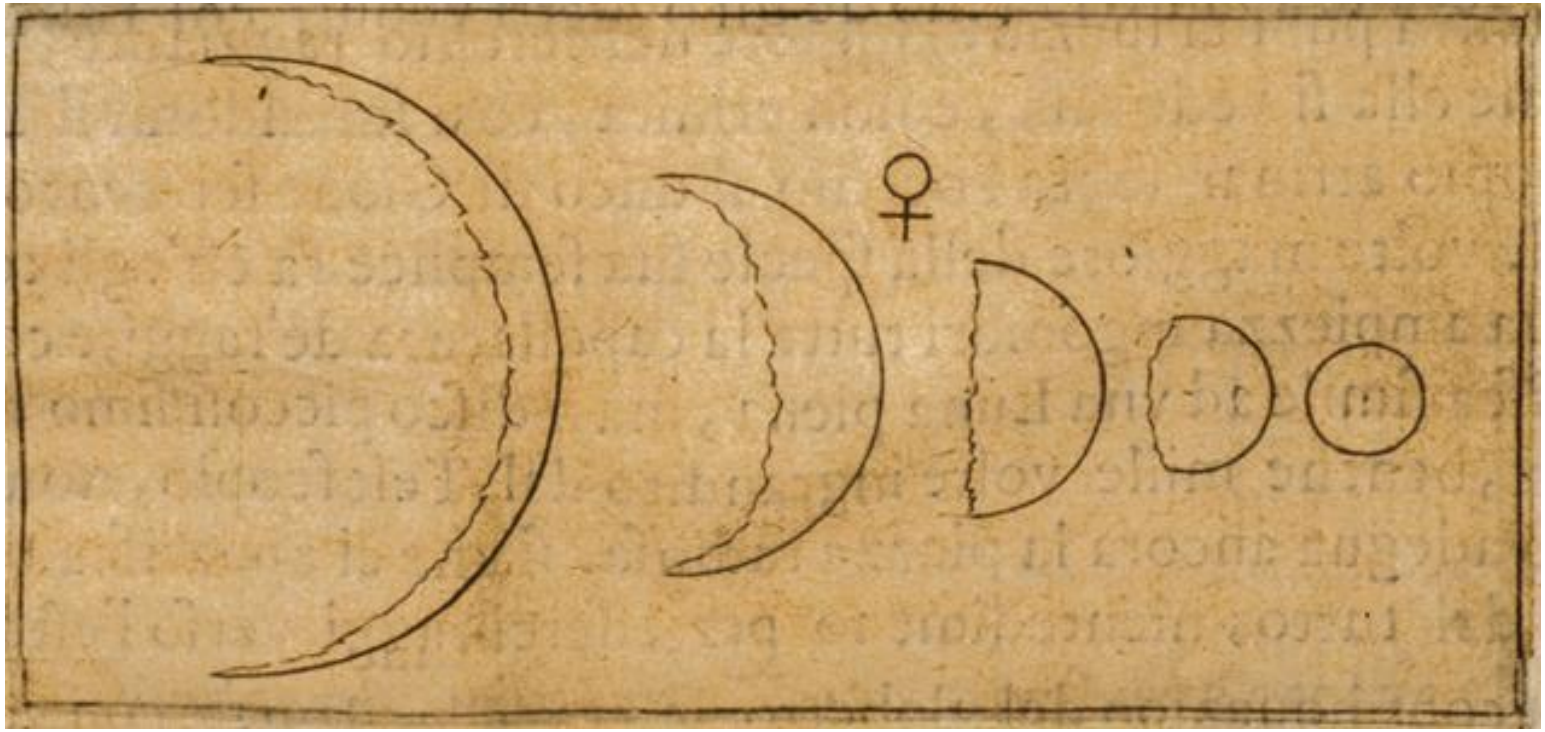






The Milky Way consists of separate stars,
Not one big cloudy (milky?) substance

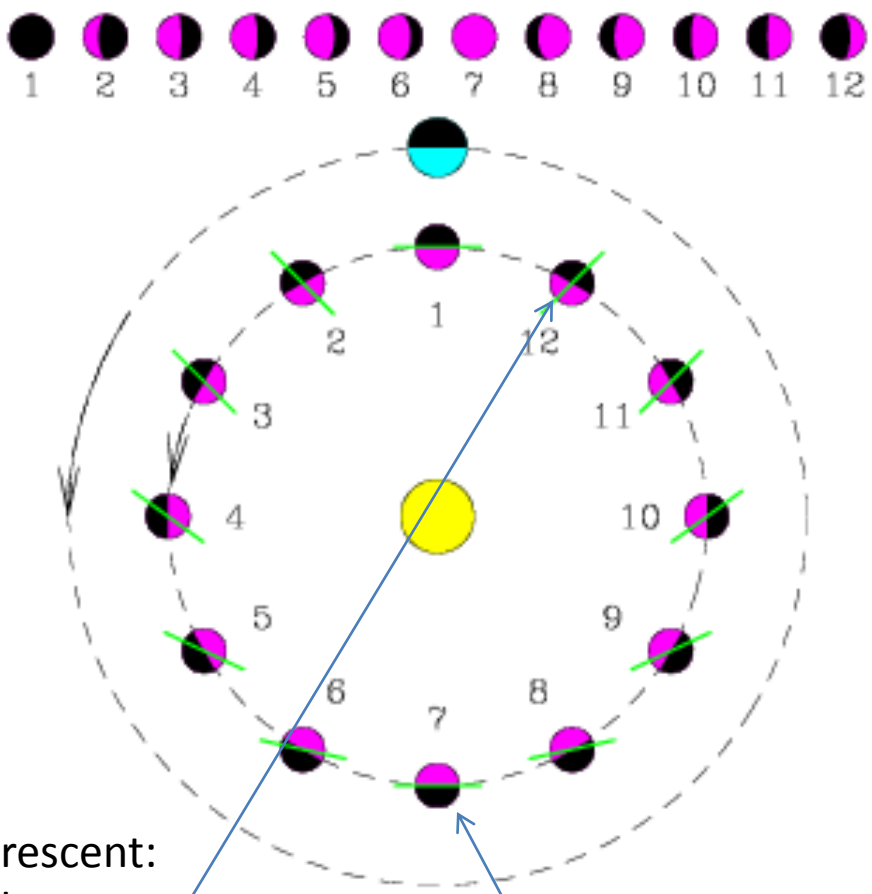
Phases of Venus



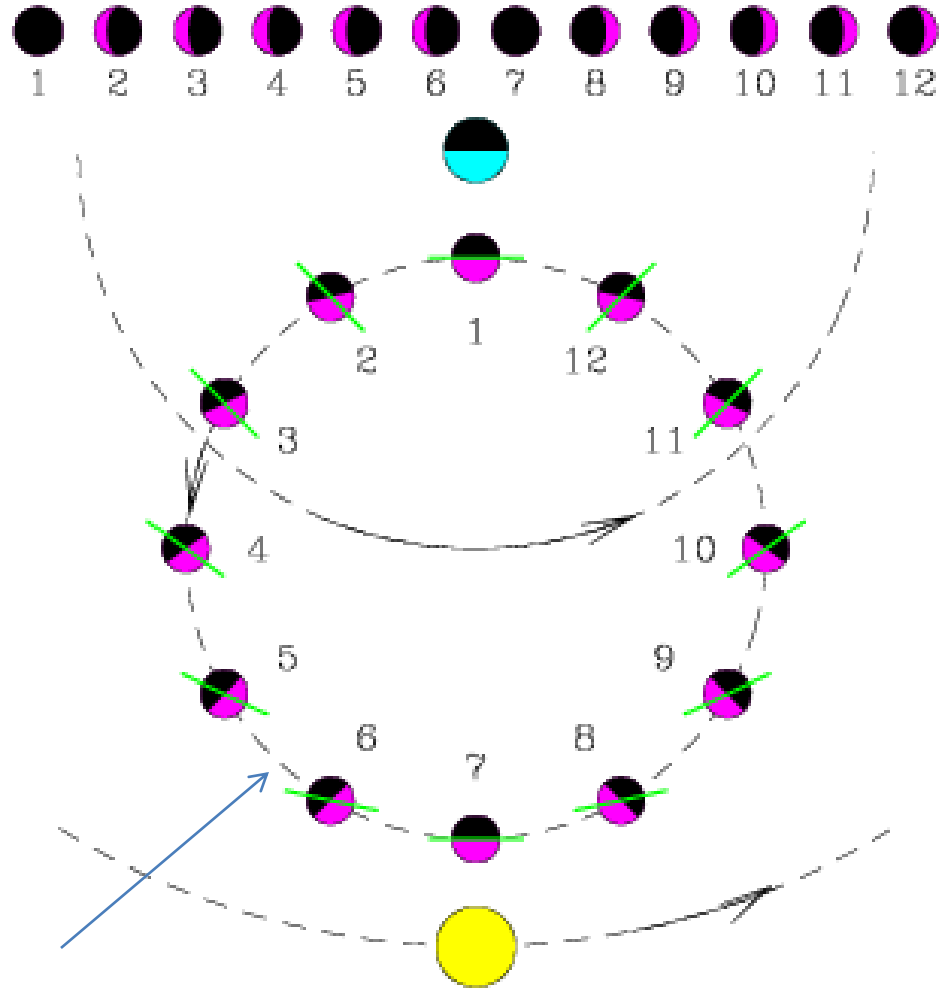
Galileo's notes

Modern telescope

Full phase

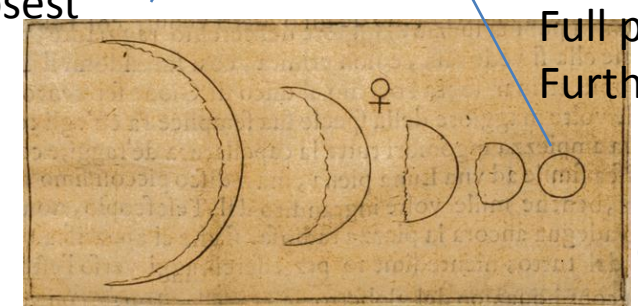


Full phase



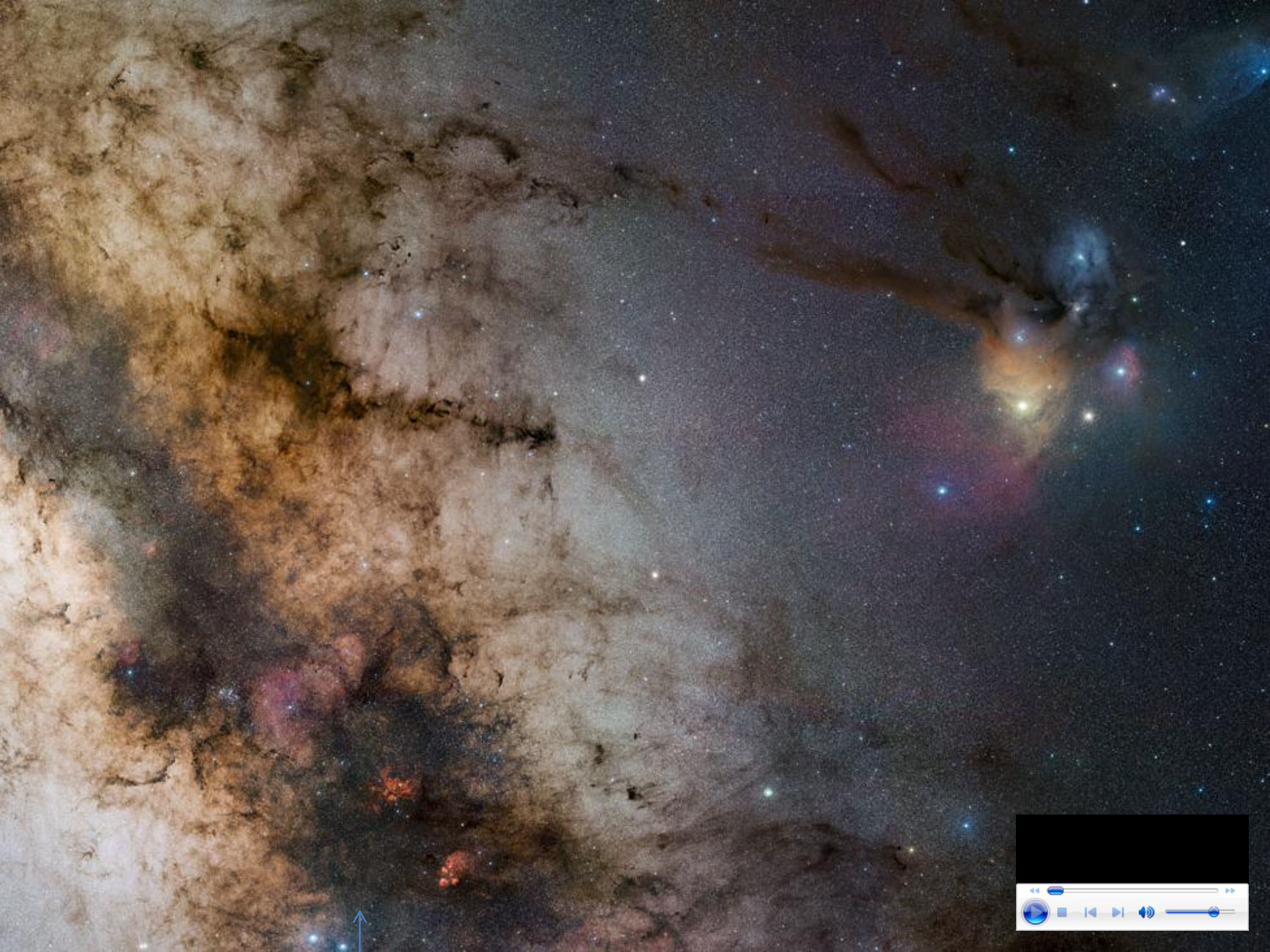
crescent:
closest

Full phase:
Furthest away



Epicircle (not to scale)

Observations support heliocentric view!



Dialogue Concerning the Two Chief World Systems

Series of discussions between Salviati (Copernican heliocentric view), Sagredo (layman, neutral), and Simplicio (Ptolomean geocentric view).

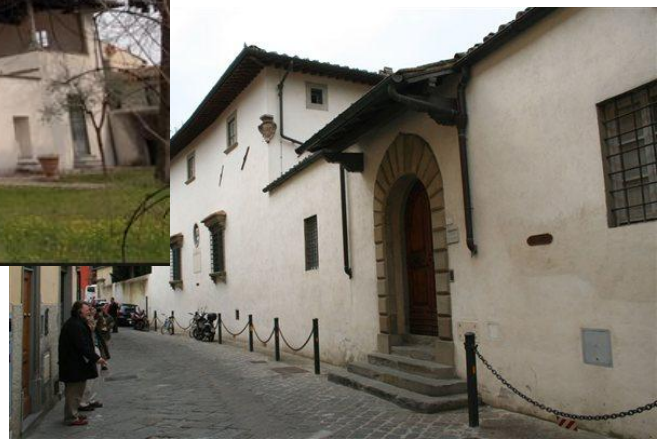
DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filosofo, e Matematico primario del
SERENISSIMO
GR. DVCA DI TOSCANA.
Doue ne i congressi di quattro giornate si discorre
sopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPE
Proponendo indeterminatamente le ragi
tanto per l'vna, quanto per
CON PRI
IN FIORENZA, Per Gio:Batista
CON LICENZA DE'

Got into problem with the church, who found Galileo "vehemently suspect of heresy"

Galileo's sentence of imprisonment was converted into house arrest

Eppur si muove---And yet it moves

Arcetri 1633-42

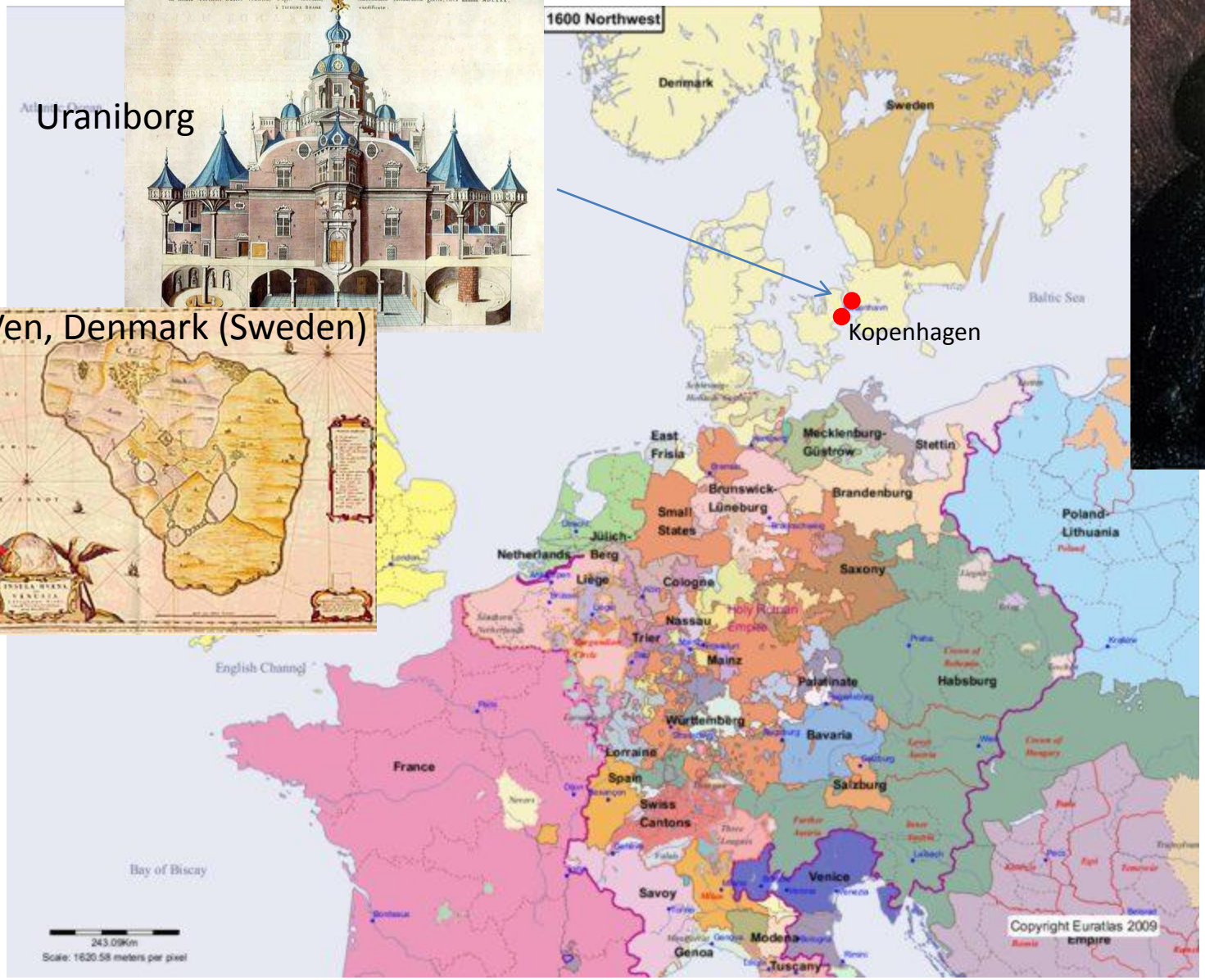


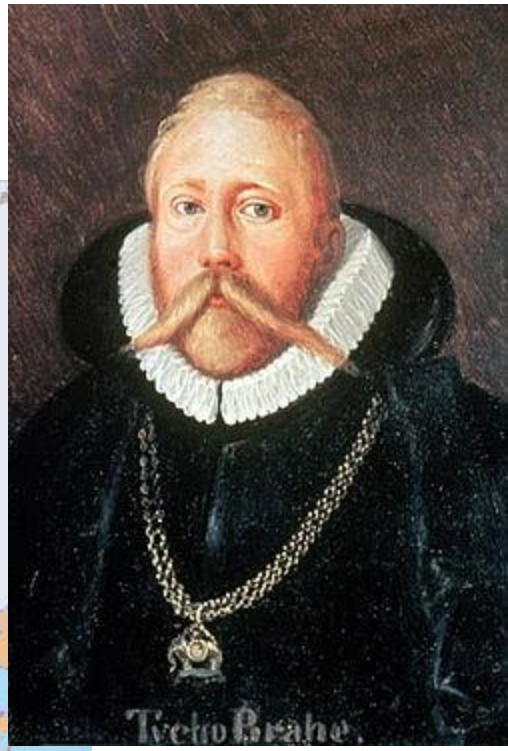
Brahe and Kepler

Further additions to the heliocentric system
Tycho Brahe (1546-1601) and Johannes Kepler

Uraniborg

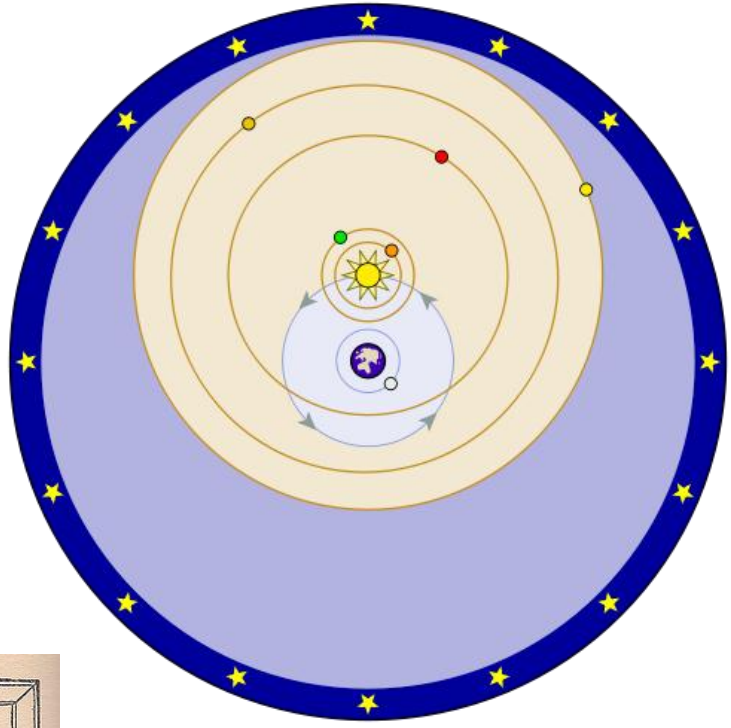
Ven, Denmark (Sweden)



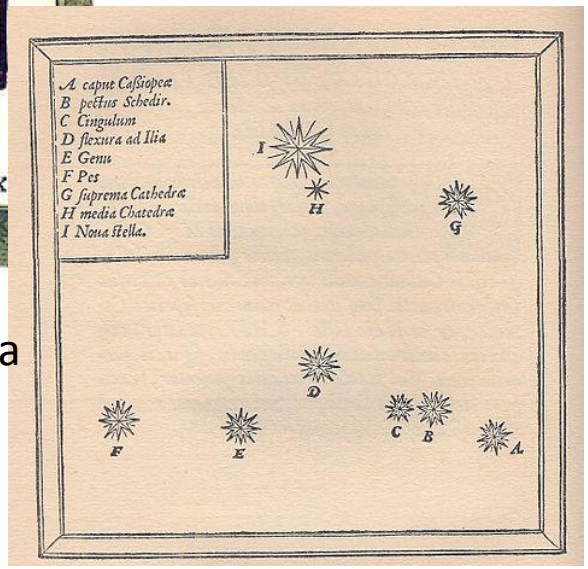


Brahe was known for his accurate measurements of planetary motions

We return to that with Johannes Kepler



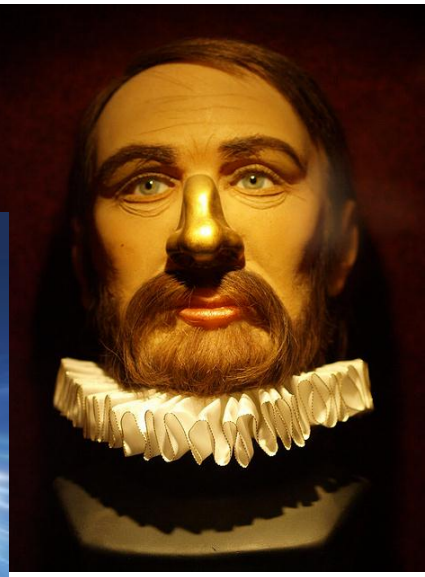
Had his own compromise geo/heliocentric model (it kind of sucked…)



Also observed supernova

However Brahe is also know for:

Loosing part of his nose in a sword duel over a mathematical formula with his third cousin Manderup Parsberg

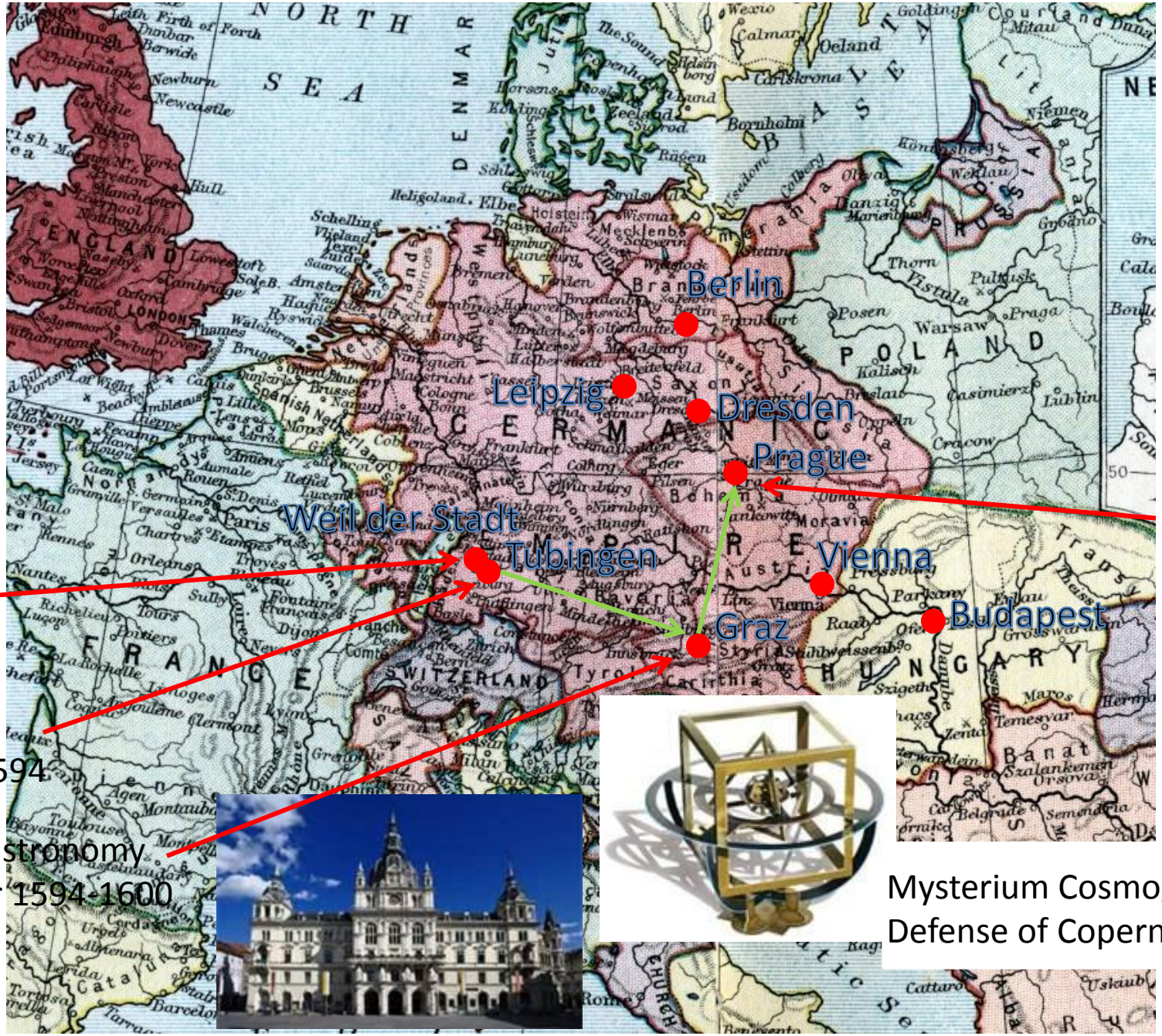


Brahe was from a very rich noble family

Had a pet moose (does such a thing exist) that died by falling down the stairs, drunk….

Brahe died by contracting kidney failure by refusing to go to the bathroom since that would be bad etiquette

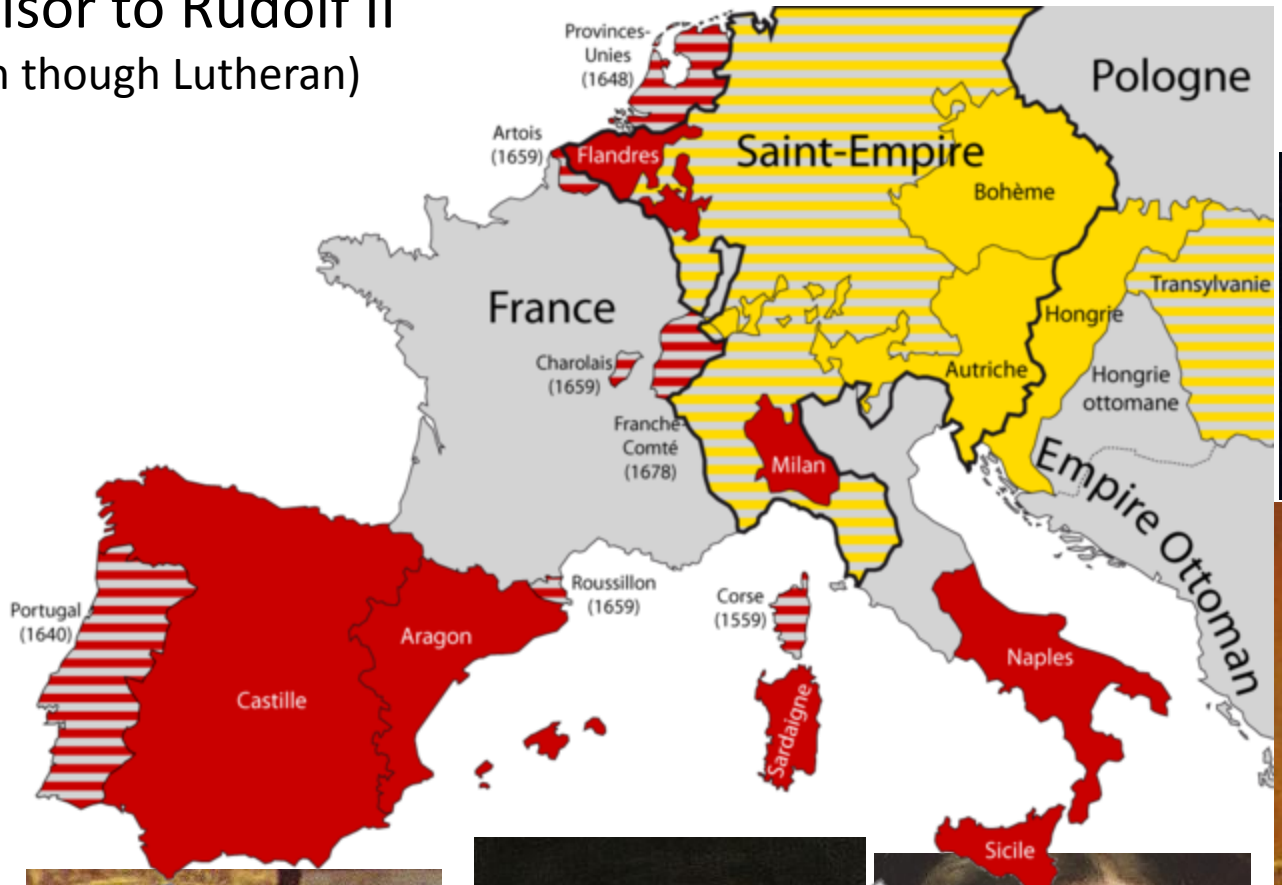
He was succeeded by Johannes Kepler (1571-1630)



Banished from Graz for refusing to convert
To Catholicism 1600-1609 Prague

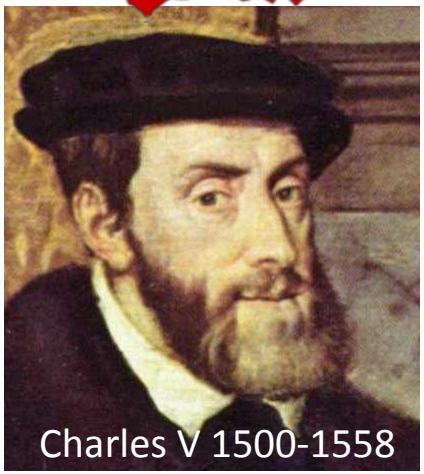
Worked for Brahe who died in 1601

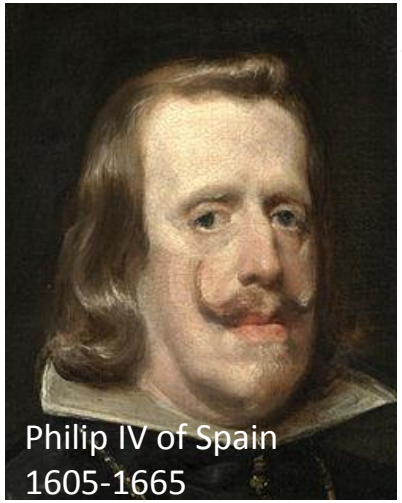
Advisor to Rudolf II
(even though Lutheran)

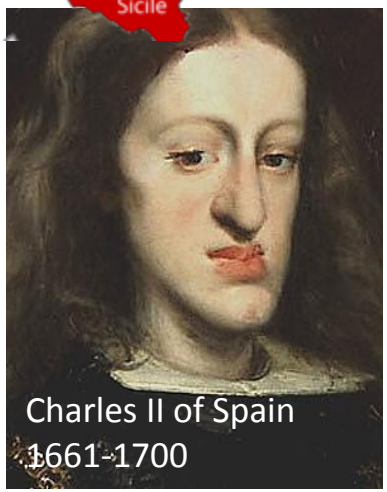



Rudolf II of Austria
1552-1612


Leopold I of Austria
1640-1705

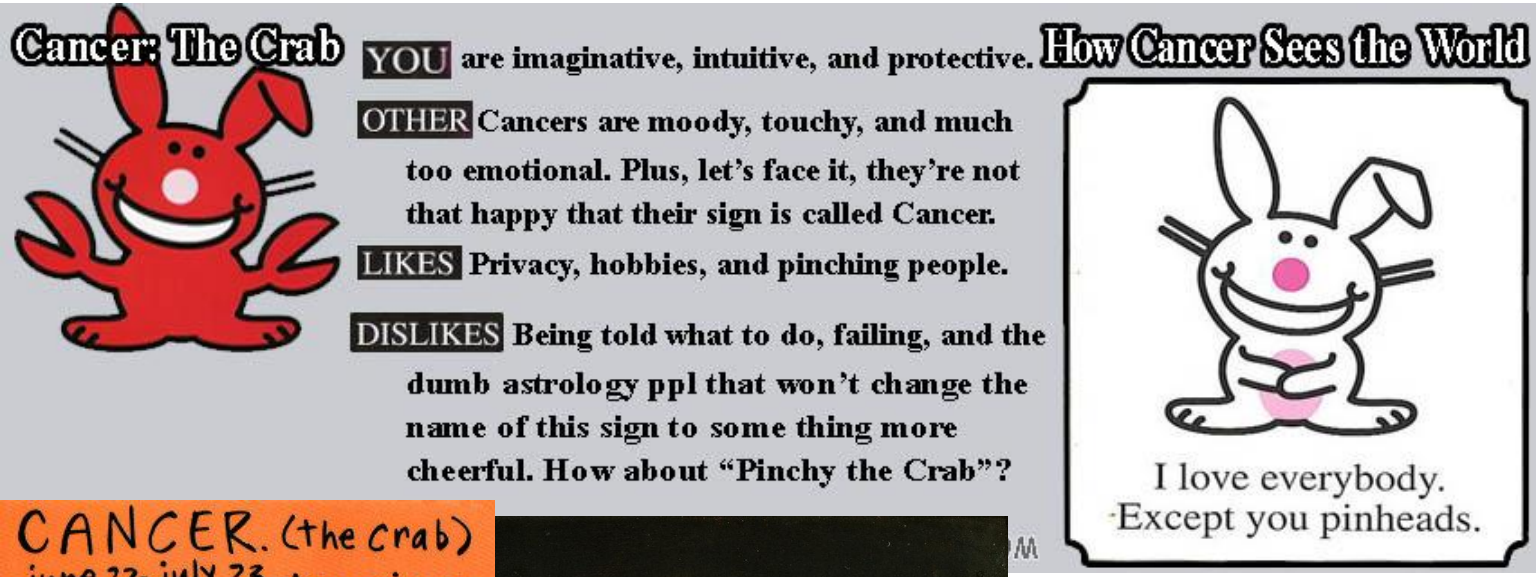

Charles V 1500-1558

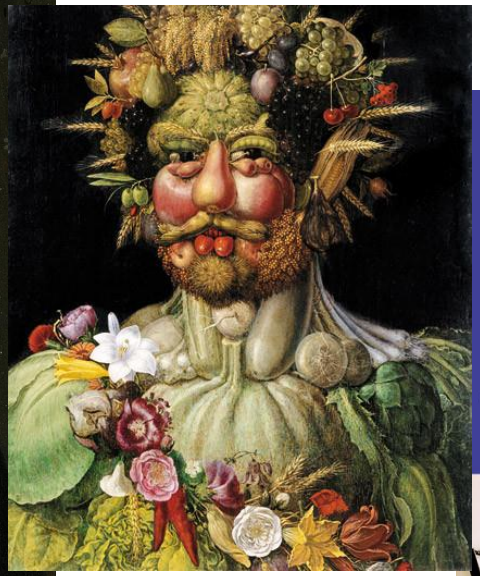

Philip IV of Spain
1605-1665


Charles II of Spain
1661-1700

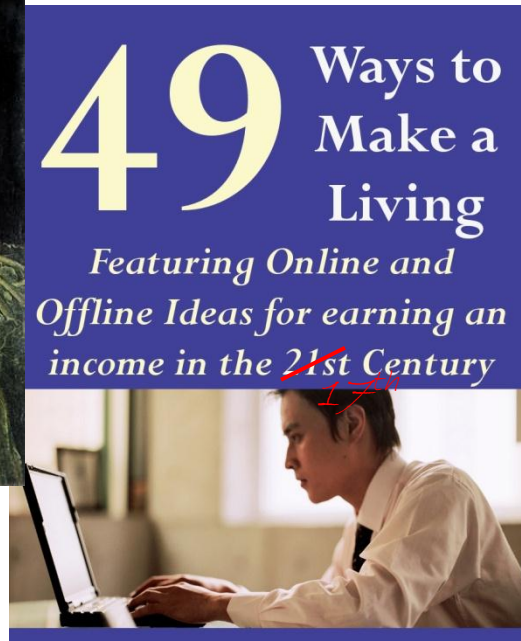

Angelina Jolie (not a Habsburg ...) 1975-

Ok, the major part of the job involved being Rudolf II's personal astrologer

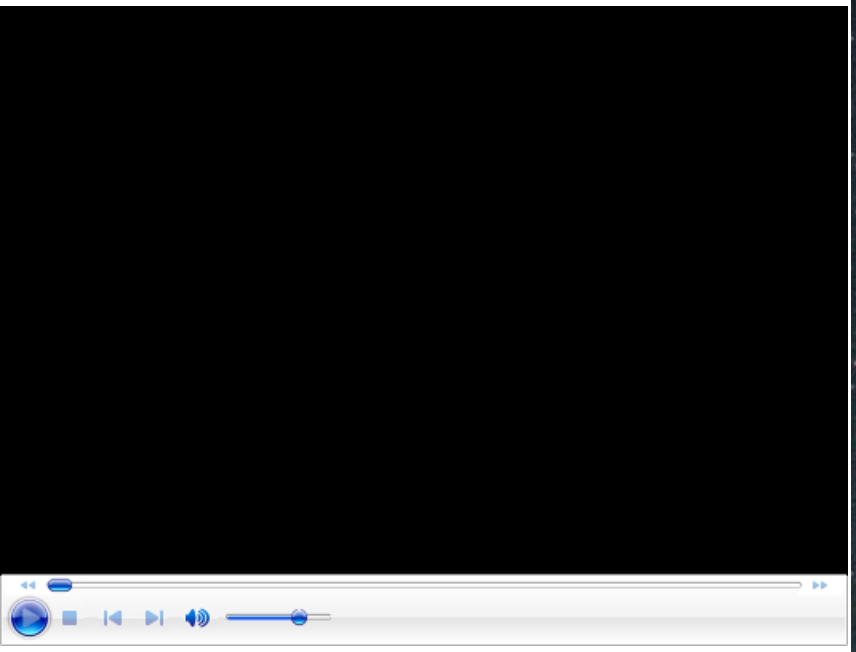


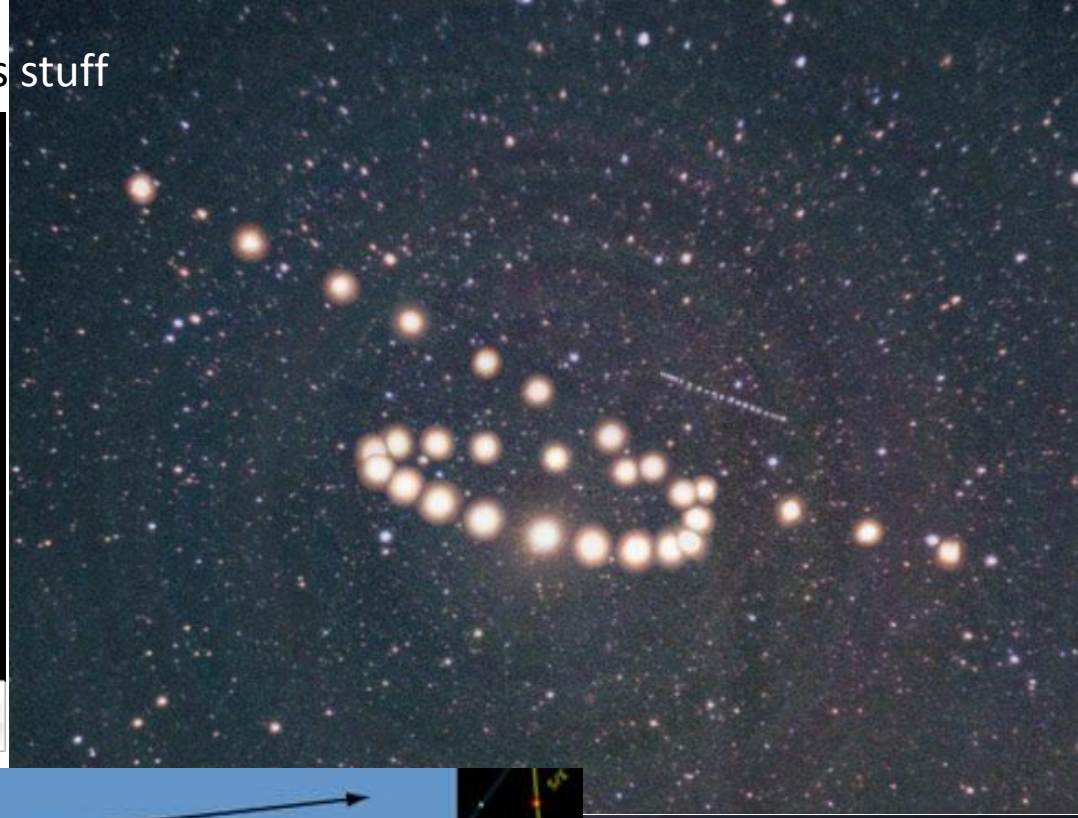


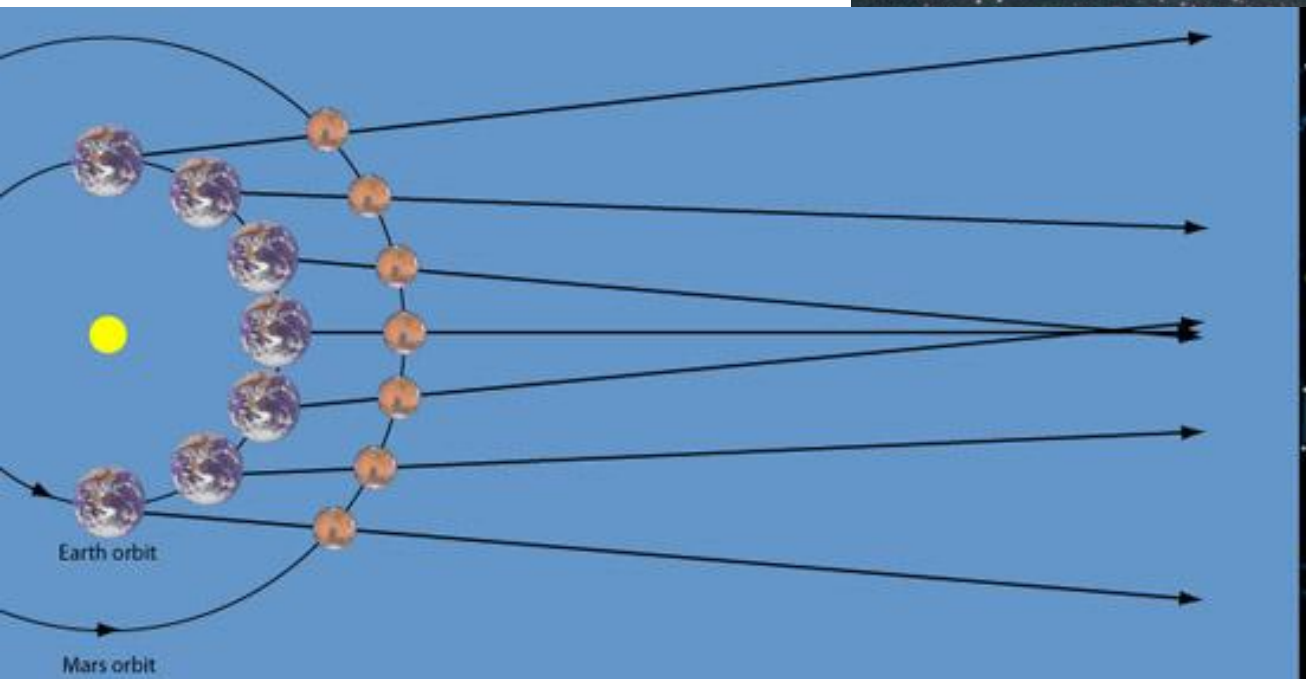
Arcimboldo's fruity version of Rudolf II



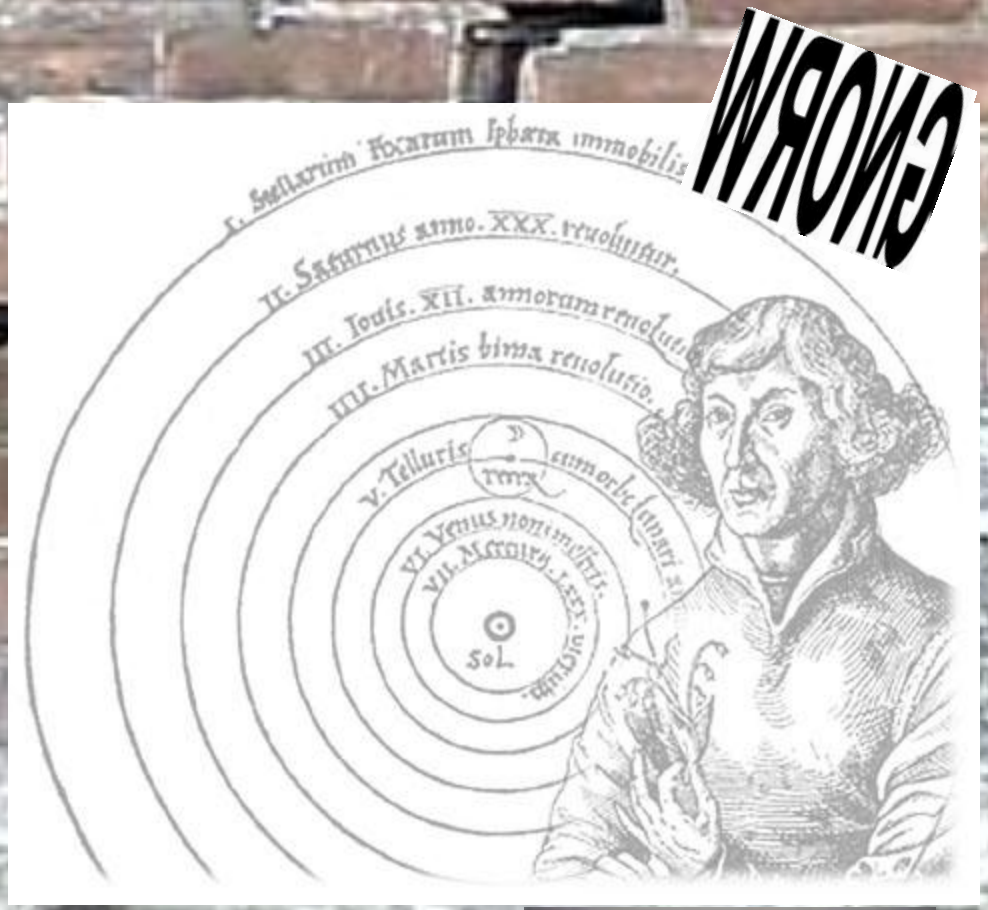
He still had some time to do some serious stuff





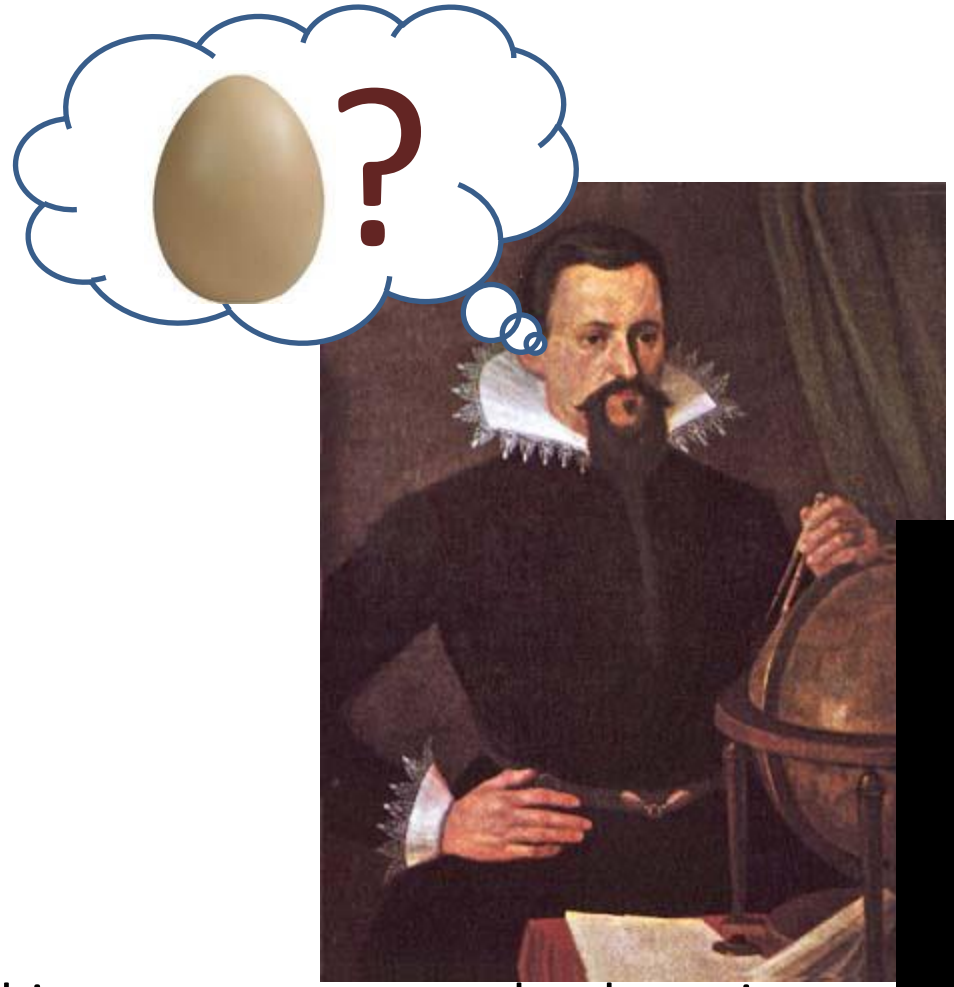


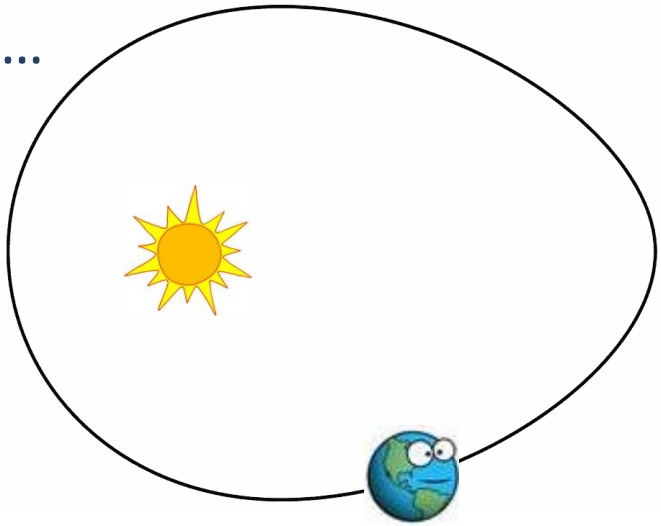
However, Johannes Kepler noticed failings in the heliocentric model proposed by Copernicus



Are we starting to see cracks in the harmony and reform of the renaissance?

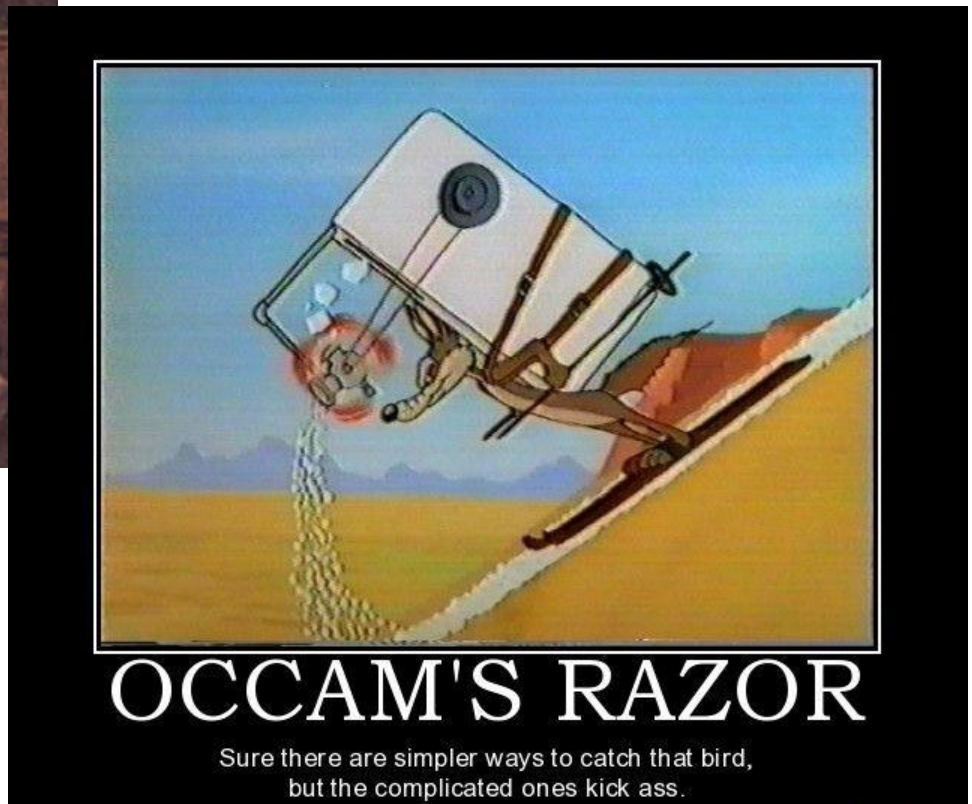
So Kepler had to search for something else…





This seems to go completely against

Occam’s razor that simpler ( ) is better.



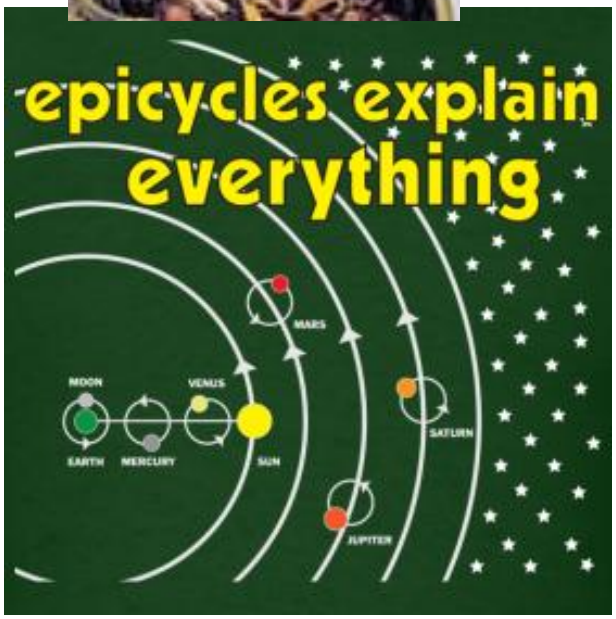
The renaissance was focused on

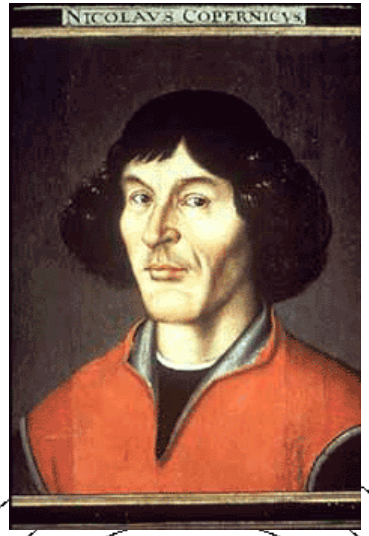


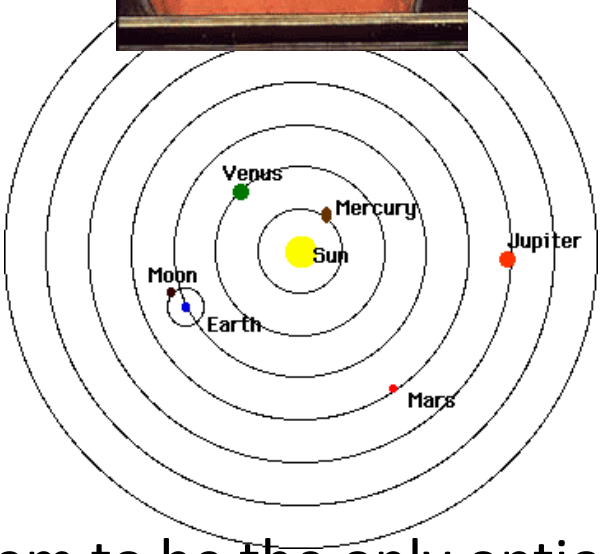


classical beauty and perfection

So when it came to switching from geocentric to heliocentric

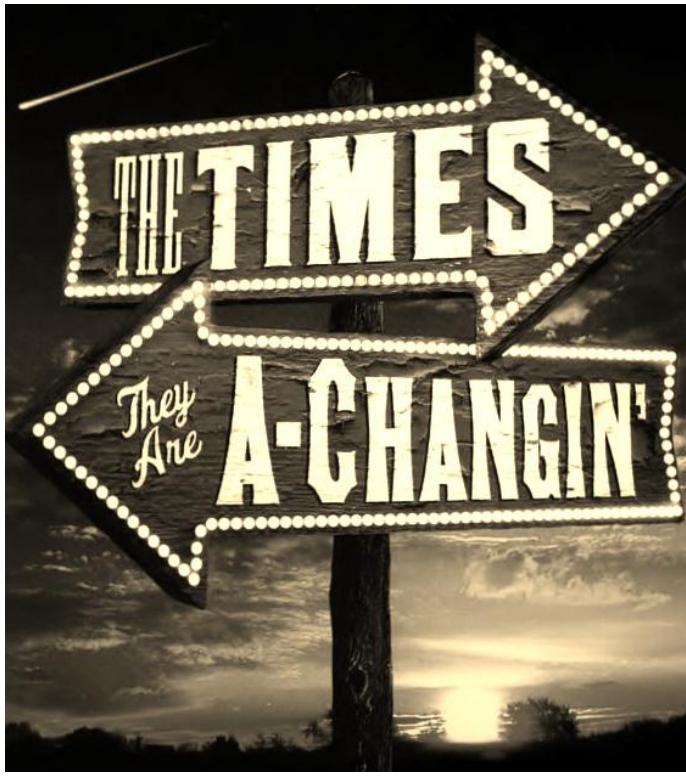






Circles seem to be the only option

However, the times were changing



That's what I said

Renaissance

Baroque=imperfect pearl

One discovered there was more than being created in the image of God

There’s beauty in just about everything

Renaissance ideas on a dead-end track?

Early renaissance

Gentile Bellini (1429-1507)
The virgin and child enthroned 1475-85

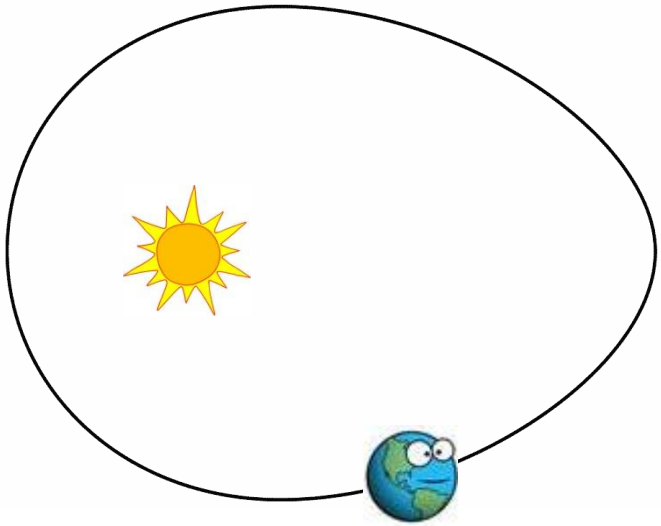
High renaissance

Raphael (1483-1520)
Sistine Madonna 1513-14

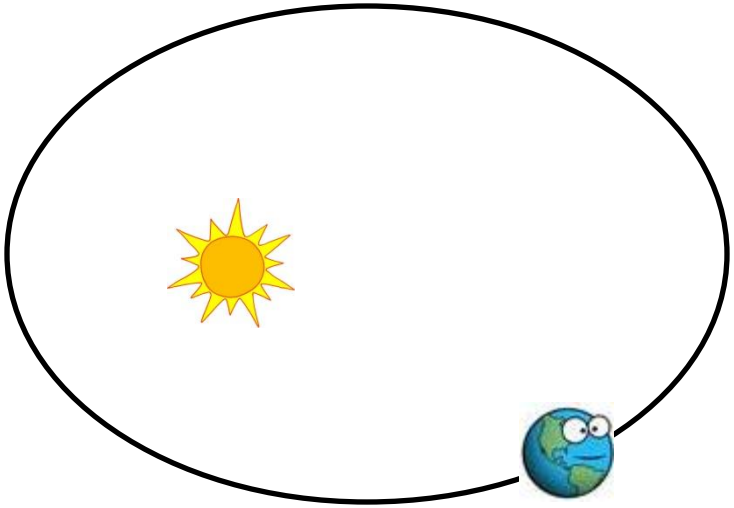
Late renaissance

Parmigianino (1503-1540)
Madonna with the long neck 1540

So after 40 failed egg-shaped orbits….



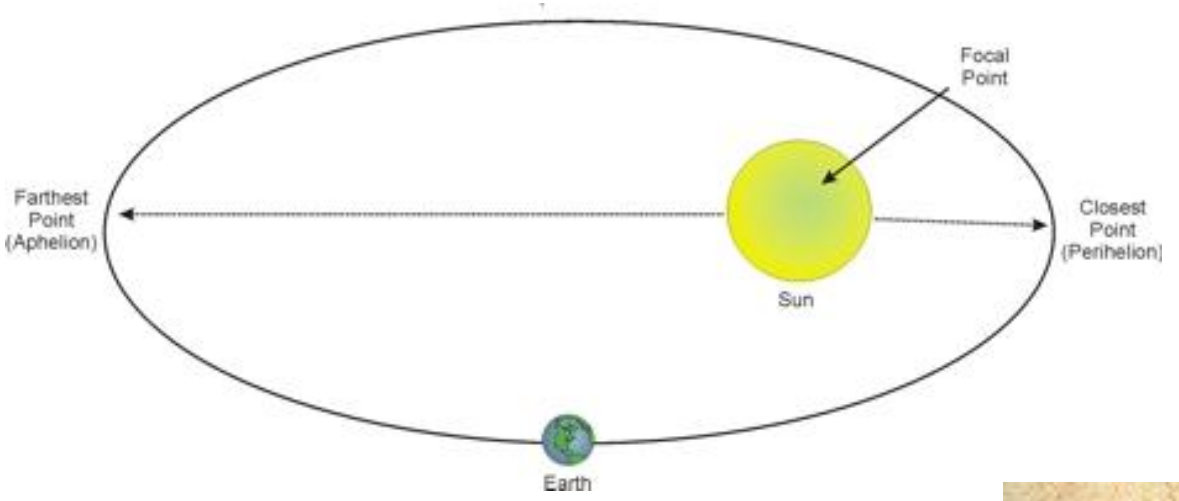
You're telling me that those Renaissance dude never tried ellipses? And I am wasting my time with egg-shaped orbits?

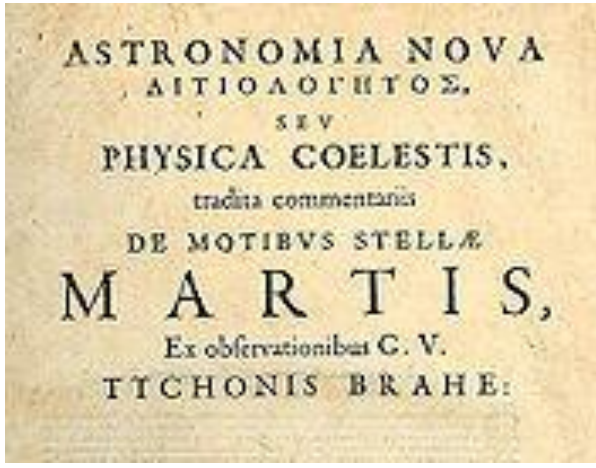


I don't like it!

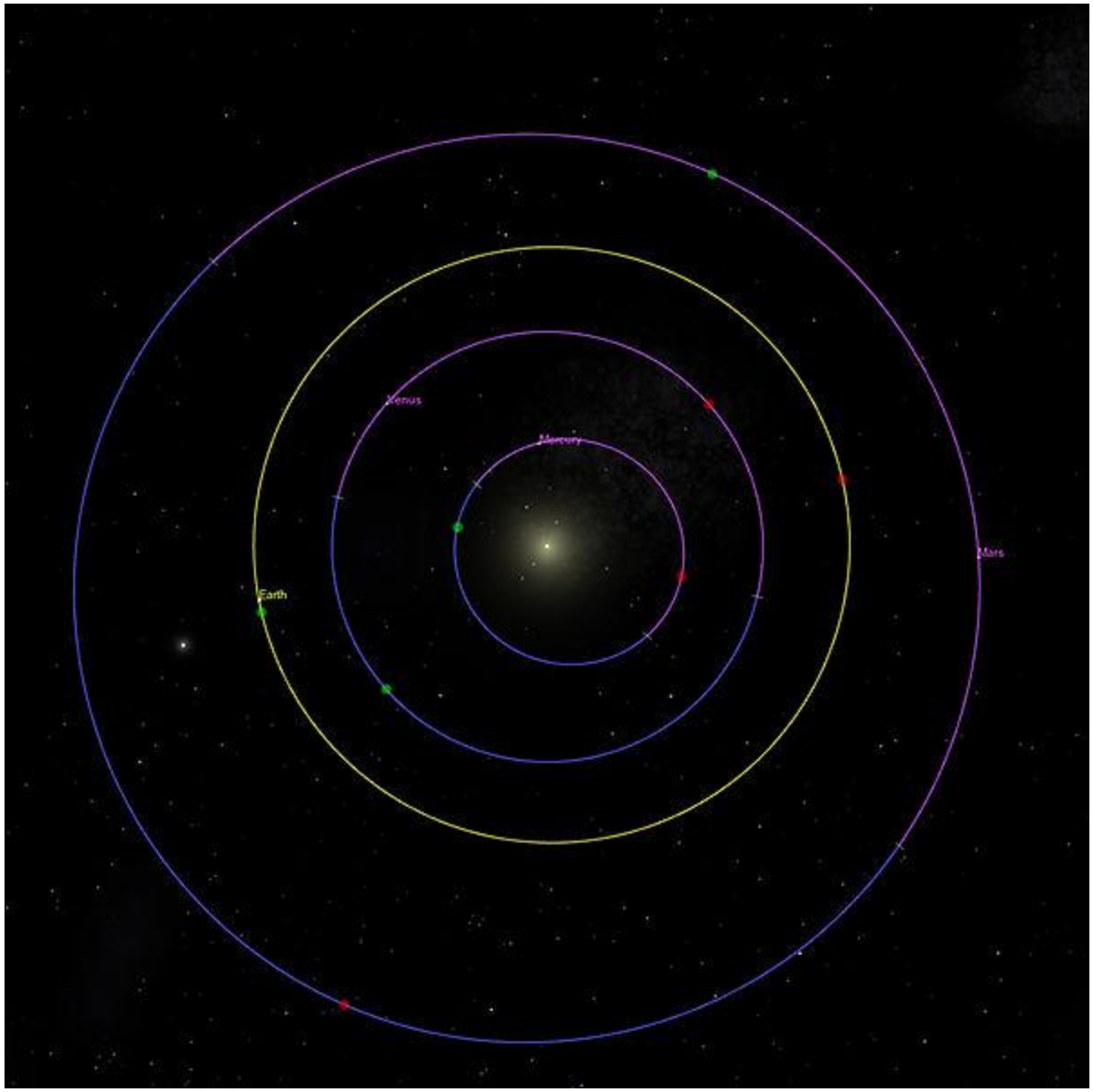
1609: Kepler formulates his first two laws:

1. The orbit of every planet is an ellipse with the Sun at one of the foci



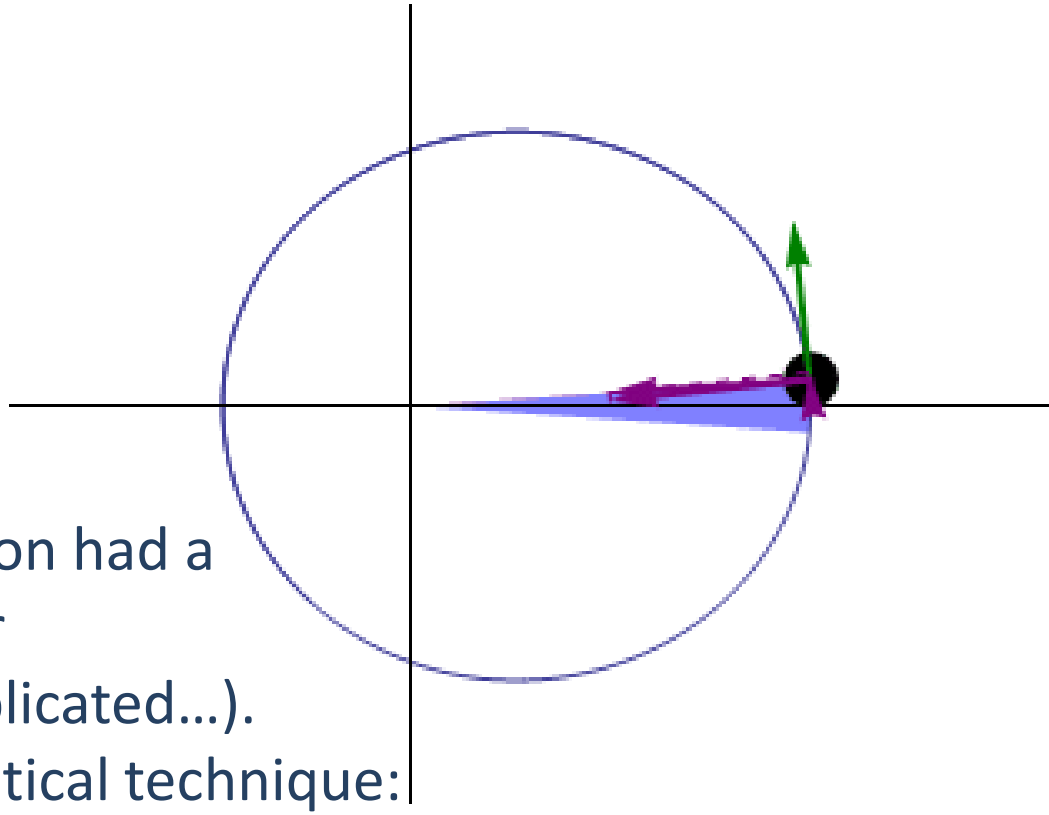

ASTRONOMIA NOVA
ΑΙΤΙΟΛΟΓΗΤΟΣ,
SEV
PHYSICA COELESTIS,
tradita commentariis
DE MOTIBVS STELLÆ
MARTIS,
Ex observationibus G. V.
TYCHONIS BRAHE:

How ellipse are the orbits?

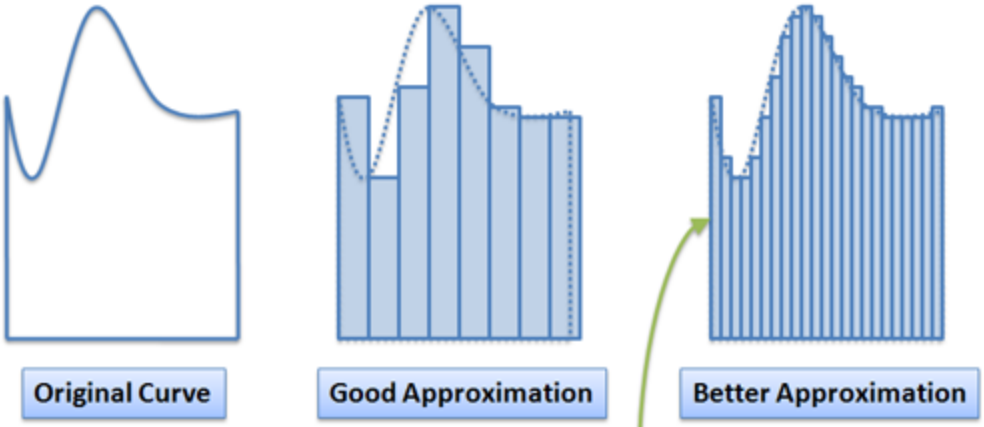


2. A line joining a planet and the Sun sweeps out equal areas during equal time intervals

Speed is not constant



Now how do we get there. Newton had a proof, but that was 80 years later (and in addition somewhat complicated…). Kepler used a different mathematical technique: infinitesimals.

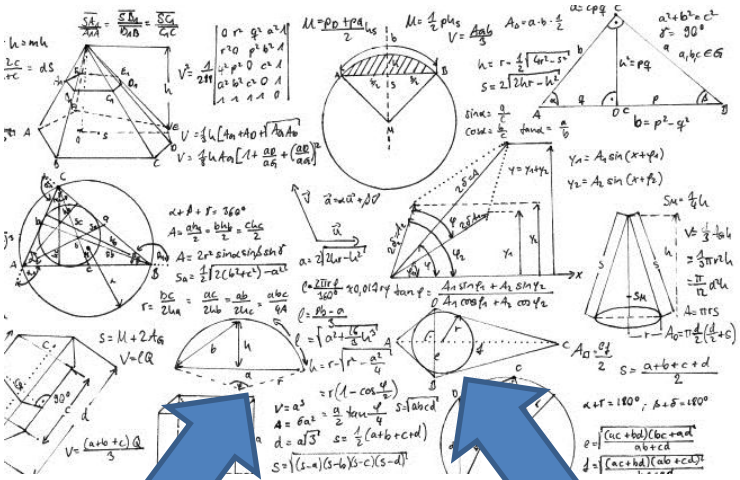


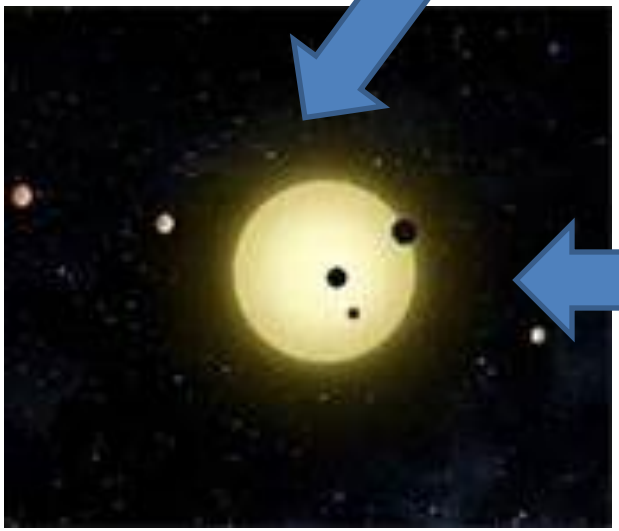
So what is happening here? It doesn't look like much…

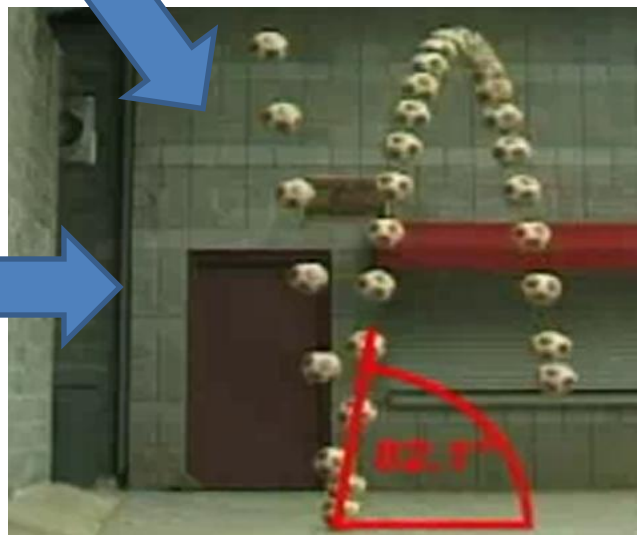
Renaissance: it looks like renaissance scientists and artists are doing everything

However, the “modern” disciplines are still quite disconnected

Mathematics







Astronomy

Physics

Science in the renaissance

Physics:

- Laws of motion mainly discussed in philosophical/metaphysical terms

(what we did when describing a falling object in terms of mathematics was not done in the renaissance)

- Mathematics hardly used in physics
- Trying to escape from Aristotle

Astronomy

- Observation was key
- One was not clearly making the connection between the laws of motion in physics and planetary motion
- Trying to escape from Ptolomy

Mathematics

- Still a rather separate discipline concerned with mainly algebra and geometry (and related to that trigonometry)

Obviously this slide oversimplifies things a little bit

Science in the 17th Century

Mathematics/Physics

- Development of calculus

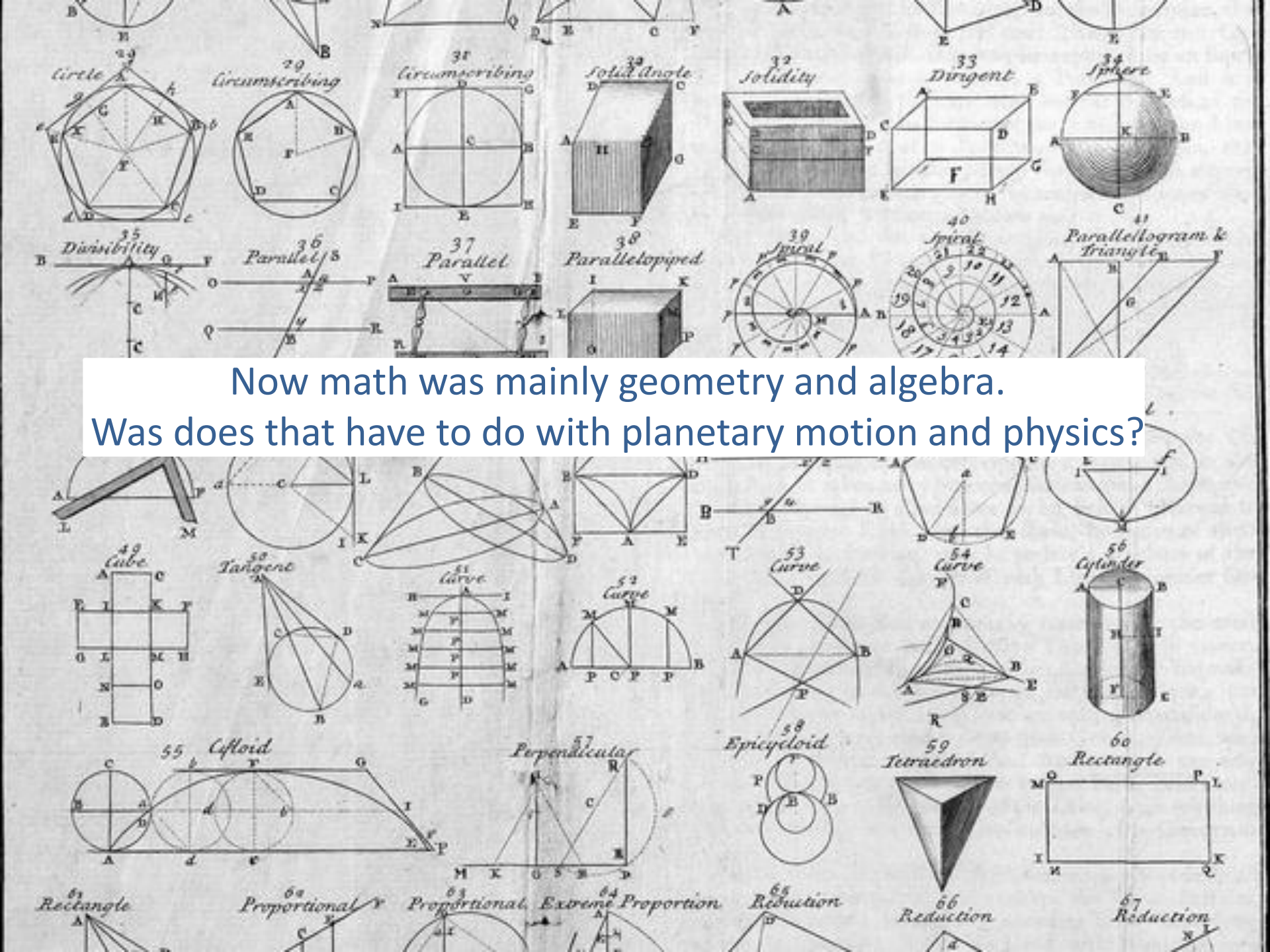
Physics:

- Laws of motion described using calculus
- Development of classical mechanics based on mathematical principles

Astronomy

- Planetary motion described in terms of laws of physics

Johannes Kepler: astronomy=celestial physics



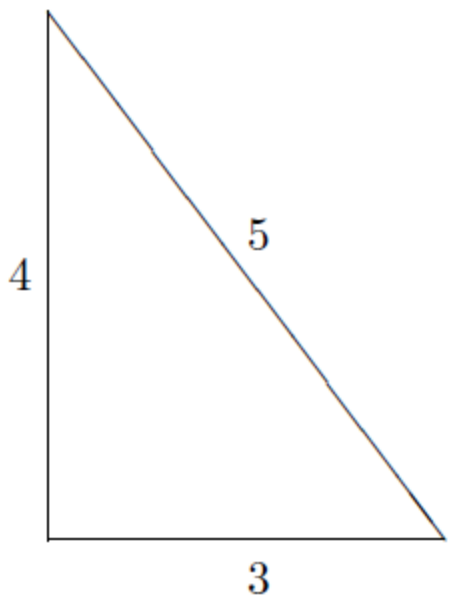
Now math was mainly geometry and algebra.
Was does that have to do with planetary motion and physics?

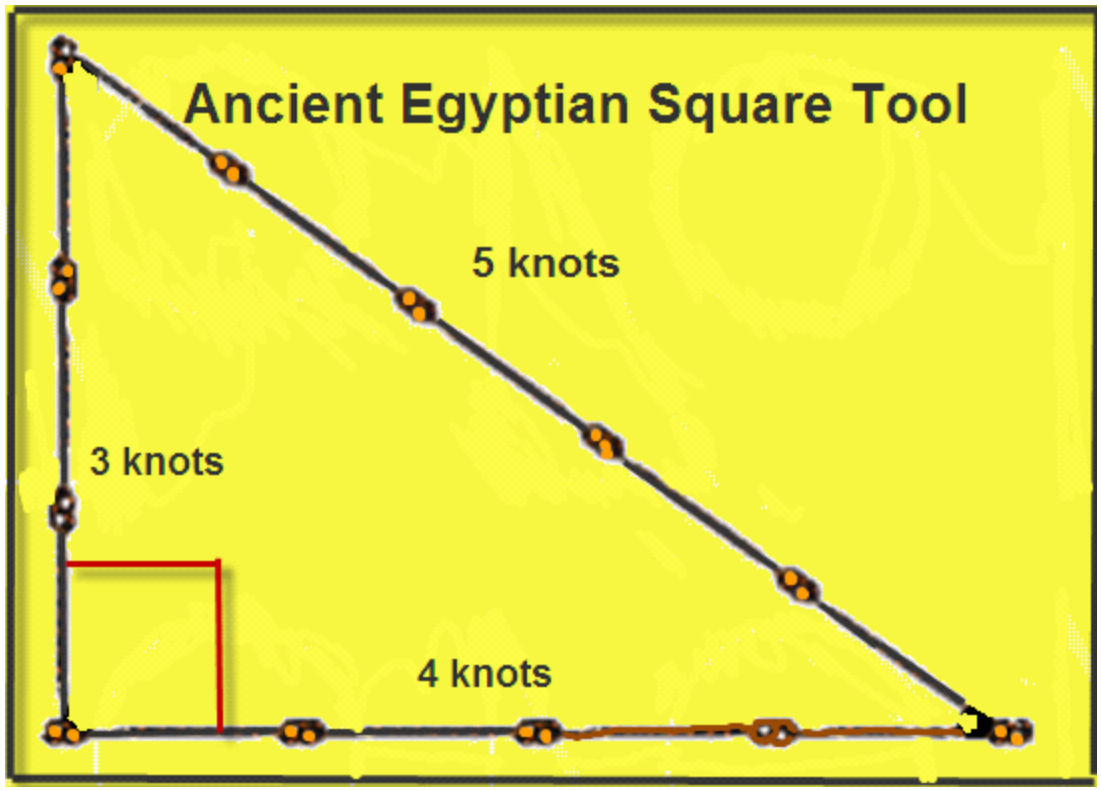
Ok….Back to the ancient Greeks….

We have all heard of Pythagoras rule

The Egyptians before 2000 BC were aware of the 3-4-5 triangle

But probably not of the proof (unless aliens helped them…)

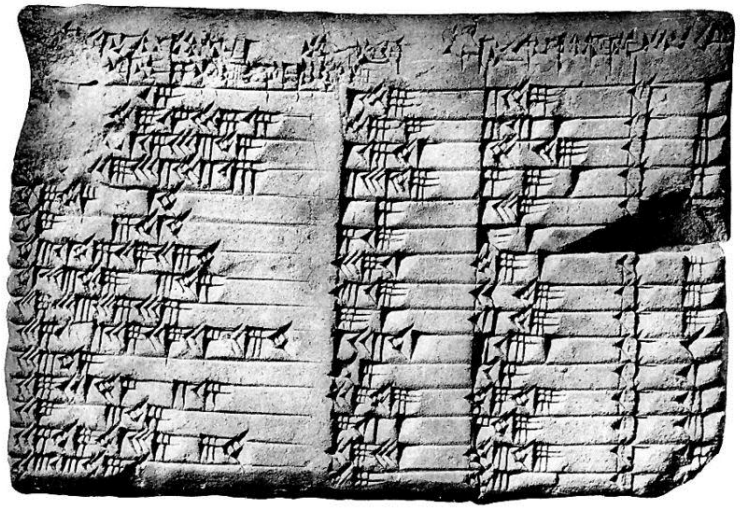


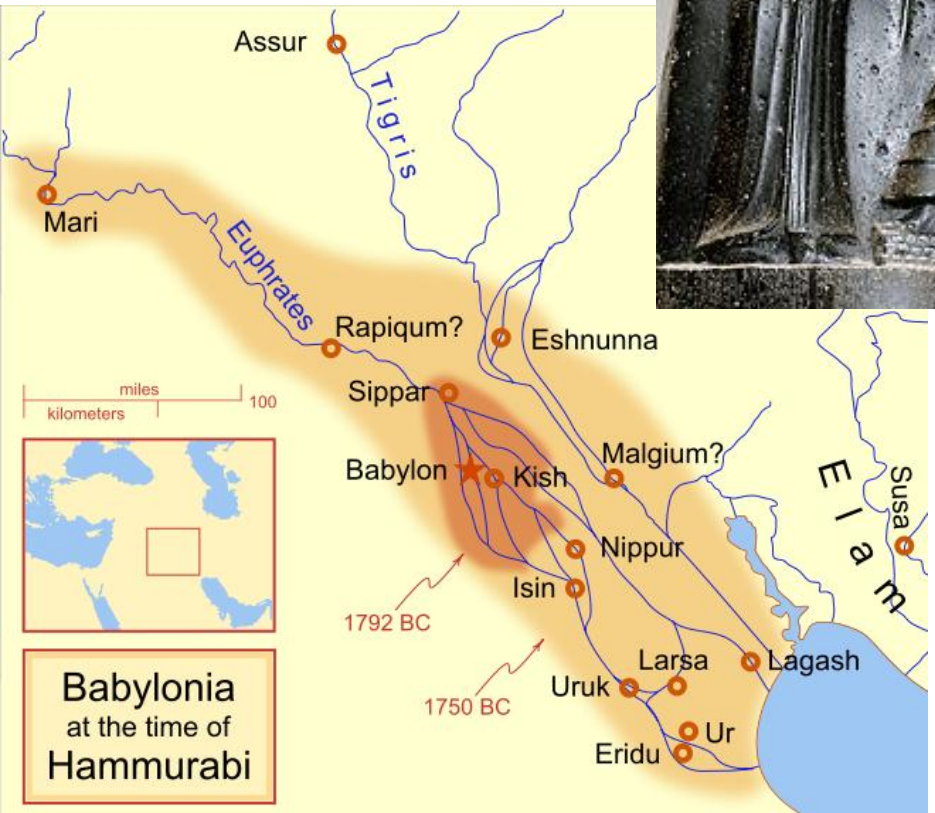


where $3^2 + 4^2 = 9 + 16 = 25 = 5^2$

The Babylonians knew other Pythagorean triangles, such 5-12-13 and 65-72-97

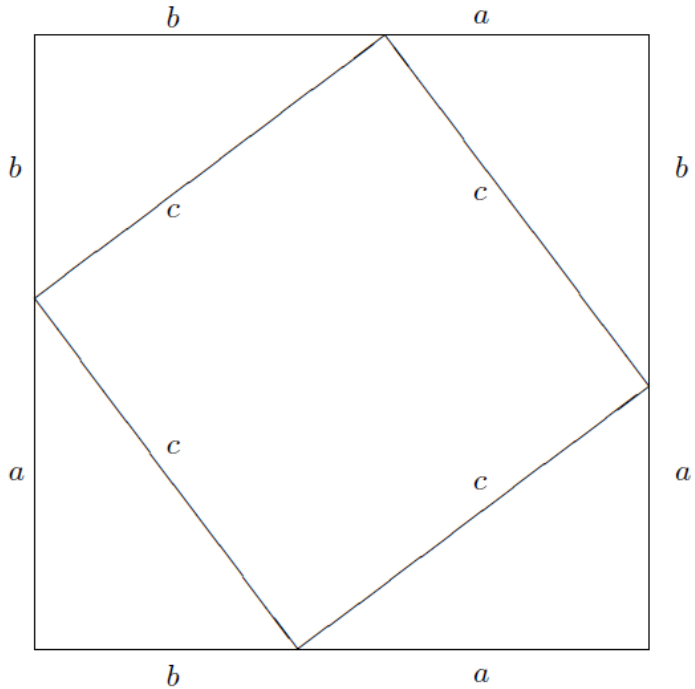
Such as those found on the clay tablet Plimpton 322 (1790-1750 BC)

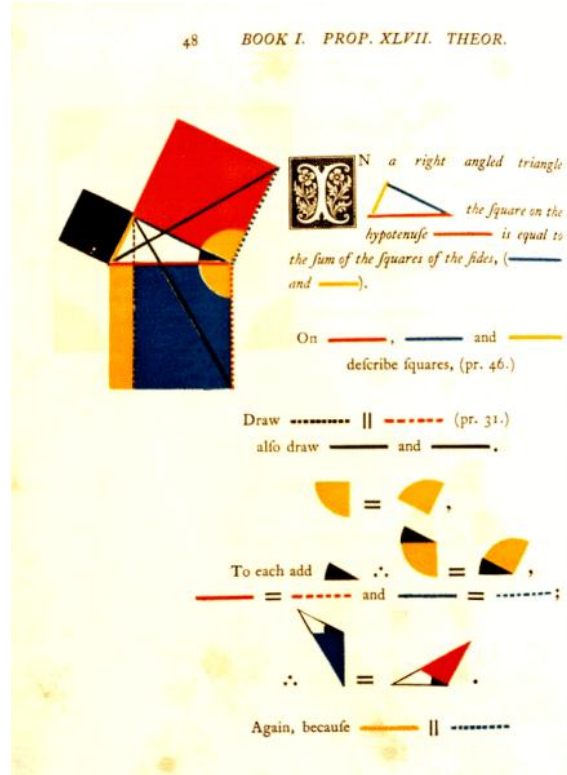


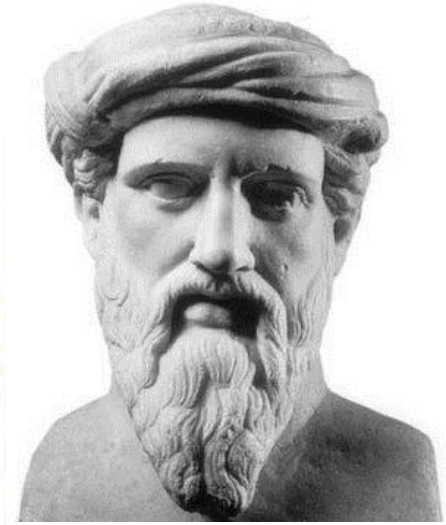


To the Babylonian we also owe the sexagesimal (you know 60 minutes, 360 degrees).

But the first known proof came from Pythagoras







Pythagoras 570-495 BC

Euclid's proof

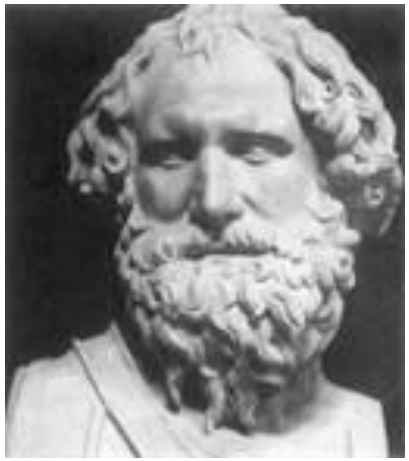
Area big square $(a+b)^2$

Area small square plus four triangles: $c^2 + 4 \times \frac{1}{2} a \times b$

$$(a+b)^2 = c^2 + 2ab \quad \Rightarrow \quad a^2 + 2ab + b^2 = c^2 + 2ab$$

$$\Rightarrow \quad a^2 + b^2 = c^2$$

Ok, that's all nice, but let's get a little bit more serious

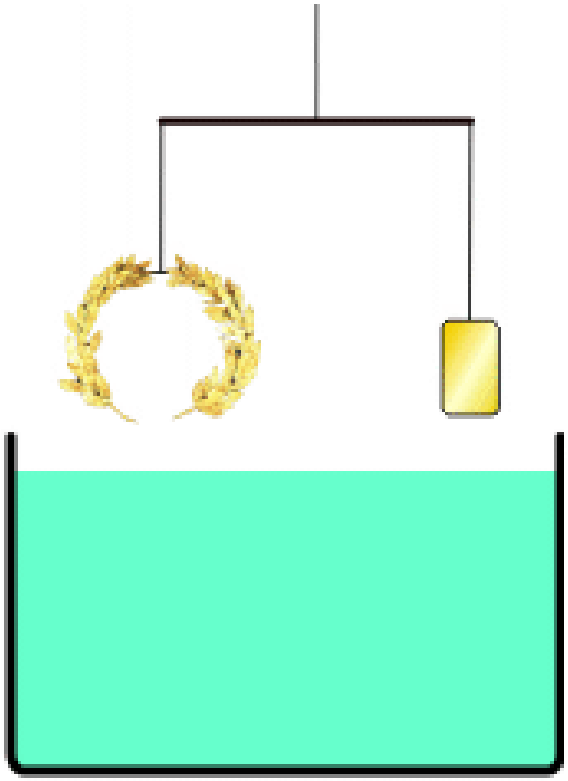


The first real attempts at calculating surfaces was done by Archimedes, 287-212 BC (the first great mathematician/physicist?)

Archimedes was born in Syracuse (Sicily, not NY)

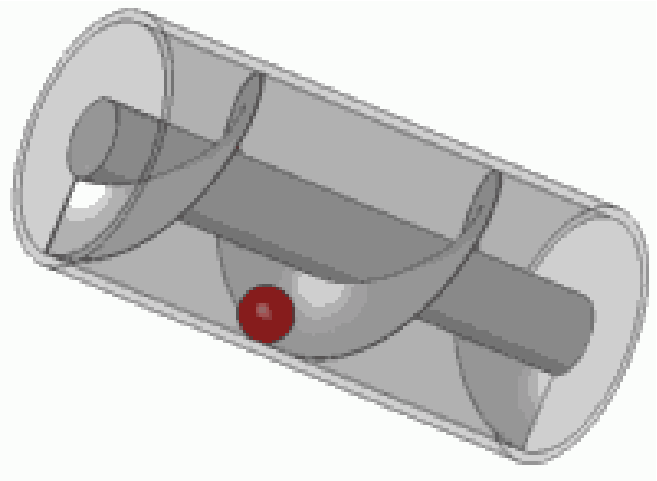
He came up with some amazing stuff

Archimedes principle: (I guess he did not make the name)



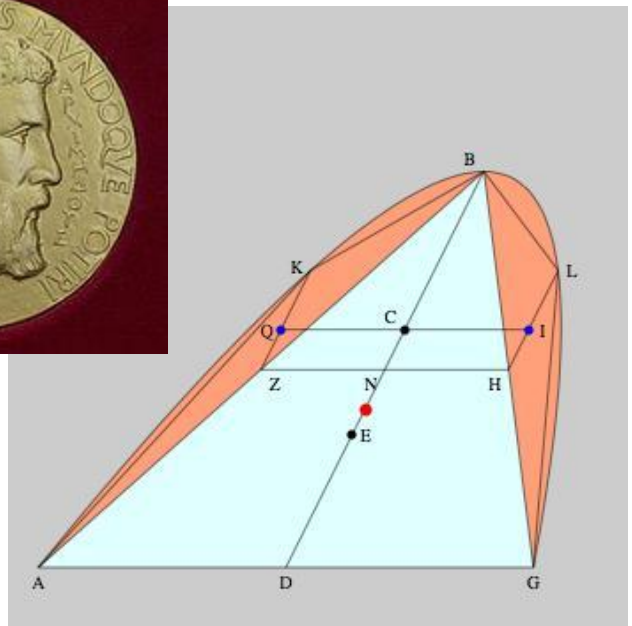
First scientific streaker

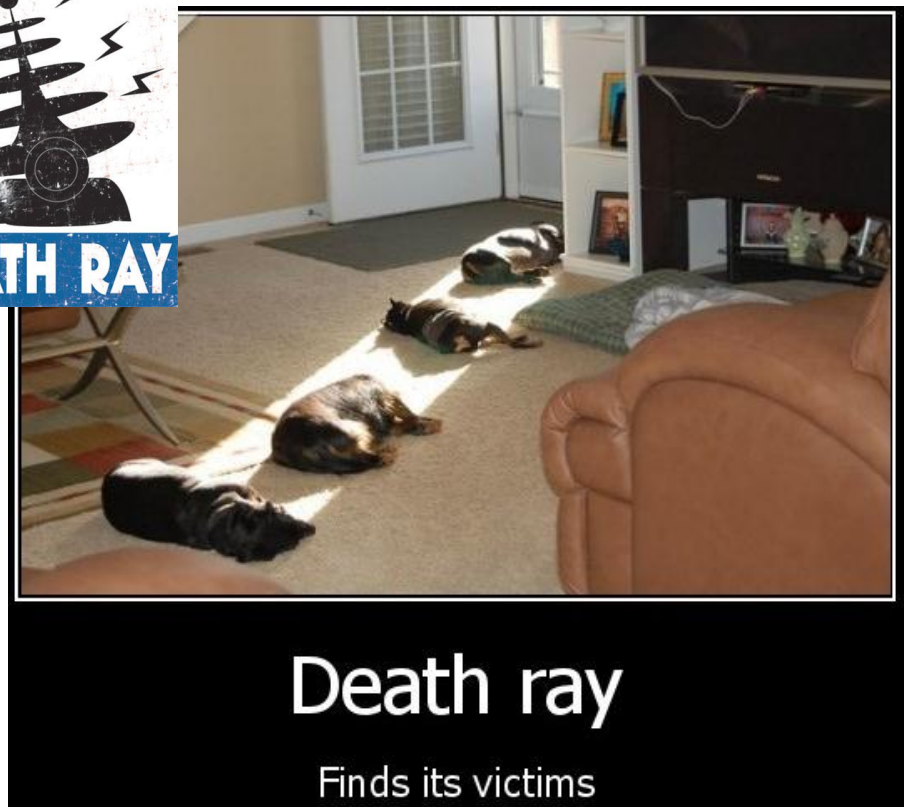
Archimedes screw



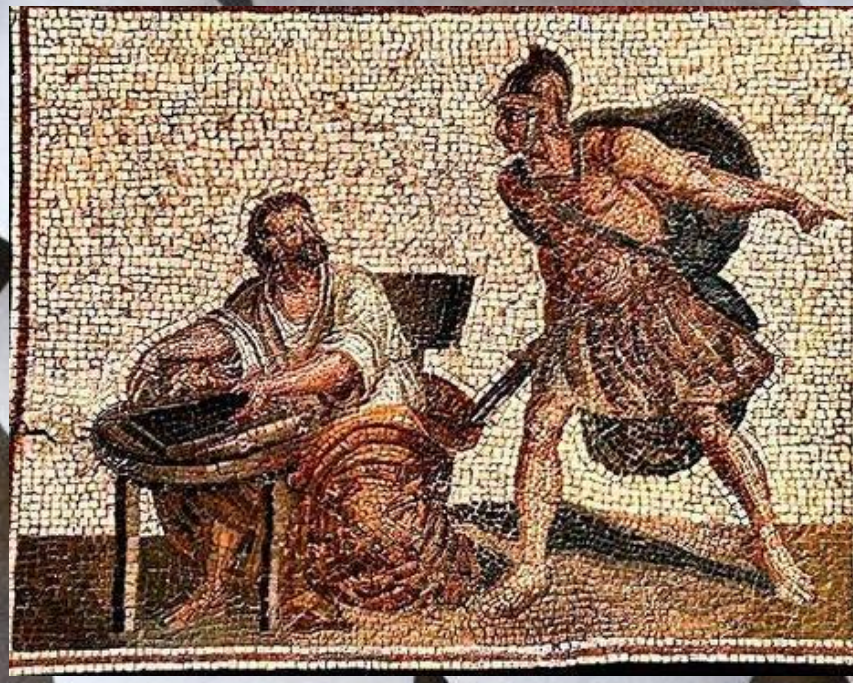
And the first death ray

Plus quite a few things in mathematics



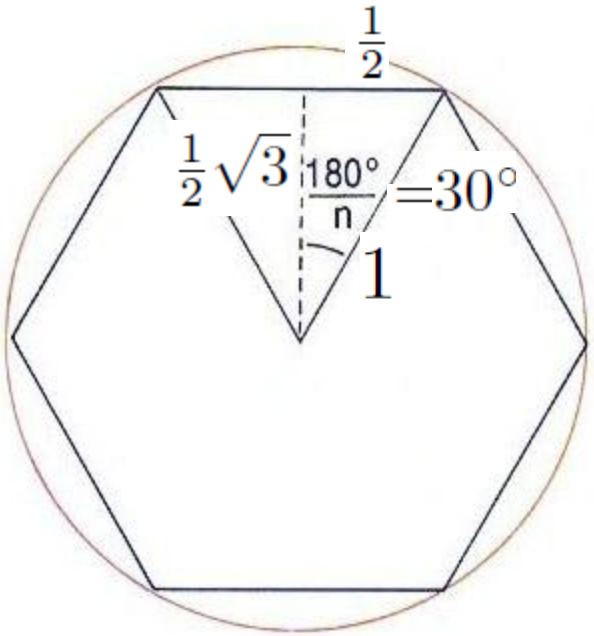


Archimedes was killed after a two-year siege of Syracuse by the Romans.
His last attributed words were: “Do not disturb my circles”



How to calculate the area of a circle?

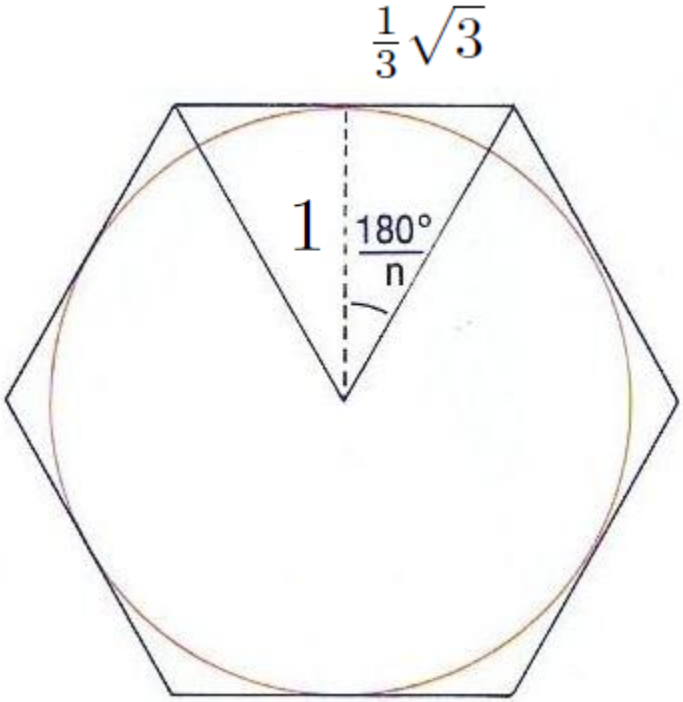
In the example, n=6 triangles



The circle is bigger than this hexagon:

Area triangle $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}\sqrt{3} = \frac{1}{8}\sqrt{3}$

Area hexagon $12 \times \frac{1}{8}\sqrt{3} = \frac{3}{2}\sqrt{3} \cong 2.59$



But smaller than this hexagon:

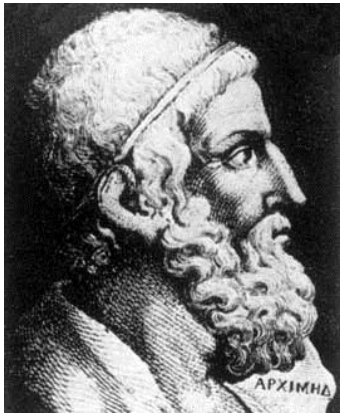
Area triangle $\frac{1}{2}\frac{1}{3}\sqrt{3} = \frac{1}{6}\sqrt{3}$

Area hexagon $12\frac{1}{6}\sqrt{3} = 2\sqrt{3} \cong 3.46$

Therefore

$2.59 \leq \pi \leq 3.46$

(It works somewhat better with the circumference)



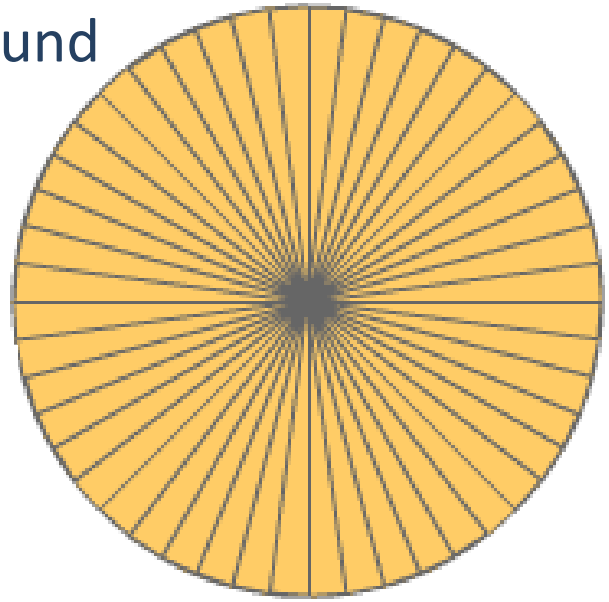
Well, that's a pretty bad guess….

$2.59 \leq \pi \leq 3.46$

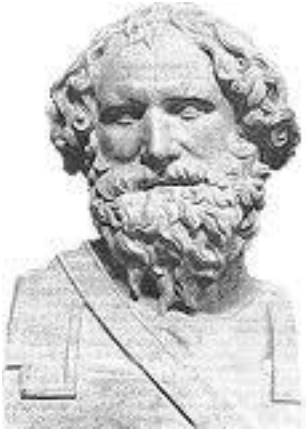
However, it gets better with more triangles!

Using 96 triangles, Archimedes found

$$3\frac{10}{71} = 3.1408 < \pi < 3.1428 = 3\frac{1}{7}$$



3 1/7 =22/7



=

That's exactly that number that we found with the pyramids, showing that Archimedes is an alien….

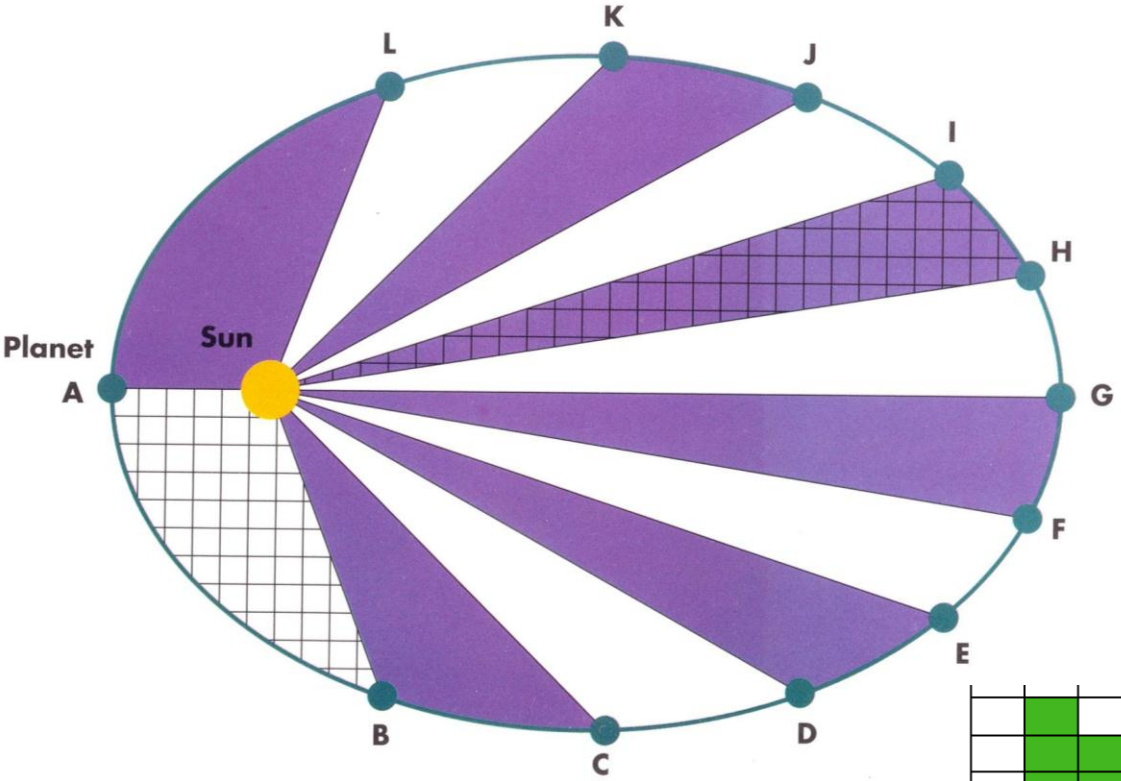
This method was the only method used to calculate π for the next 2,000 years

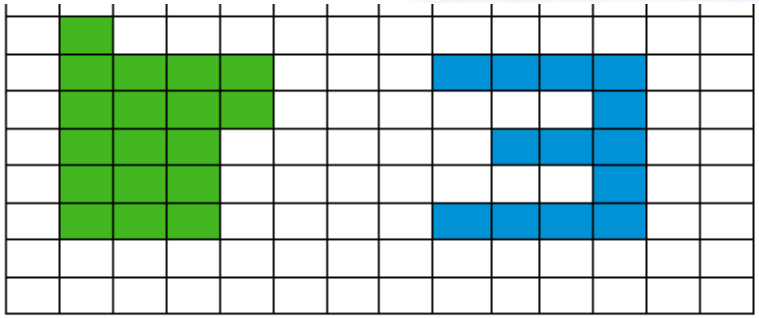
1596 Ludolph van Ceulen used a 2^{62}-gon.
He calculated π up to 35 digits:

3.14159265358979323846264338327950 29

First professor of mathematics at Leiden University, founded 1575. Needed after the separation from Spain.

So that's how Kepler finds the areas





That's what daughter did in sixth grade…

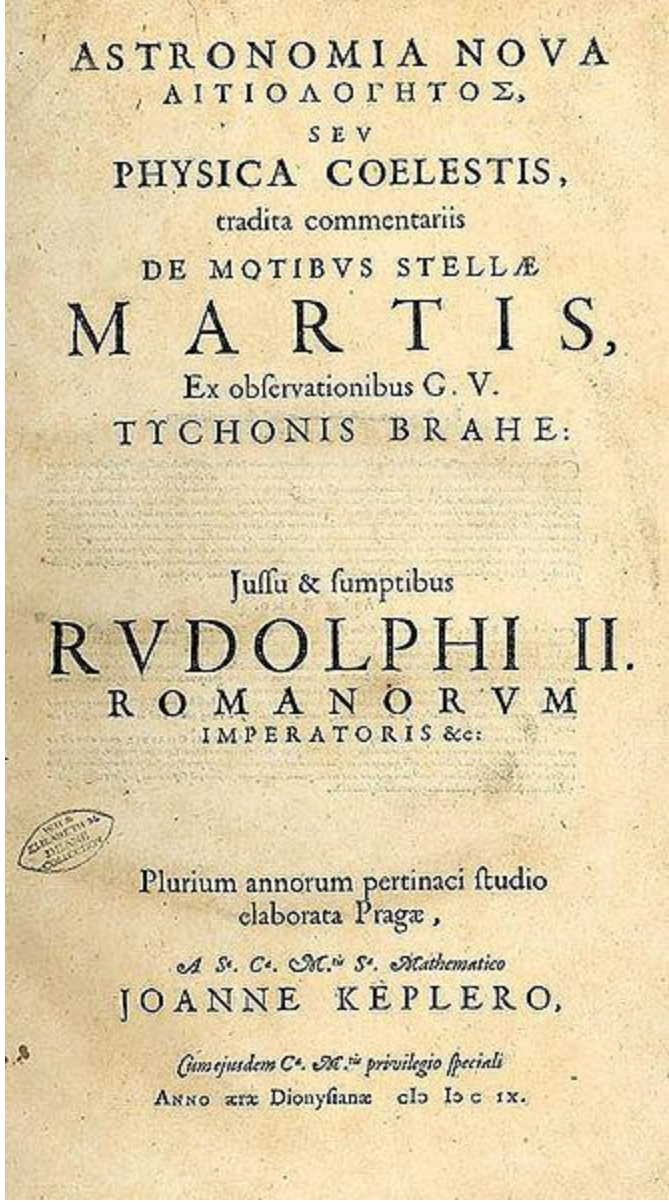
$$\text{Area} = \sum \text{area}_{\text{square}}$$

$\sum$ is the sum over all small squares

Kepler published his results in 1609
in “astronomia nova”

Or somewhat less catchy
New Astronomy, Based upon Causes,
or Celestial Physics, Treated by Means of Commentaries
on the Motions of the Star Mars,
from the Observations of Tycho Brahe

He also proves in Chapter 16, that physics is boring:
“If thou art bored with this wearisome method of calculation, take pity on me, who had to go through with at least seventy repetitions of it,
at a very great loss of time.”


ASTRONOMIA NOVA
ΑΙΤΙΟΛΟΓΗΤΟΣ,
SEV
PHYSICA COELESTIS,
tradita commentariis
DE MOTIBVS STELLÆ
MARTIS,
Ex obſervationibus G. V.
TYCHONIS BRAHE:

Juſſu & ſumptibus
RVDOLPHI II.
ROMANORVM
IMPERATORIS &c:

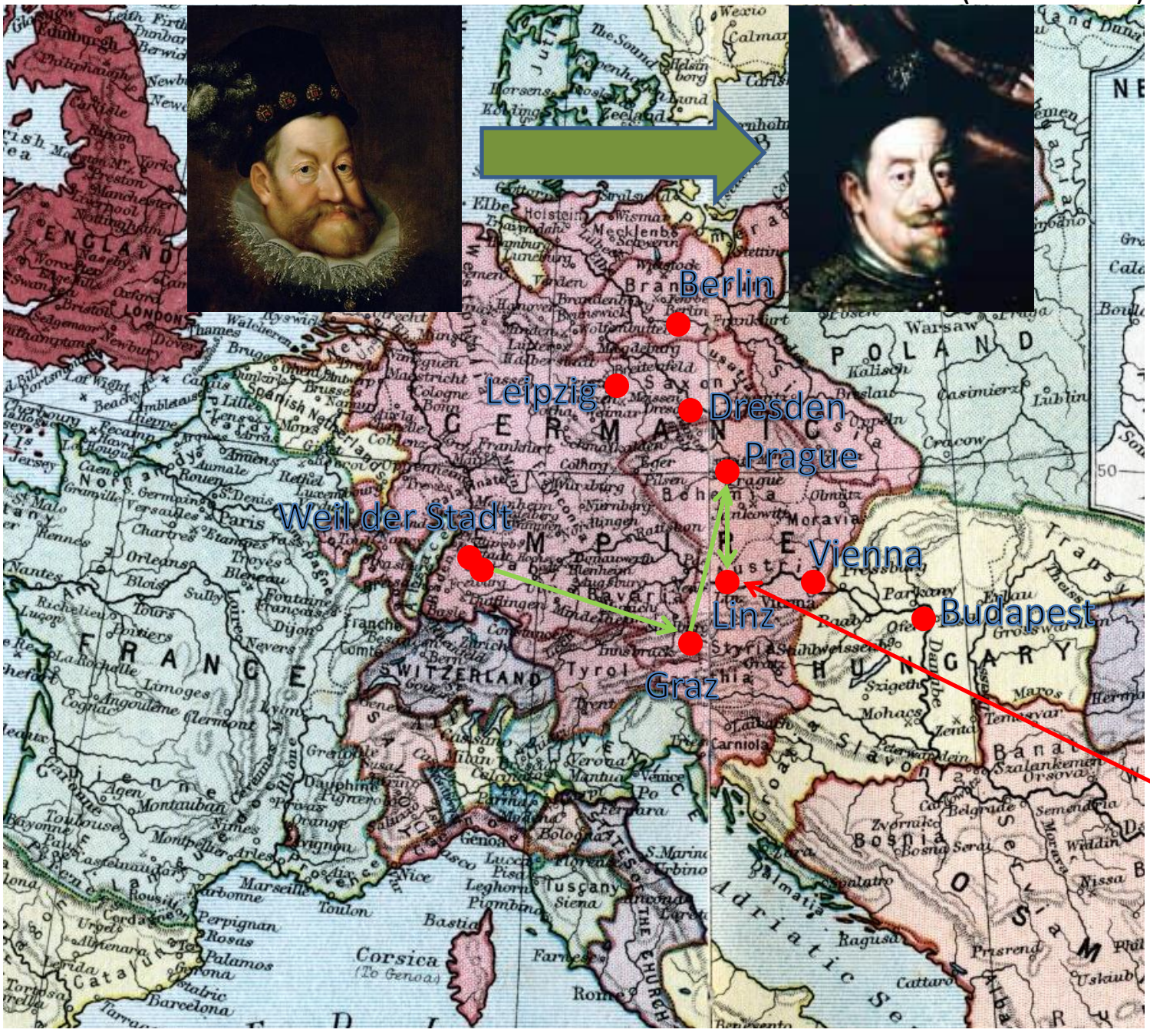
Plurium annorum pertinaci ſtudio
elaborata Pragæ,
A S. C. M.ti S. Mathematico
JOANNE KEPLERO,

Cum ejusdem C. M.ti privilegio speciali
ANNO æræ Dionyſianæ cIↃ IↃ c IX.

One more stop

Rudolf II

Matthias (his brother)



And one more law:

The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

$$\text{Period}^2/\text{Axis}^3 = \text{constant}$$

Let us compare Earth and Mars:

Mars:

Axis=227,939,100 km

Period=686.971 days

$$\text{Period}^2/\text{Axis}^3 = 3.9849 \times 10^{-20}$$

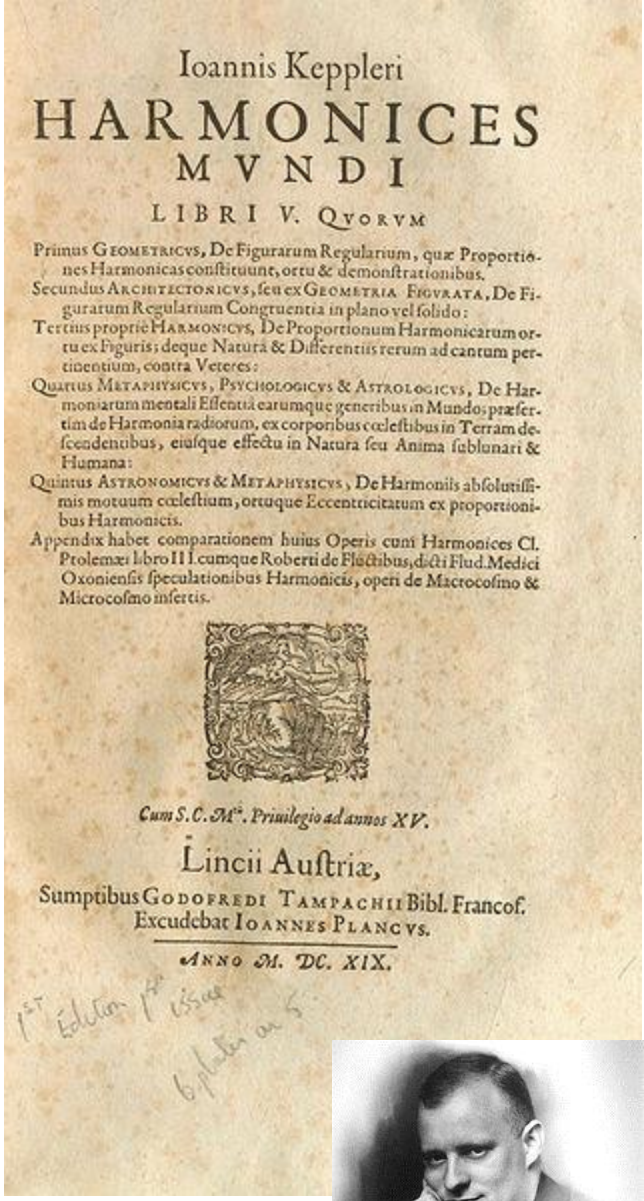
Earth:

Axis=149,598,261 km

Period=365.25636 days

$$\text{Period}^2/\text{Axis}^3 = 3.9849 \times 10^{-20}$$

WOW!



Ioannis Keppleri

HARMONICES MVNDI

LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiones Harmonicas constituunt, ortu & demonstrationibus.

Secundus ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel solido:

Tertius propriè HARMONICVS, De Proportionum Harmonicarum ortu ex Figuris; deque Naturâ & Differentiis rerum ad cantum pertinentium, contra Veteres:

Quartus METAPHYSICVS, PSYCHOLOGICVS & ASTROLOGICVS, De Harmoniarum mentali Essentiâ earumque generibus in Mundo; præsertim de Harmonia radiorum, ex corporibus cœlestibus in Terram descendentibus, eiusque effectu in Natura seu Anima sublunari & Humana:

Quintus ASTRONOMICVS & METAPHYSICVS, De Harmoniis absolutissimis motuum cœlestium, ortuque Eccentricitatum ex proportionibus Harmonicis.

Appendix habet comparationem huius Operis cum Harmonices Cl. Ptolemæi libro III. cumque Roberti de Fluctibus, dicti Flud. Medici Oxoniensis speculationibus Harmonicis, operi de Macrocosmo & Microcosmo insertis.

Cum S.C.M^ti. Priuilegio ad annos XV.

Lincii Austriæ,

Sumptibus GODOFREDI TAMPACHII Bibl. Francof.

Excudebat IOANNES PLANCVS.

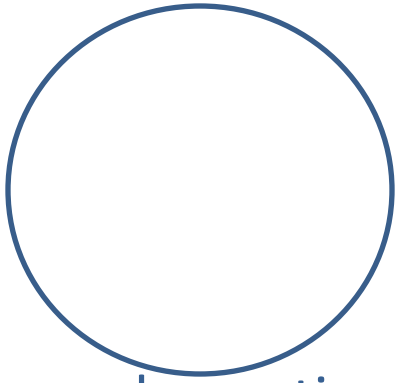
ANNO M. DC. XIX.

No wonder Kepler's last book was called Harmonices Mundi

The Harmony of the world

Even turned into an opera, premiered 1957

Renaissance defined by ideal shapes:



Limitations to perfection:

- There is only so much you can do with it: no decoration, sober
- Too rational and intellectual
- There is more to life: emotions, drama
- People are not Gods

Time for something new:

Baroque defined by rules: P^2/A^3 =constant

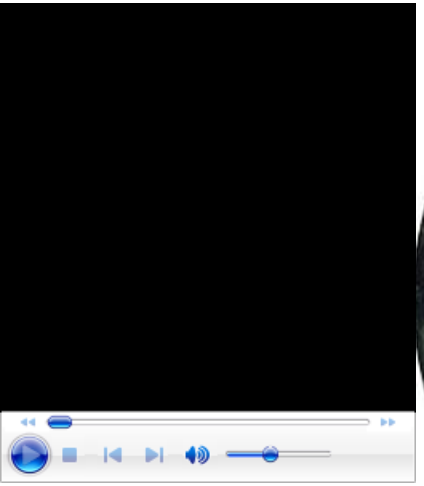
In the arts:

- Focus on more direct emotions
- Abundance of details, decorative elements
- Life is a theatre

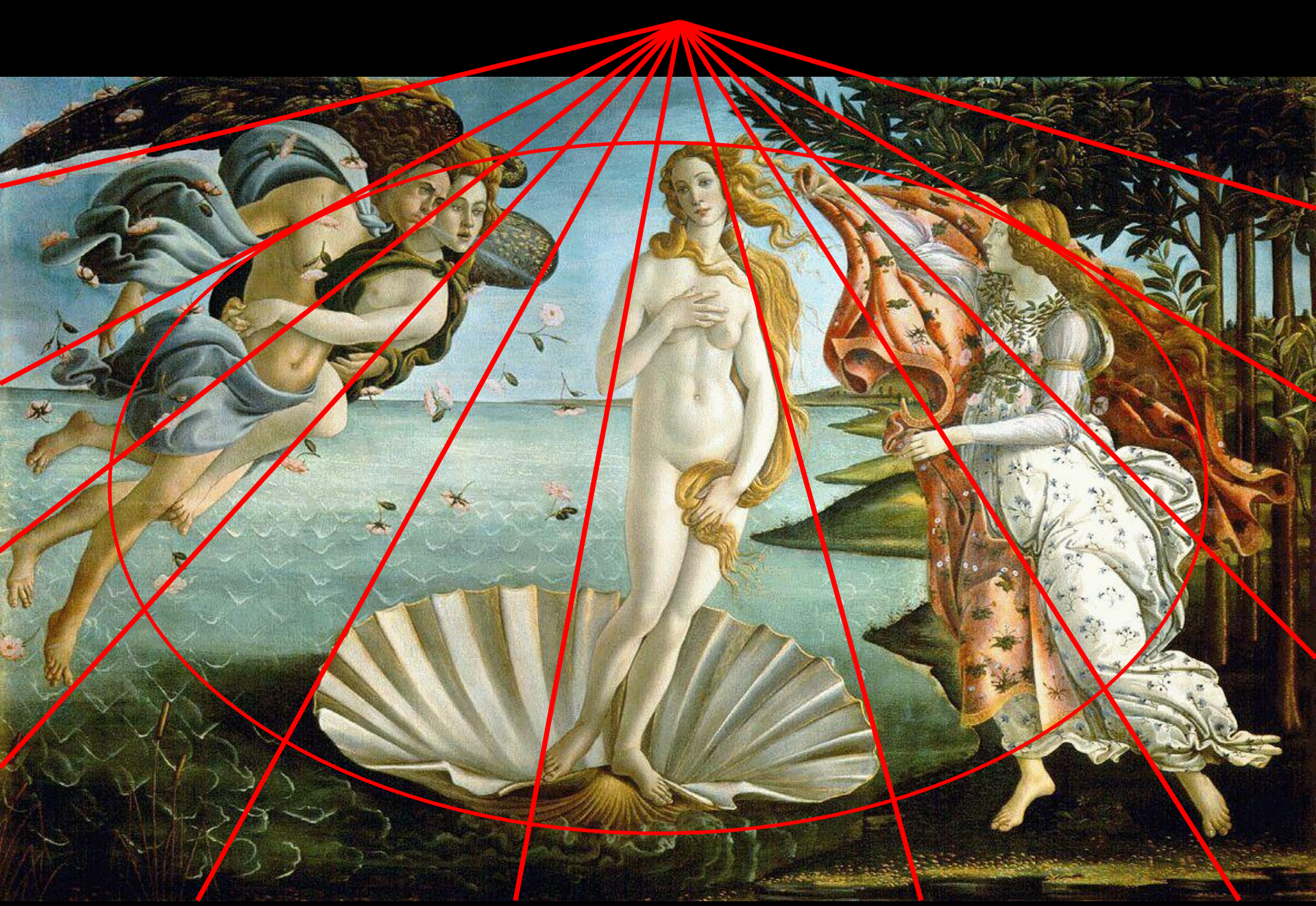
Intellectual plays of, for example, Shakespeare are replaced by….

To be, or not to be, that is the question:
Whether 'tis Nobler in the mind to suffer
The Slings and Arrows of outrageous Fortune,
Or to take Arms against a Sea of troubles,
And by opposing end them: to die, to sleep
No more; and by a sleep, to say we end
…..

the more direct form of Opera



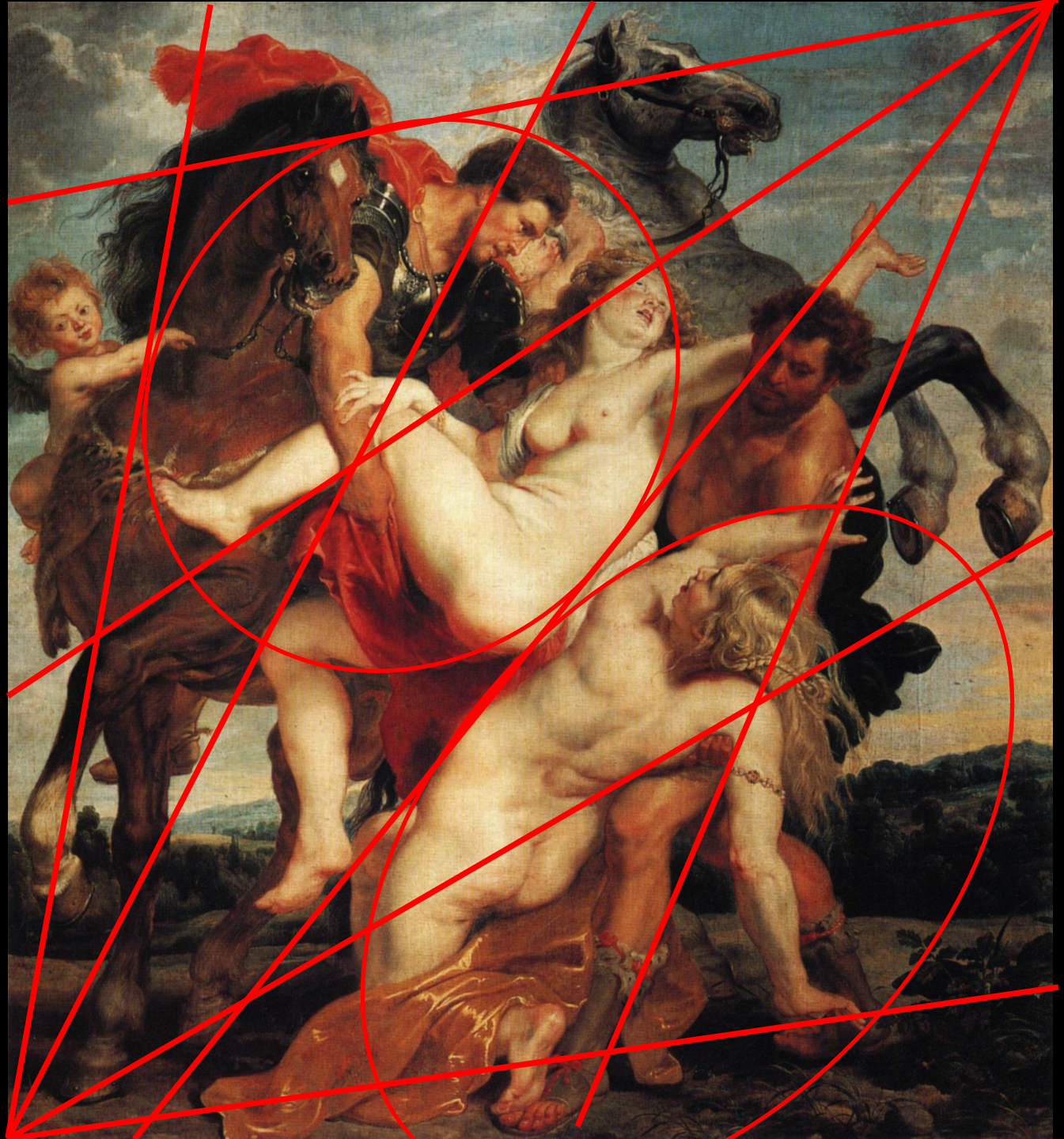
Jean-Baptiste Lully (1631-87)

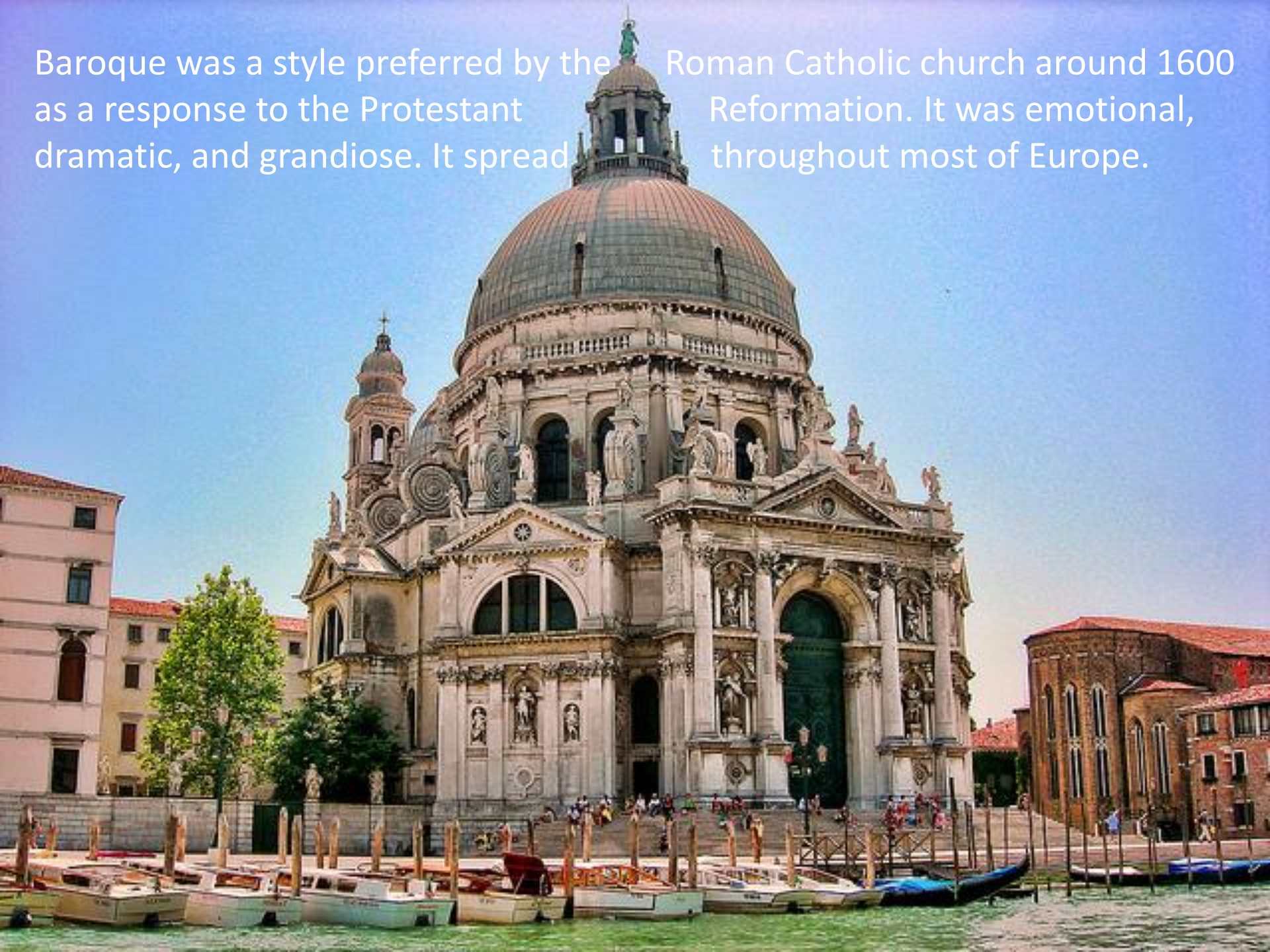


Harmony and balance Botticelli, the birth of Venus, 1486

Drama through Contrapposto or counterpoise

Rubens
The rape of the daughters of Leucippus (1618)





Baroque was a style preferred by the Roman Catholic church around 1600 as a response to the Protestant Reformation. It was emotional, dramatic, and grandiose. It spread throughout most of Europe.

Baroque tends to be busy

You might feel that there are no rules.

The problems is that there are too many rules.

Life is a theatre, so everyone must play their part following the rules

Louis XIV (Le Roi Soleil) developed a highly codefied etiquette, meant to assert his supremacy

However, if everything is theatre, what about Rembrandt’s calm introspection?

Sword

Scroll=
Bible

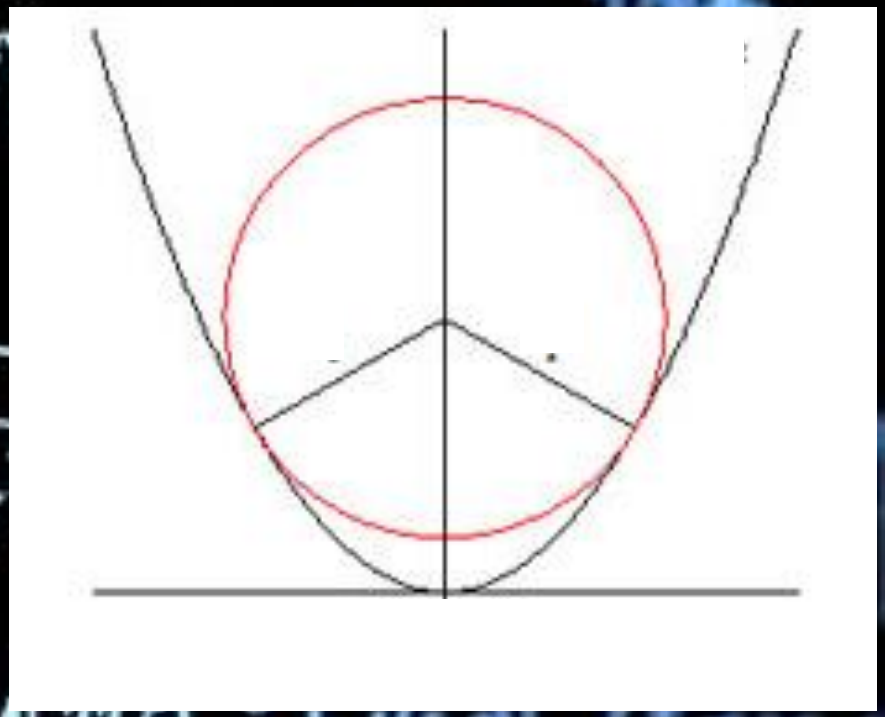
This is Rembrandt as the Apostle Paul

Which leaves us with the following questions:

- Is this really a modern type of self-portrait?
- Why all the dress-up as the Apostle Paul?
- Is this really about Rembrandt himself or is he just playing a role?
- Self-reflection or theatre?
- Are we fooling ourselves and projecting out own 20th Century ideas on this painting?
- Are we falling into the same trap as the Renaissance artists with ancient Greece and Rome?

Back to physics:

If it is no longer about ideal shapes, then what gives us the rules that govern physics?



The answer is simple:

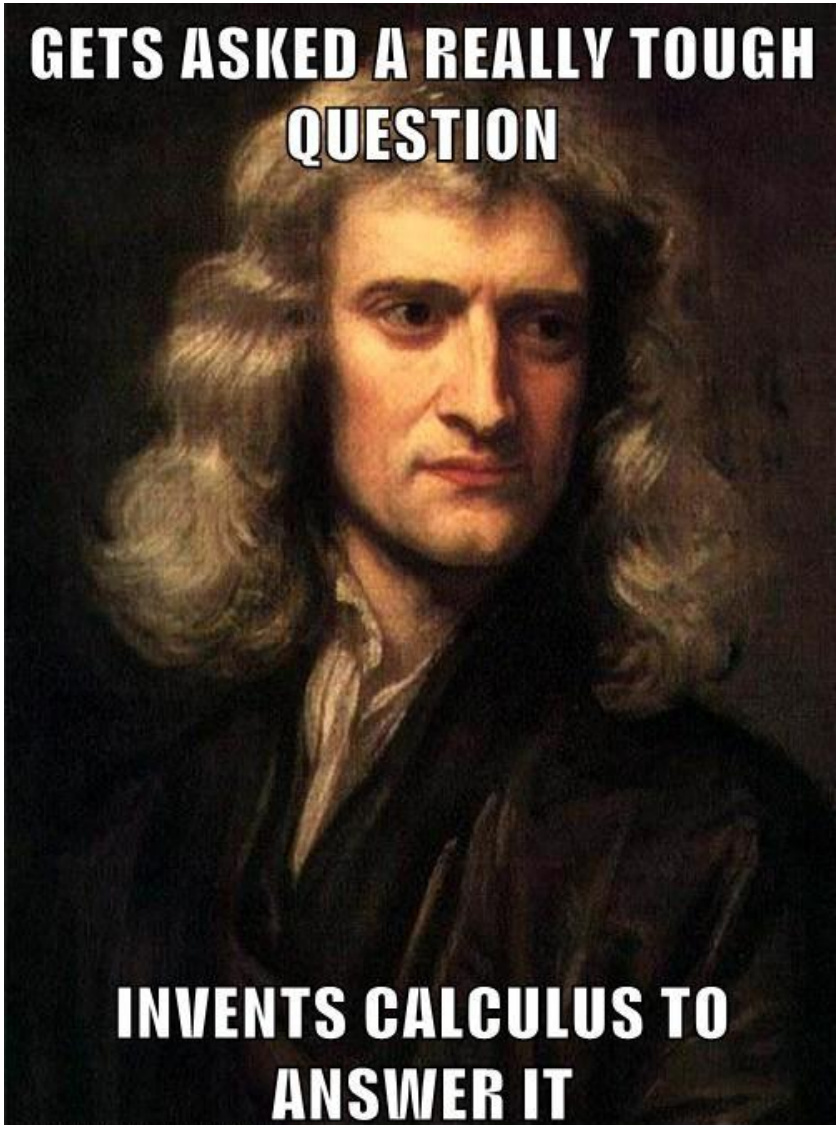
MATHEMATICS

Although Newton's three laws are nice (we still haven't done the 3rd law), his real achievement was developing a mathematical basis for mechanics

This was

CALCULUS

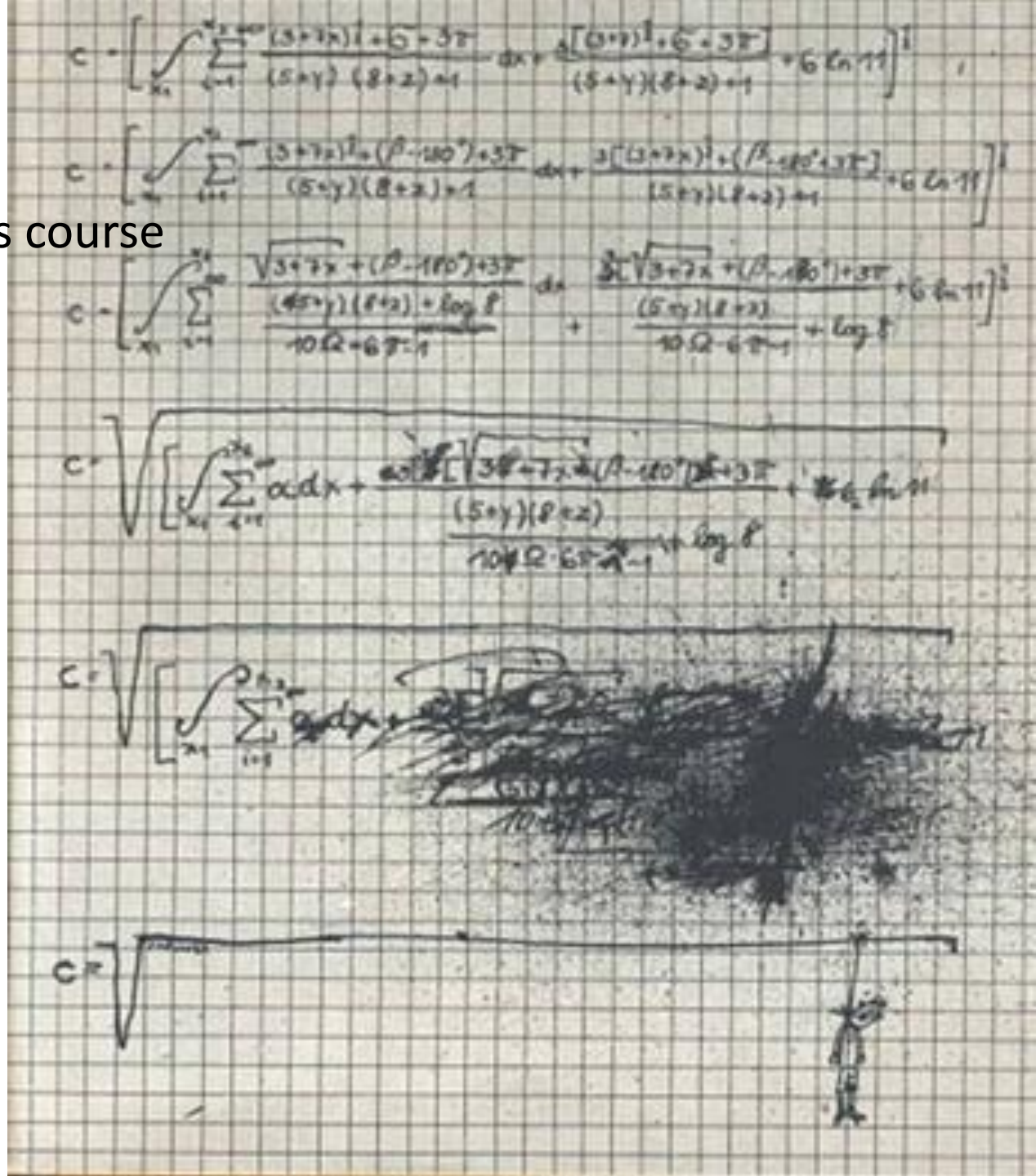
This had a tremendous impact, not only on mechanics, but on virtually all disciplines in physics



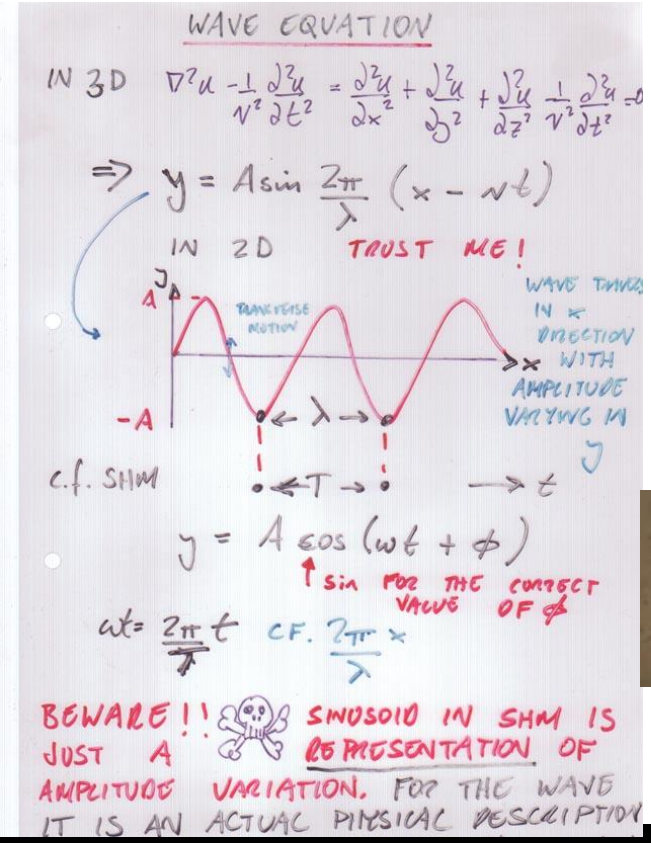
I know:

- This is a non-calculus course
- Calculus is hard
- We all hate it….
- And there will be no exam question about it

- However, physics revolves around it



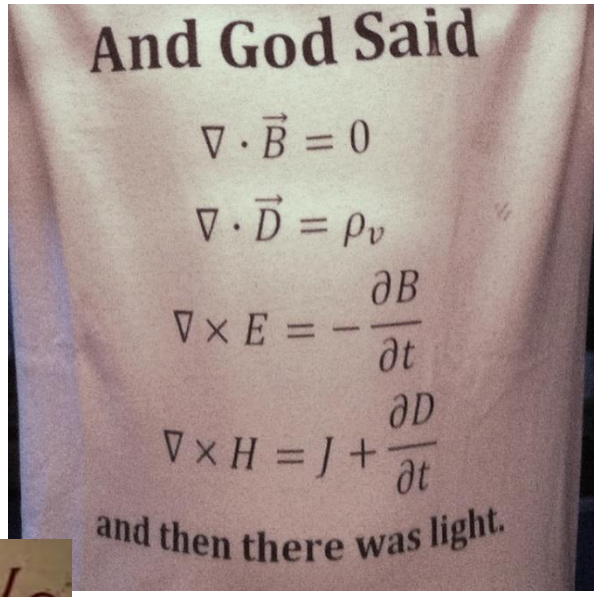
Waves: Optics and acoustics



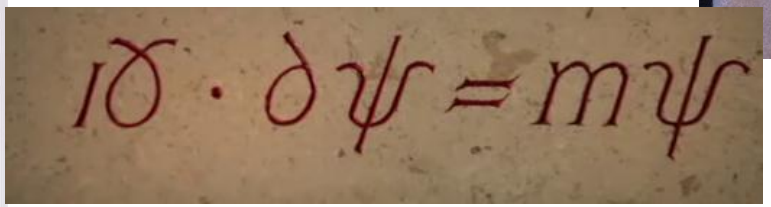
Classical mechanics

$$F = m\frac{d^2x}{dt^2}$$

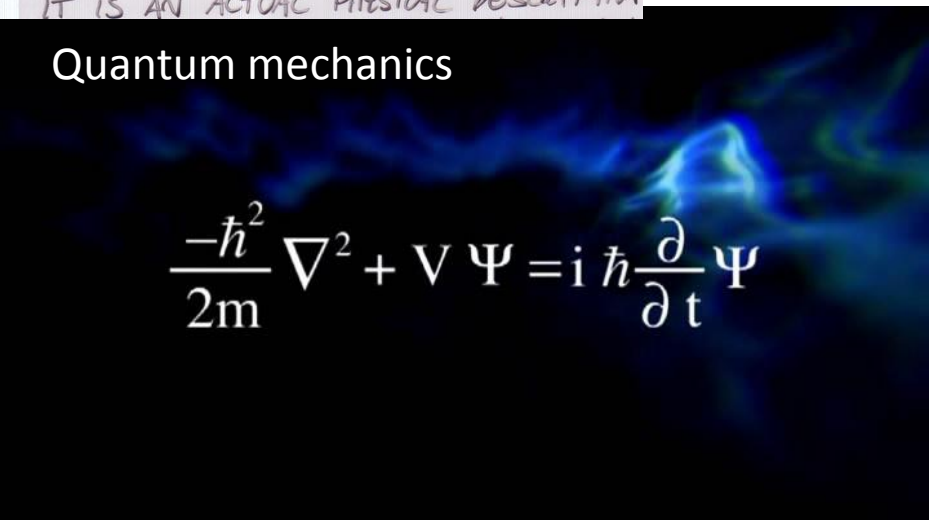
Electricity and magnetism



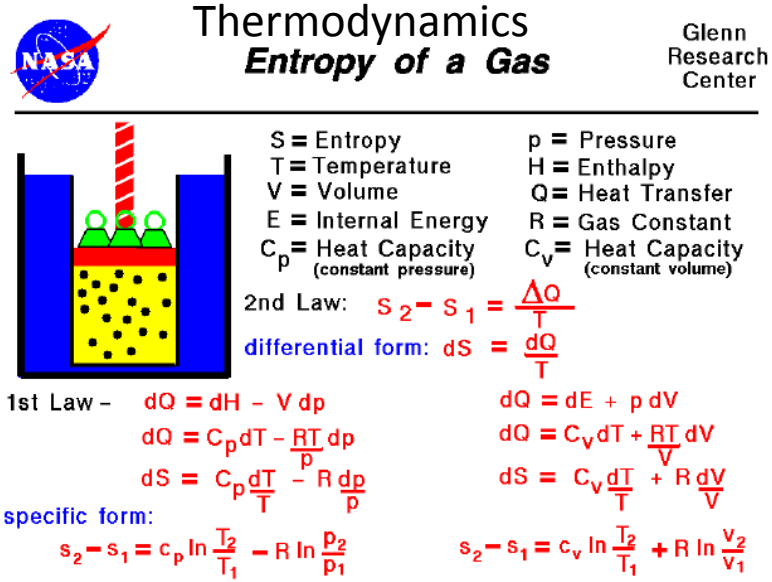
Relativistic quantum mechanics



Quantum mechanics



Thermodynamics



However, we (sneakily already did calculus)

$$v = \frac{\Delta x}{\Delta t}$$

Velocity is the change in position divided by the change in time

However, this caused problems when Δt was very small.
But in the end, we worked around these problems

$$v = \frac{x_{\text{end}} - x_{\text{begin}}}{t_{\text{end}} - t_{\text{begin}}} = \frac{\frac{1}{2}a(t+\Delta t)^2 - \frac{1}{2}at^2}{(t+\Delta t) - t}$$

Now if Δt is very small

$$(t+\Delta t)^2 \cong t^2 + 2t\Delta t$$

And we obtain

$$v \cong \frac{\frac{1}{2}a(t^2 + 2t\Delta t) - \frac{1}{2}at^2}{\Delta t} = \frac{at\Delta t}{\Delta t} = at$$

Well, that was differentiation!!

From

$$v = \frac{\Delta x}{\Delta t}$$

We found that

$$x = \frac{1}{2}at^2 \quad \Rightarrow \quad v = \frac{\Delta x}{\Delta t} = at$$

Gottfried Wilhelm Leibniz
(1646-1716)

However, if the change is very small, we indicate this as:

$$\Delta \rightarrow d \quad \Rightarrow \quad v = \frac{dx}{dt}$$

Pronounce: the velocity *v* is the derivative or change of the position *x* with respect to time.

Or: the velocity describes the change in position due to a change in time, since $\Delta x = v\Delta t$

For the relation between the velocity and the acceleration, we also found that:

$$a = \frac{v(t+\Delta t) - x(t)}{t + \Delta t - t} = \frac{a(t+\Delta t) - at}{\Delta t} = \frac{a\Delta t}{\Delta t} = a$$

Or, if the change is very small:

$$a = \frac{\Delta v}{\Delta t} \qquad \rightarrow \qquad a = \frac{dv}{dt}$$

Therefore,

$$v = \frac{dx}{dt} \qquad \text{and} \qquad a = \frac{dv}{dt}$$

This means we can rewrite Newton's second law as

$$F = ma \quad \Rightarrow \quad F = m\frac{dv}{dt} \quad \Rightarrow \quad \frac{dv}{dt} = \frac{F}{m}$$

What if there is no net force working on the object?
Then:

$$m\frac{dv}{dt} = 0 \quad \text{or} \quad \frac{dv}{dt} = 0$$

Now read it: The change of the velocity *v* due to a change in time is zero. This means that the velocity does not change as the time changes. Or:

$$v = \text{constant}$$

However,

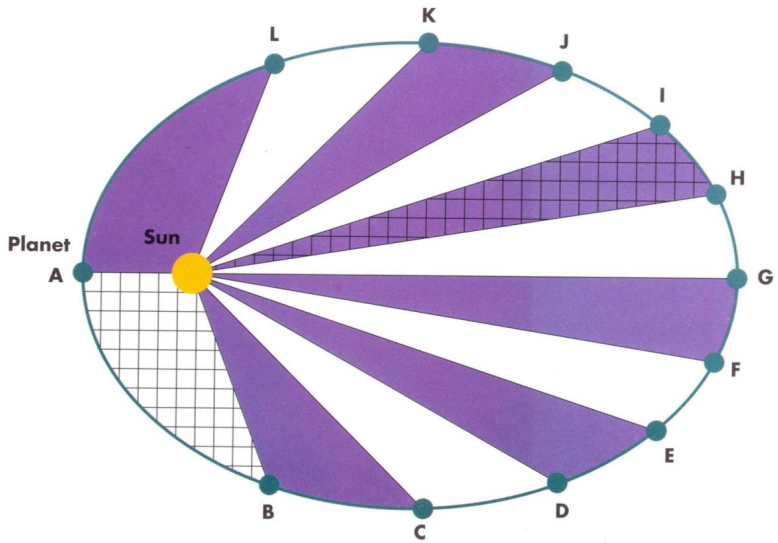
$$v = \text{constant}$$

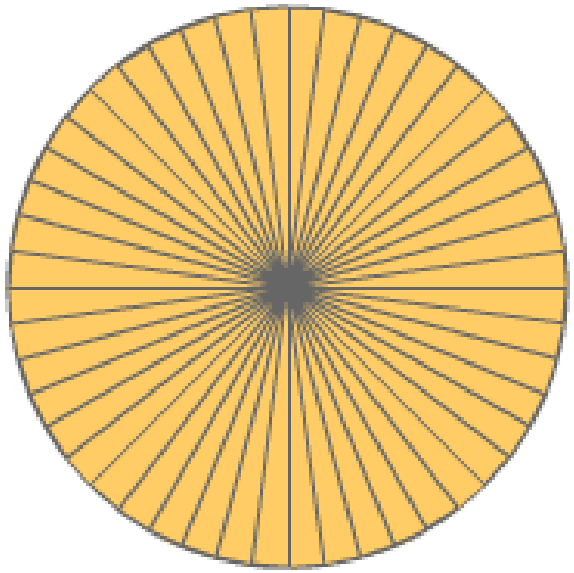
in the absence of a net force, is just Newton's first law:
An object in motion stays in motion

So Newton's first law is just a special case of Newton's second law!

(Why are we still teaching them separately).

What about integration?





Integration has to do with the calculation of areas

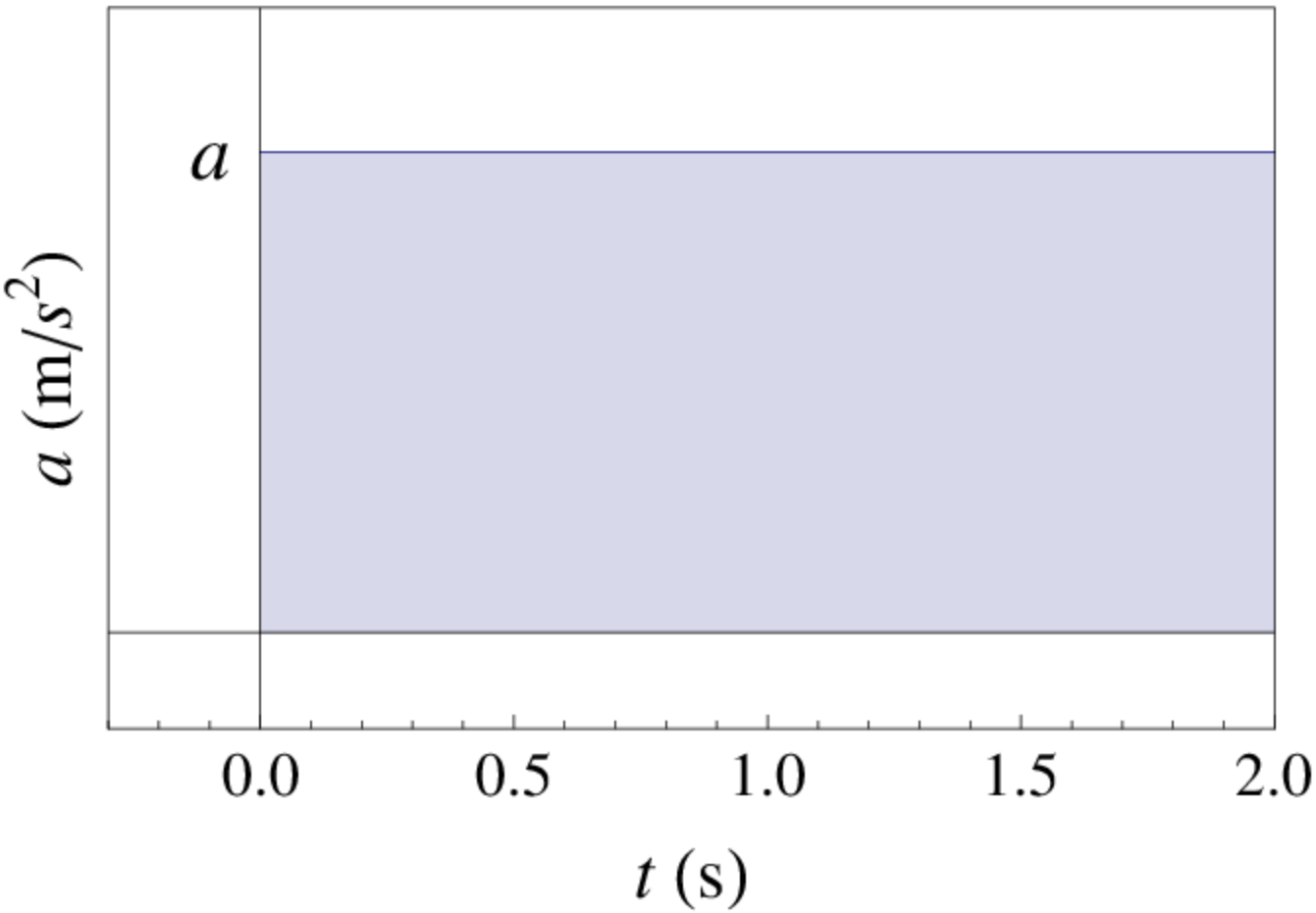
$$\text{Area} = \sum \text{area}_{\text{small}}$$

$\sum$ is the summation over all the small areas

The smaller the small areas are, the better the total area is calculated.

Preferably, we want the small areas to be infinitesimally small

But what does that have to do with mechanics?

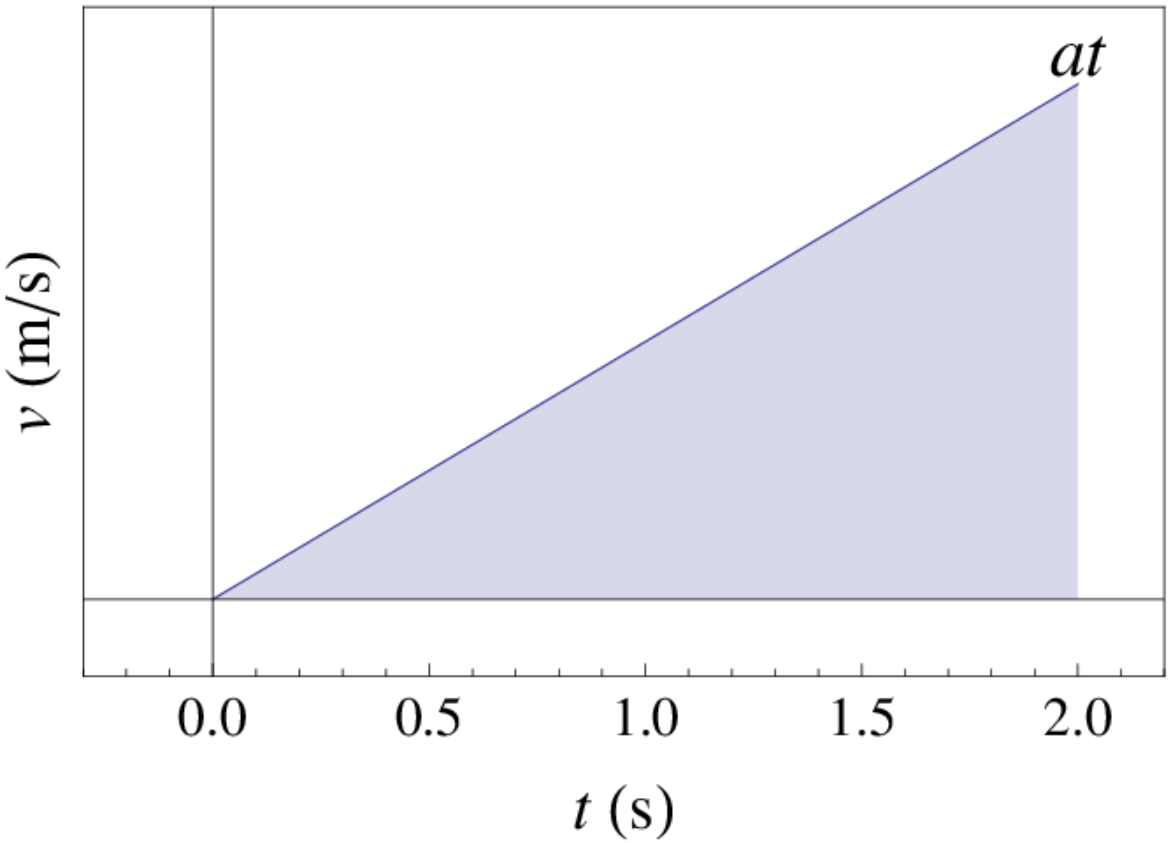


$$v = at$$

We know that

However, that is exactly the shaded are in the graph!

Let us see if we can get the expression for the position

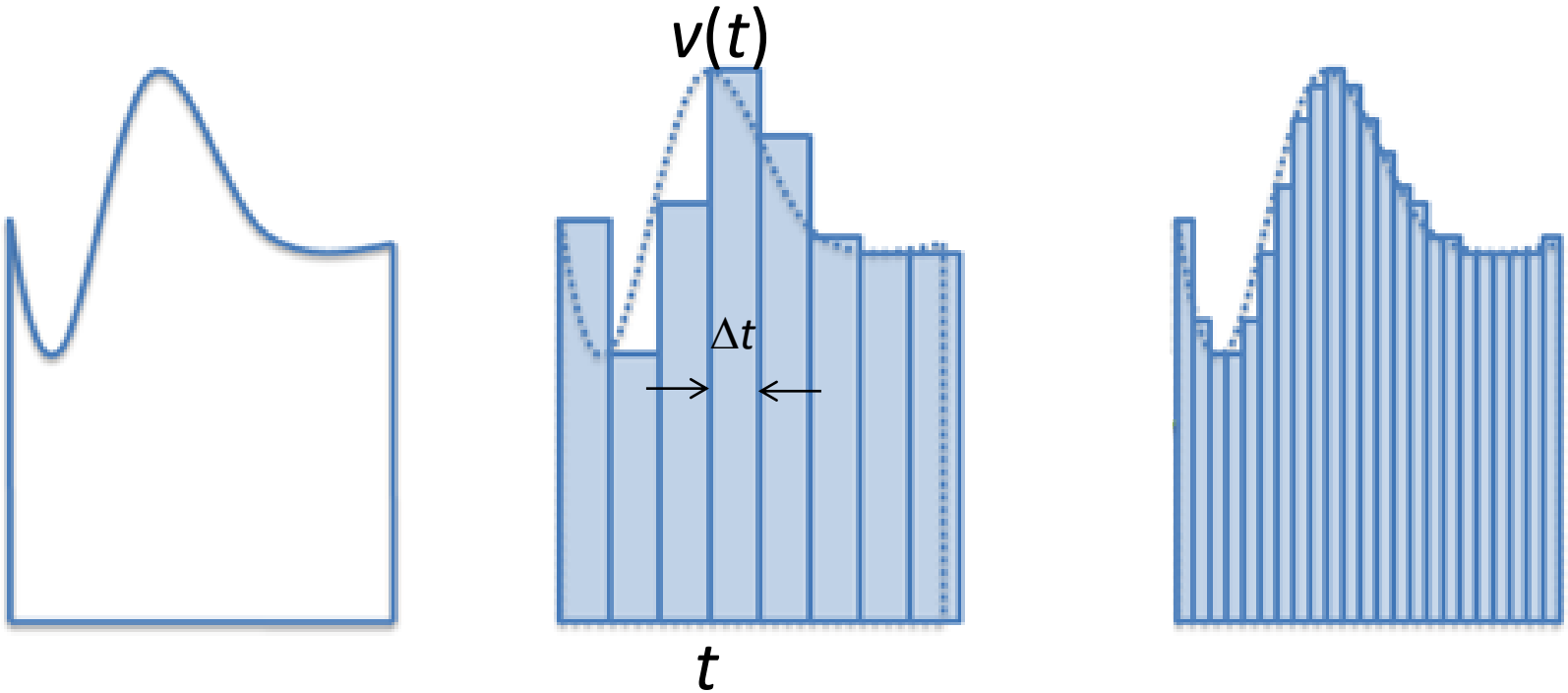


We just found that $v = at$

Long ago, we saw that $x = \frac{1}{2}at^2$

This is again the shaded area in the graph

Usually things are more complicated



$$x = Area = \sum_{\text{all rectangles}} \text{area}_{\text{rectangle}} = \sum_{t} v(t)\,\Delta t$$

For infinitesimally small rectangles: $\sum \rightarrow \int$ and $\Delta t \rightarrow dt$

This gives $x = \int v(t)\,dt$

So, knowledge of differentiation and integration allows one to switch between position, velocity, and acceleration

$$v = \frac{dx(t)}{dt} \quad \text{and} \quad a = \frac{dv(t)}{dt}$$

$$x = \int v(t)dt \quad \text{and} \quad v = \int a(t)dt$$

This works for any dependence on the time. Not just Galileo's simple cases of constant speed and constant acceleration. Newton was ready to attack any problem!

HARMONICES MVNDI

$$v = \frac{dx(t)}{dt} \qquad a = \frac{dv(t)}{dt}$$

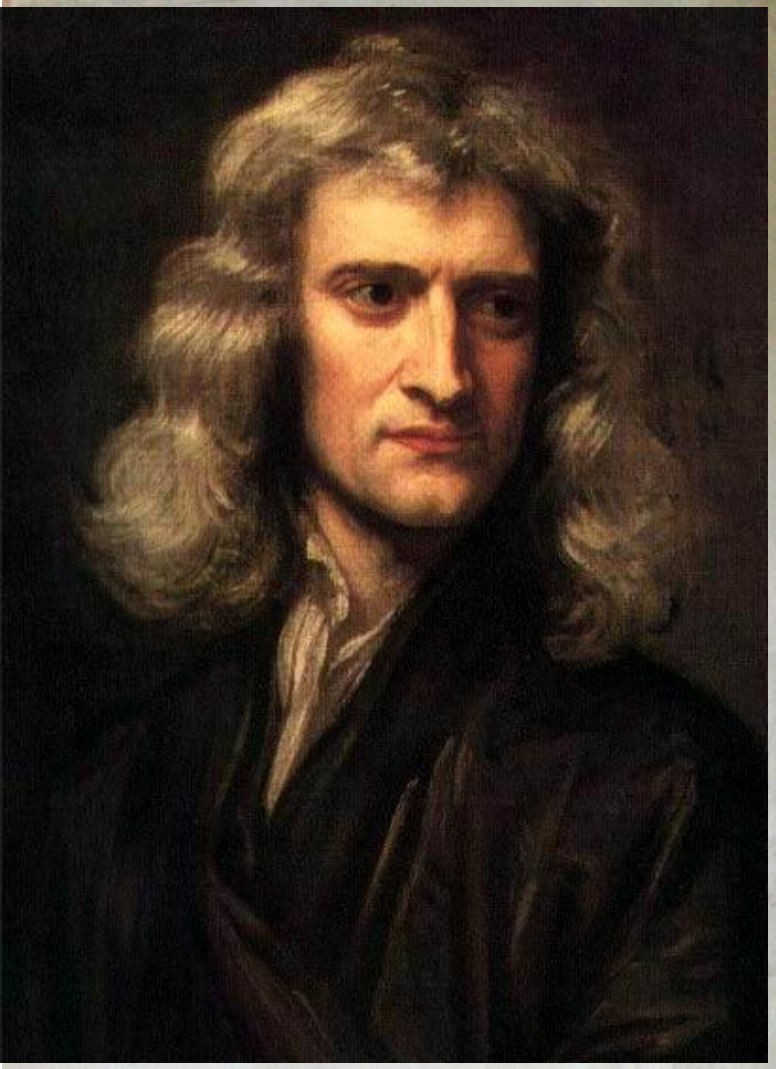
$$x \rightleftarrows v \rightleftarrows a$$

$$x = \int v(t)dt \qquad v = \int a(t)dt$$

Music by Henry Purcell (1659-1695)
Rondeau from Abdelazer 1695

Britten 1913-76

James II



PHILOSOPHIÆ NATURALIS PRINCIPIA MATHEMATICA.

Autore JS. NEWTONO Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.