ET: Astronomy 230

HW 7 due today!

This Class (Lecture 32):

Cultural Evolution

Next Class:

Lifetime

Music: *Human* –
Human League

Outline

- Will a civilization develop that has the appropriate technology and worldview?
- The most important worldview shift for humans was the Copernican revolution.
- From center of the Universe to not special.

Drake Equation

= 1.6

Intelligent Life /decade

Frank Drake

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	10 stars/ yr	**0.38 systems/ star**	**0.11 planets/ system**	**0.5 life/ planet**	**0.75 intel. /life**	comm./ intel.	yrs/ comm.

Our First View

- The first concepts of the Universe were Earth-centered.
- How did we come to this point– Astro 230?
- First recorded cosmology was from the Babylonians.
  - The Universe is a large oyster, and we are inside.
  - But other aspects of their astronomy was advanced.
  - Regularity of astronomy for crop planting, harvesting, and accurate calendars back to the 3800 BC.

Our First View

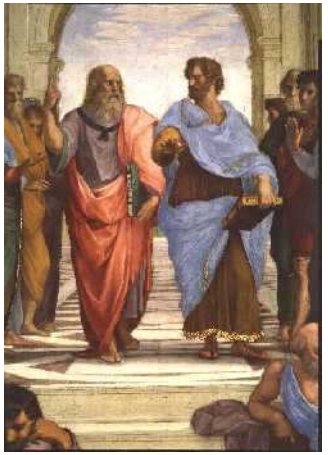
- The Mayans computed the length of year to within a few seconds (0.001%).
- So early humans had a weird mixture of precise calendar astronomy with primitive concept of the Universe and mythological systems incorporating magic.

http://www.mayasites.com/equinox.html

http://ephemeris.com/history/mayan-calendar.jpg

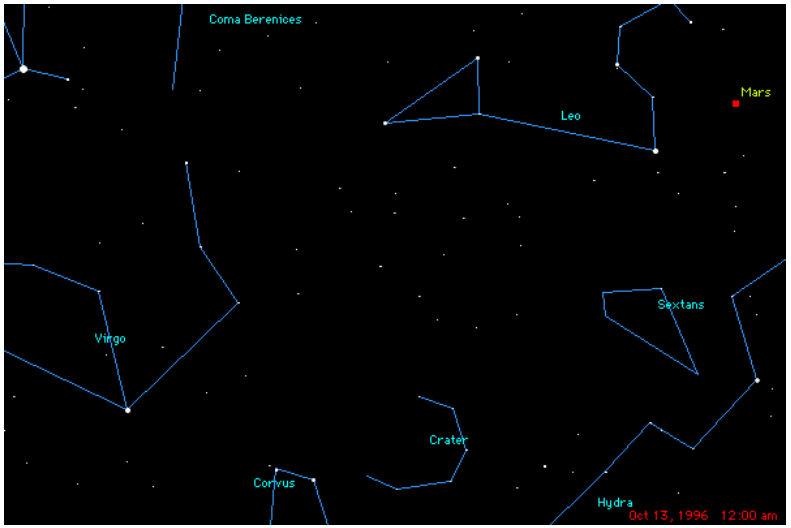
Greek Astronomy

- Greeks were excellent Astronomers
  - Cataloged star positions & brightness.
  - Systematic, quantitative observations.
  - Natural philosophers.
- They observed that the stars, Sun, and planets revolved around the Earth.
- So Earth is center of Universe- ***geocentric cosmology*** (mostly from Plato and Aristotle).
- Perfect Spheres of motion?



Mars Moves WRT the Stars!

E A S T



W E S T

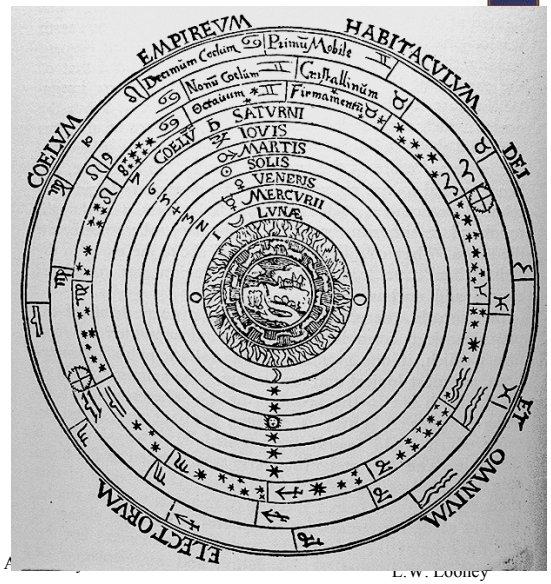
Motions of Planets

- So, over time the planets seem to move along the ecliptic from <u>west to east</u> over long time periods.
  - This is called ***prograde*** motion
- But once in a while, a planet appears to stop and reverses direction
  - Reverse direction is called ***retrograde*** motion (east to west).
- Planets move counter-clockwise (looking down at the north pole)

How can we explain the Planet motion?

With a ***geocentric cosmology*** you can't easily explain this retrograde motion of the planets.

Note: perfect circles

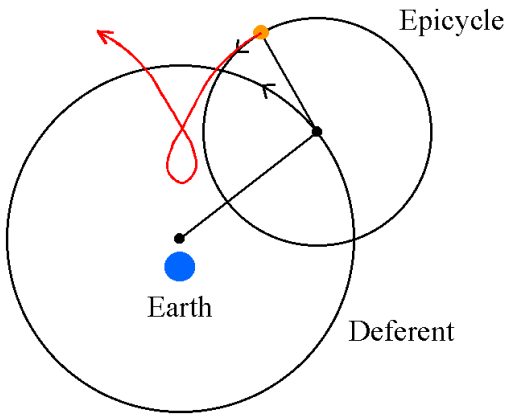


Ptolemy (140 AD: `p` is silent)

Took geocentric model with uniform circular motion to introduce the Ptolemaic system, or model, of the Solar System that could explained retrograde motion

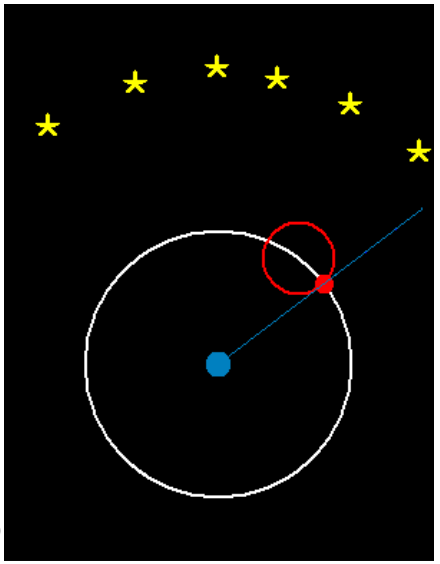
Ptolemaic system

- Geocentric
- Nice circular motion



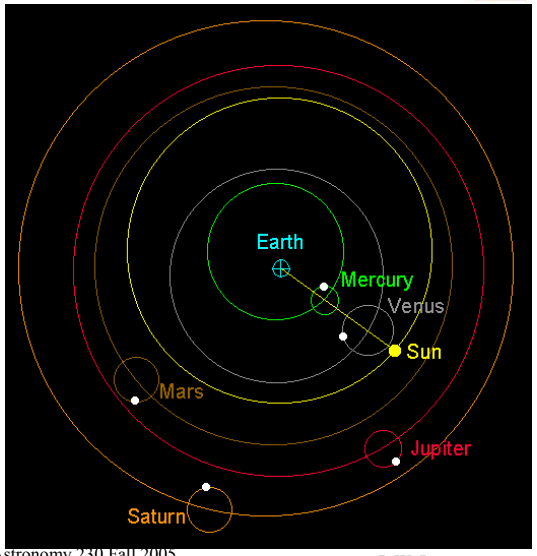
Ptolemaic system

Yes, it can explain retrograde motions



Ptolemaic system

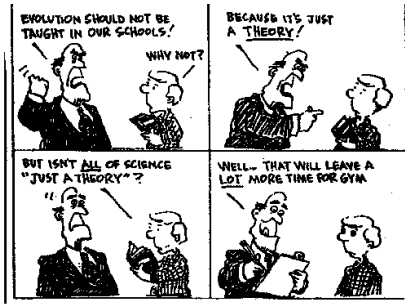
Overall system of the Solar System.



Ptolemy's Geocentric Cosmology: Is it a Scientific Theory?

Yes! …and an accurate one too

- Data: Sun/moon/star motions
- Tentative Model: circular orbits
- Prediction: uniform motion on sky
- New data: retrograde motion
- Refined model: epicycles
  – explains data!



http://home.comcast.net/~fsteiger/theory.htm

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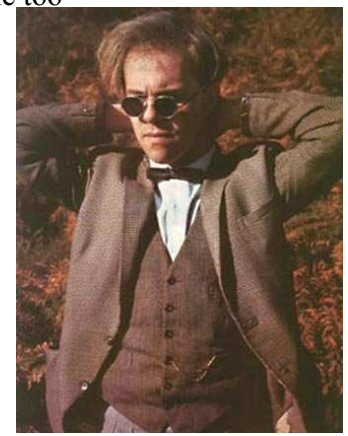
Result: Ptolemaic system (theory)

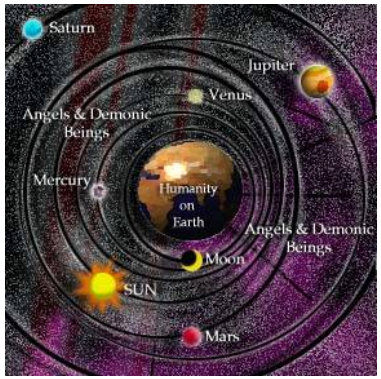
- *Strength*: accurate fit of data
- *Weakness*: predictions for new data?



http://www.tmdrfan.com/rthurlow/ThomasDolby1982.htm

Ptolemaic Problems

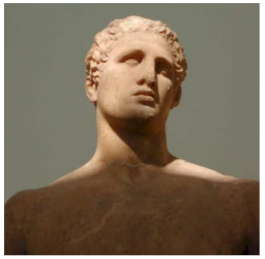
- Each planet acted independently of others
- There was no universal rule governing the planets motions.
- Nonetheless, for a 1000 years this model ruled western thought
- However, by the late middle-ages astronomers felt that it was too complex, and a search began for a system with simple underlying principles



http://gbgm-umc.org/umw/bible/images/ptolmai2.jpg

Lessons: Were the Greeks Stupid?

- Not at all!
  Developed sophisticated, successful model
- But built in prejudices about the world
  not just geocentric but egocentric



What about scientists today?
Still can fool ourselves! (And have!)
But: *scientific method* is tool:
- To keep from fooling yourself
- To correct yourself when you have

My guess:

70% of the material in this course will stand the test of time
- Compare baseball: 30% success good
- But also: 30% of course is wrong/incomplete!
  - Which 30%? Don't know! Would fix it if we knew! So…
  - You have to learn all of it!

http://www.farhorizon.com/europe/images/images-greece/head_of_Greek_god.jpg

Power of Ignorance

- Geocentric model was absorbed by Christianity.
- If Geocentric, then of course no ET life.
- St. Augustine (420 AD) incorporated Neo-Platonism. He listed science as a temptation to avoid: "a mere itch to experience and find out"
- Also said, "Nor do I care to know the course of the stars."

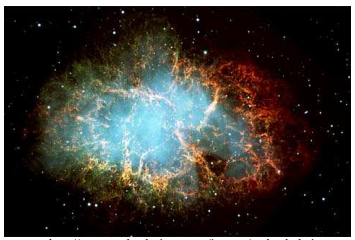
http://www.flholocaustmuseum.org/history_wing/assets/room1/St._Augustine.jpg

Power of Ignorance

- The European worldview degenerated for years.
- No one in Europe mentioned the supernova of 1054 (Crab Nebula), unlike China or Americas. People were afraid to notice it and be described as a heretic.
- Could an ET civilization reach technology with that sort of attitude?

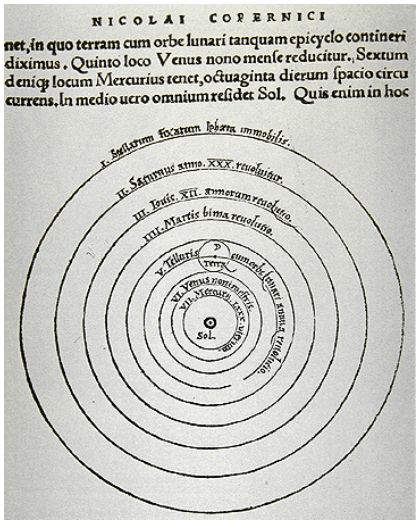
http://www.pbs.org/deepspace/timeline/tl14.html

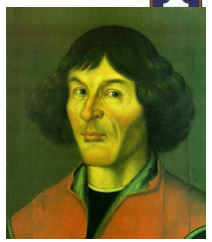
http://www.tulane.edu/~danny/southwest.html



http://www.godandscience.org/images/crabnebula.jpg

Copernicus (1540) resurrected the heliocentric model





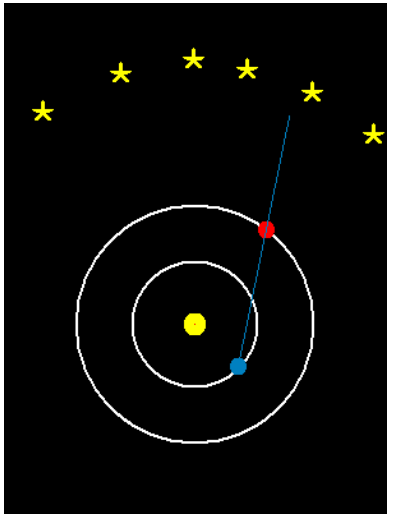
- If Earth moves, then stars have to be very far away.
- Was rejected on theological and philosophical grounds.
- 1616, the Church listed it as heresy.

Giordano Bruno

- Seems to have taken it one step further.
- Thought that the stars were all little Suns.
- Possibly with planets of their own.
- Maybe life on those other planets.
- Maybe more advanced than those on Earth.
- These are some of the reasons why he was burned at the stake around 1600.

Copernican Theory

- Can explain retrograde motion
- Much simpler
- Still kept to circular motion
- Eventually changed the way we think of ourselves!

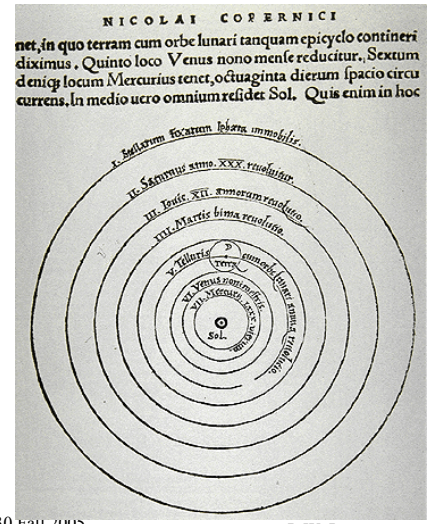


Copernicus (1540) Heliocentric Model

BUT, keep in mind that the geocentric model was still valid. Both models explained the observed motion.

Heliocentric is NOT obvious!

IT was determined a philosophical argument for 50 years! New observations were required to determine which is correct.

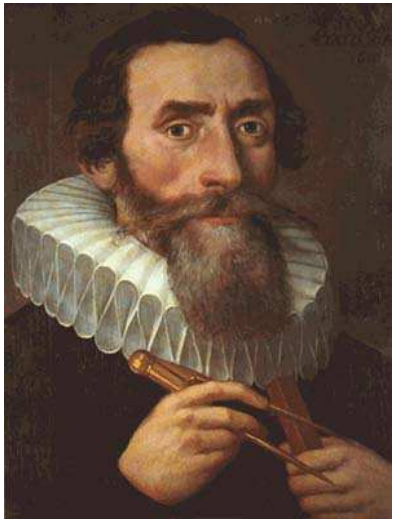


Tycho Brahe (1580): Uraniborg

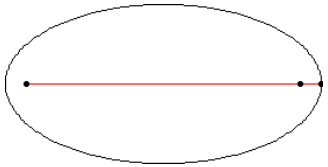
Accurate measurements to about 1 minute of arc (1/15 the diameter of the moon). No telescopes!

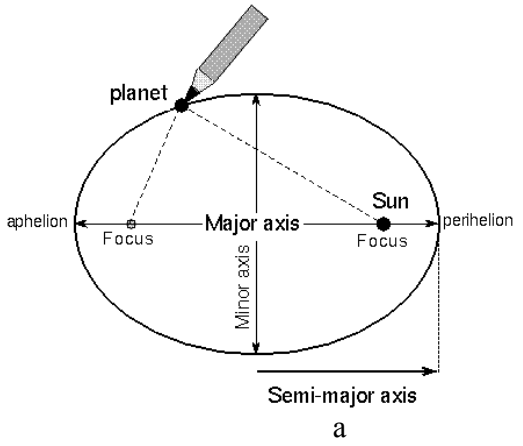
Johannes Kepler (1600)

- Tycho's assistant in Prague
- After Tycho's death, succeeded Tycho's position and had access to the excellent data
- How to fit the Heliocentric model to accurate data of Mars?
- Circles didn't work.
- Ellipses!



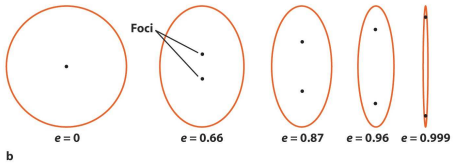
Kepler's 1st Law: Orbits of planets are ellipses with the Sun at one focus

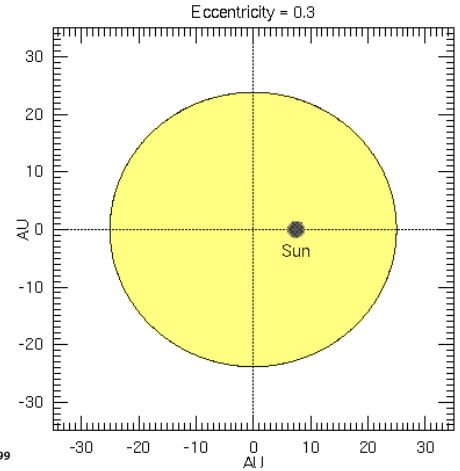




Orbits of planets are ellipses with the Sun at one focus

Not a perfect circle, but ellipses with varying eccentricity.





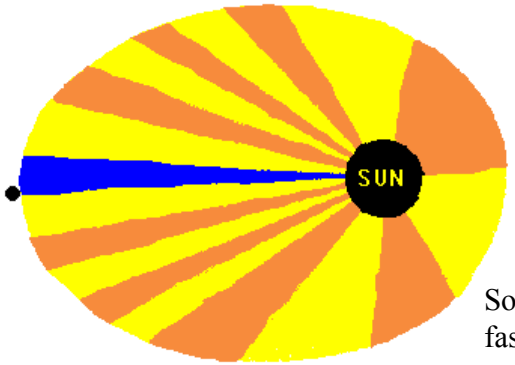
Implications

New Twist– even the Sun isn't at the center of the solar system now. How does that change our view of the Universe and our place in it?

http://antwrp.gsfc.nasa.gov/apod/ap010101.html

Kepler's 2nd law:
The Line that connects the planet to the Sun sweeps out equal areas in equal time

aphelion



perihelion

So, planet moves faster at perihelion.

Kepler's 3rd Law:
The squares of the orbital sidereal periods of the planets about the Sun are proportional to the cubes of the orbital semimajor axes

Planet	P (yr)	a (AU)	P^2	a^3
Mercury	0.24	0.39	0.06	0.06
Venus	0.61	0.72	0.37	0.37
Earth	1.00	1.00	1.00	1.00
Mars	1.88	1.52	3.5	3.5
Jupiter	11.86	5.20	141	141
Saturn	29.46	9.54	868	868

$$P^2 = a^3$$

$$P \times P = a \times a \times a$$

Where P is in years and a is in AU.

Kepler's Laws

The farther away from the Sun, the longer it takes for the planet to orbit AND the slower it's average orbit speed.

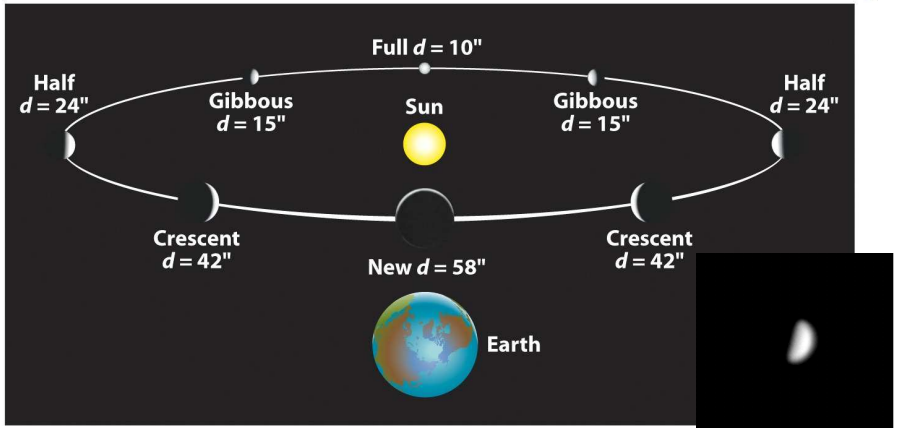
Galileo (1610)

First to systematically use the telescope (but did not invent it).

- Moon has mountains and valleys
- Milky Way consists of faint stars
- Saturn is elongated
- Venus shows phases
- Jupiter has moons (now called Galilean moons)

Wow! Big stuff. The moons of Jupiter did not orbit the Earth!

The Phases of Venus



Could not be explained with the Geocentric model

http://www.astro.ubc.ca/~scharein/a310/SolSysEx/phases/Phases.html

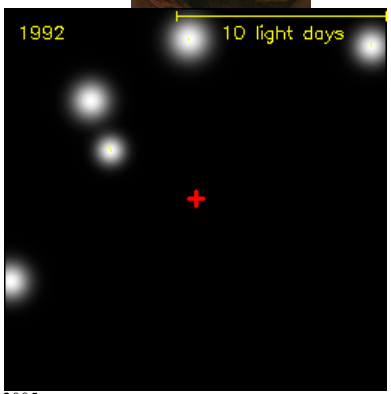
http://www.calvin.edu/academic/phys/observatory/images/venusmay.usb.html

Galileo (1610)

- Disproved Ptolemaic system
- Rome bullied him into recanting (cleared in 1992)
- Now we understand the motions and the fact that the solar system MUST be Heliocentric, but now we need a reason why?
- Need something with predictive power.

Isaac Newton

- Gave us a reason why--GRAVITY.
- Developed fundamental laws of nature.
- Kepler's 3rd law now became a way to probe the structure of the Universe!
- We are not the center of the Universe.
- In the 1920s, we realized that we are not the center of the galaxy, and that there are <u>many</u> other galaxies.



f_c Development

- Given that an intelligent civilization exists, what is the likelihood that it can (technologically advanced enough) and will want to (knows astronomy and thinks that its chances are good) communicate?
- Cultural evolution to <u>technology</u> and <u>worldview</u> are essential components of f_c
  - Extra-somatic storage of info crucial.
  - Technology and innovation– quantum mechanics
  - Copernican revolution played an important role.
  - ET has to realize that they are not the center of the Universe and that there might be other life.

f_c Development

- Are we typical?
- Is it inevitable fc = 100% or a fluke 1/10000?
- Remember civilizations come and go, but in general the gains (technology/worldview) aren't lost.
- Picked up by the next civilization.
- Even if one civilization goes dark for centuries, eventually another rekindles the technology/worldview.