Alexandria: Eratosthenes and Ptolemy

And Hypatia

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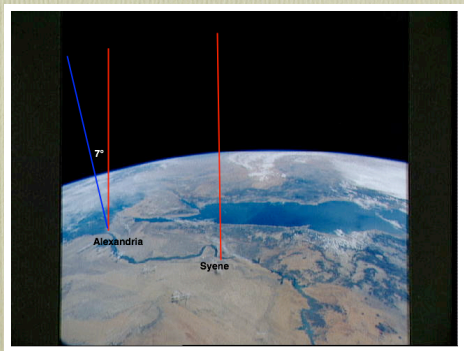
How the Greeks knew the world was round

- 1500 years before Columbus!

Eratosthenes: 276-195 BC

- How big is the earth?



- Sun is vertically above Syene (Aswan) whereas it is 7° off the vertical at Alexandria,
- Distance is 720 km
- Gives ~5900 km instead of 6400.
- First step into finding how big the universe is!

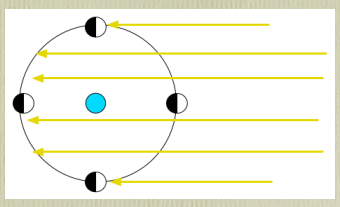
•How far is the Moon?

- Moon is about 1/2° in the sky
- Can use the moon as a "Screen" on which the shadow of the earth is projected:
- The shadow of the Earth ~2° wide.

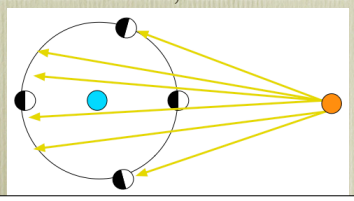
Photo by Anthony Ayiomitas

- Radius of the earth ~6500 km (4000 mi).
- This gives d ~ 375,000 km
- d = 384,400 km by modern methods.
- How far is the sun?

- Much More Clever: If the sun was infinitely far away, then half-moon would occur exactly half way through month.



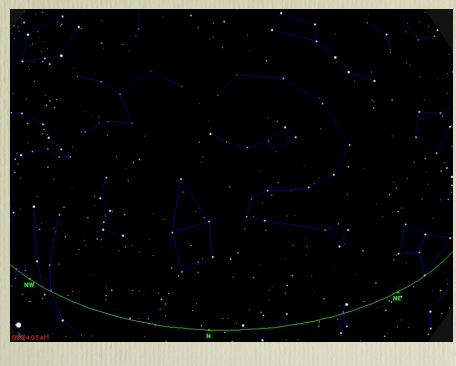
- If the sun is closer, half-moon will occur earlier



- **Very** hard to estimate when half moon occurs
- This gave an earth-sun distance ~20 times Earth-Moon distance.
- Hence ~7,500,000 km.
- We now know the distance ~150,000,000 km
- Implies the sun is a red-hot stone bigger than Greece! (Anaxagoras)

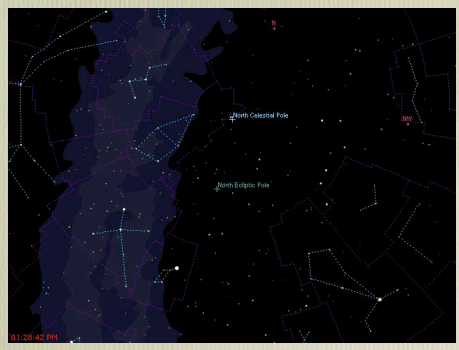
One more discovery by the Babylonians/Greeks

- What is the North star
- The point the stars appear to rotate round

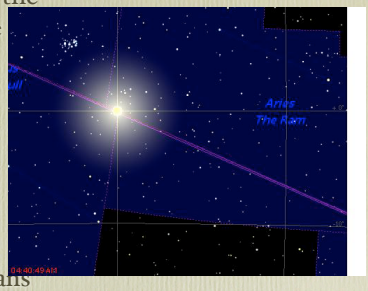


Hipparchus: 160-127 BC. Precession of the Equinoxes

- Earth's axis is tilted, but doesn't always point to the same place (i.e. the North Star isn't always!)



- March 21st & Sept 21st are special days: Sun is above the equator, but where on the equator?

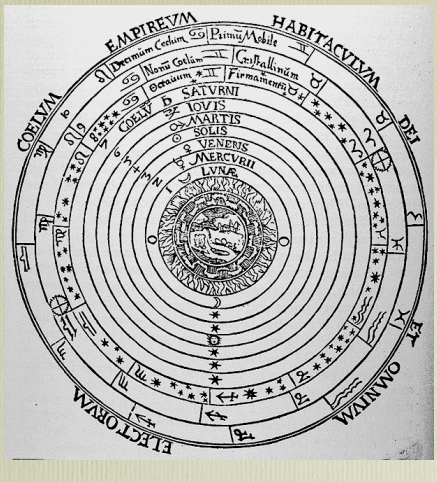


- Aries 2000 BC
- Pisces 100 BC
- (which is why the Christians chose the fish as their symbol)
- And now
- This is the dawning of the age of Aquarius

Ptolemy ~140 AD

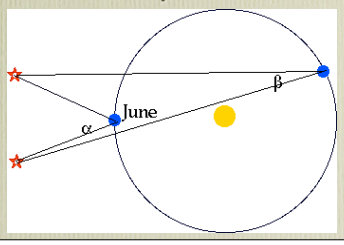
- All of these ideas came together in the Almagest (13 Volumes on Astronomy)
- First real model of the universe
- Ptolemaic model

- The simplest model is Geocentric: Earth at the centre
- Moon, Venus, Mercury, the Sun, Mars, Jupiter, and Saturn in circular orbits
- Stars and crystal sphere beyond



Why the earth must be stationary:

- Suppose that the earth revolved around the sun.
- In observing two distant stars, angle between them would change during year
- Since the separation between the stars doesn't change, the earth must be stationary.

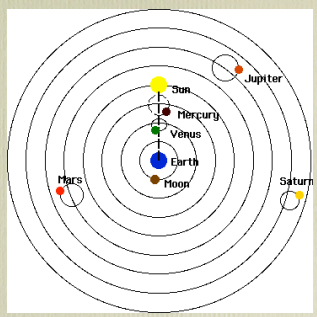


But

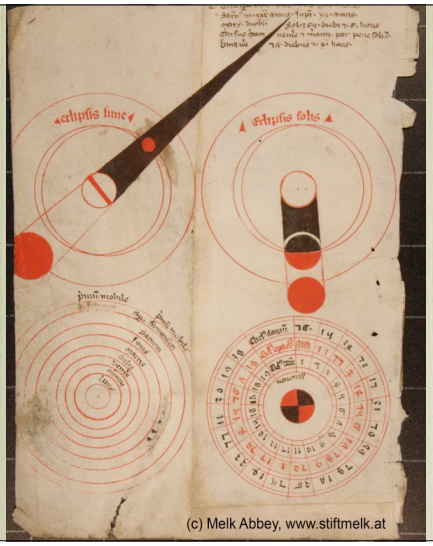
- Mercury and Venus never get far from sun.
- Retrograde Motion.

- Changing brightness of planets during year: always brightest when south at midnight

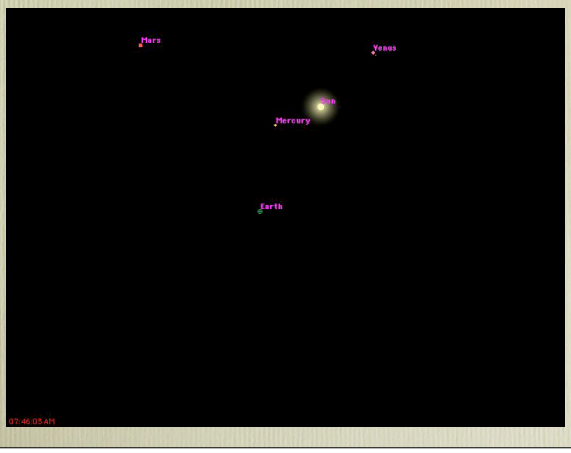
- Orbits of Mercury and Venus are locked to that of the sun.
- All planets are given epicyclic orbits: they orbit about a point, which revolves about the deferent - or orbital path about the earth.
- Finally, the earth is removed slightly to off-centre



- A medieval fragment
- Il sole no si muove (The sun does not move) Leonardo da Vinci



- And we can even get it to work!



COPERNIKUS (1473-1543)

- Ptolemy's model now required 40 epicycles to explain the increasingly accurate observations.

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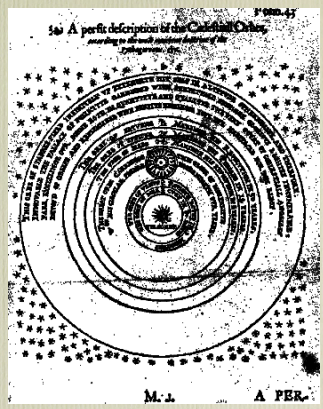
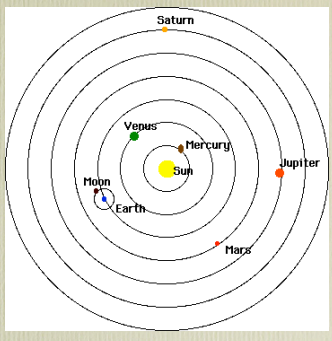
- Copernicus proposed a Heliocentric solar system.
- His model used circular orbits, so still needed epicycles.



- Motion of Mercury & Venus "unlocked" from sun.
- Lack of parallax because fixed stars are very far away
- So why did people at the time believe in Copernicus?



Reasons for asserting the earth is motionless:

1. David in Psalm 89: God has founded the earth and it shall not be moved.
2. Joshua bade the sun stand still-which would not be notable were it already at rest.
3. The earth is the heaviest element, therefore it more probably needs rest.
4. Everything loose on the earth seeks its rest on the earth, why should not the whole earth itself be at rest?

4. We always see half of the heavens and the fixed stars also in a great half circle, which we could not see if the earth moved, and especially if it declined to the north and south...
5. A stone or an arrow shot straight up falls straight down. But if the earth turned under it, from west to east, it must fall west of its starting point.
6. In such revolutions houses and towers would fall in heaps.
7. High and low tide could not exist; the flying of birds and the swimming of fish would be hindered and all would be in a state of dizziness.

Reasons for the belief that the earth is moved:

- The sun, the most excellent, the greatest and the midmost star, rightly stands still like a king while all the other stars with the earth swing round it.
- That you believe that the heavens revolve is due to ocular deception similar to that of a man on a ship leaving shore.
- That Joshua bade the sun stand still Moses wrote for the people in accordance with the popular misconception

4. As the planets are each a special created thing in the heavens, so the earth is a similar creation and similarly revolves.

5. The sun fitly rests at the centre as the heart does in the middle of the human body.

6. Since the earth has is itself its especial centrum, a stone or an arrow falls freely out of the air again to its own centrum as do all earthly things.

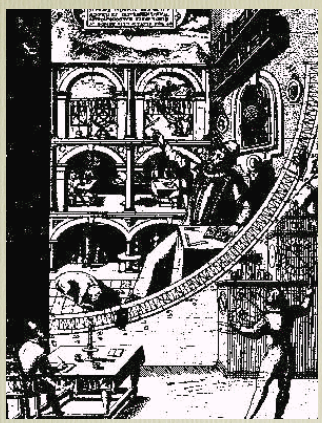
7. The earth can move five miles in a second more readily than the sun can go forty miles in the same time.

Voight (1667). Der Kurstgunstein Einfalt Mathematisher Raritaten Erstes Hundert.

Tycho Brahe 1546-1601

- Note the tin nose ...

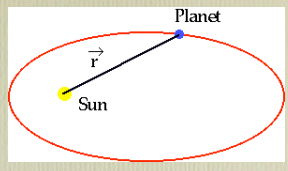
- Ruler of island of Haven, off coast of Denmark.
- Constructed Uraniborg to measure position of planets and stars
- "Now it is quite clear to me that there are no solid spheres in the heavens, and those devised by the authors to save the appearances exist only in the imaginations for the purpose of permitting the mind to conceive the motion which the heavenly bodies trace in their courses."



Kepler 1571-1627

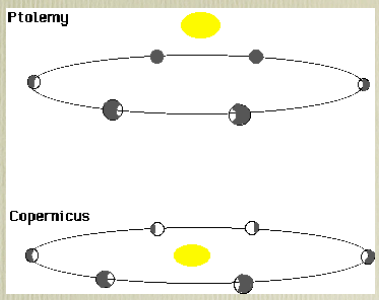
- Corresponded with Brahe and acquired records after his death.
- (i.e. refused to give them up to his heirs)

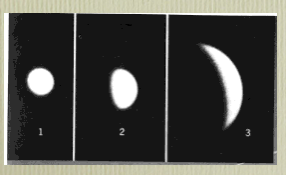
Planets move in ellipses, with one focus at the sun



GALILEO (1564-1642)

- The final nail in the coffin of Ptolemaic model
- The phases of Venus





A Failure

But a failure that lasted 1400 years!

Acknowledgements

Astronomy Picture of the Day (APOD)

- Anthony Ayiomitas

- Next:
- Farewell to Earth:

  Planets and other things

Next: