

Astronomy 230

Section 1– MWF 1400-1450

106 B6 Eng Hall



This Class (Lecture 20):

Evolution of the Worldview

Next Class:

Lifetime

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Outline



- Will a civilization develop that has the appropriate technology and worldview?
- Requires knowledge of quantum mechanics and astronomy.
- The most important shift for humans was the Copernican revolution.
- From center of the Universe to not special.
- Kepler's Laws
- Gravity– Isaac Newton.

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= 4.4

Intelligent Life
/century

Drake Equation

Frank
Drake



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

of
advanced
civilizations
we can
contact

Rate of
formation
of Sun-
like stars

Fraction
of stars
with
planets

of
Earthlike
planets
per
system

Fraction
on which
life arises

Fraction
that evolve
intelligence

Fraction
that commu-
nicate

Lifetime of
advanced
civilizations

10

0.34

0.208

0.235

0.265

Stars/year

Planetary
System/star

Livable Planets
/Planetary System

Evolved Life
/Livable Planet

Intelligence
/Evolved Life

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Technology



- Cultural evolution was fast.
- Especially after agriculture freed civilizations.
- Development of language.
- Increase of extra-somatic storage.
- We're living in a silicon age.
- Does the development of technology also include a correct worldview?

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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 explained **retrograde** motion



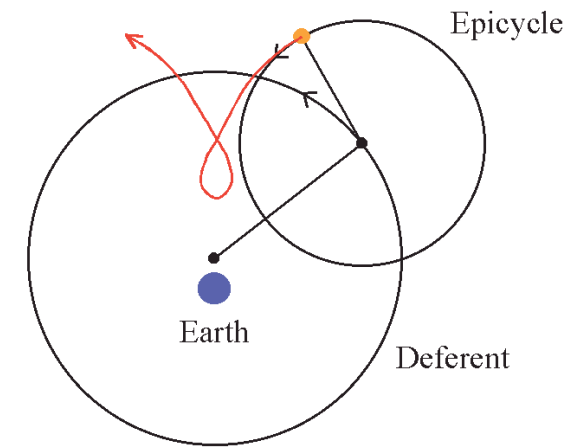
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Ptolemaic system



- Geocentric
- Nice circular motion



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Power of Ignorance

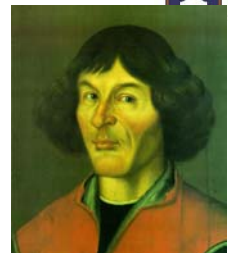
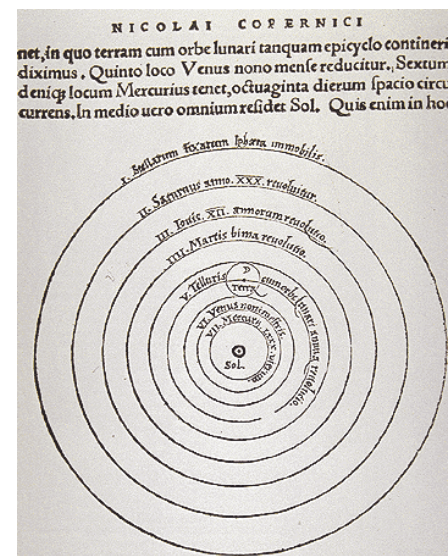


- Heliocentric model was absorbed by Christianity.
- If Geocentric, then of course no ET life.
- St. Augustine (420 AD) incorporated Neo-Platonism. He listed as a temptation to avoid: “a mere itch to experience and find out”
- Also said, “Nor do I care to know the course of the stars.”
- The European worldview degenerated for years.
- No one in Europe mentioned the supernova of 1054 (Crab Nebula), unlike China. People were afraid to notice it and be described as a heretic.
- Could an ET civilization reach technology with that sort of attitude?

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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.

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Giordano Bruno



- Took 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.

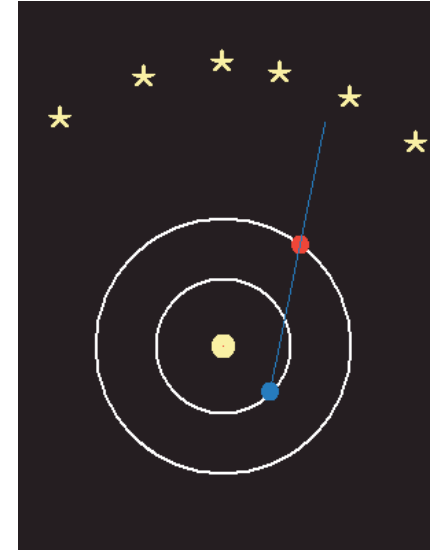
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Copernican Theory



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



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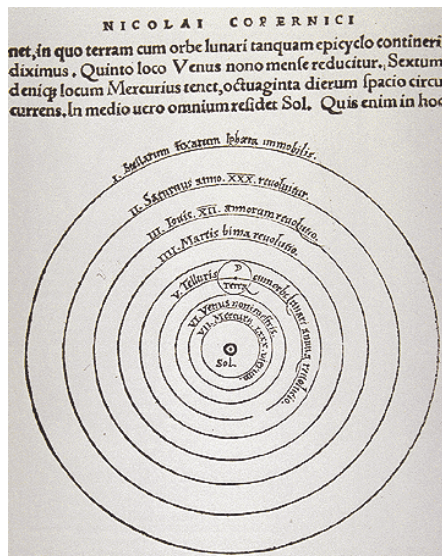
Copernicus (1540) Heliocentric Model



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.



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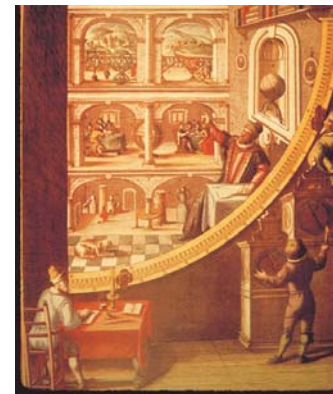
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Tycho Brahe (1580): Uraniborg



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



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Johannes Kepler (1600)



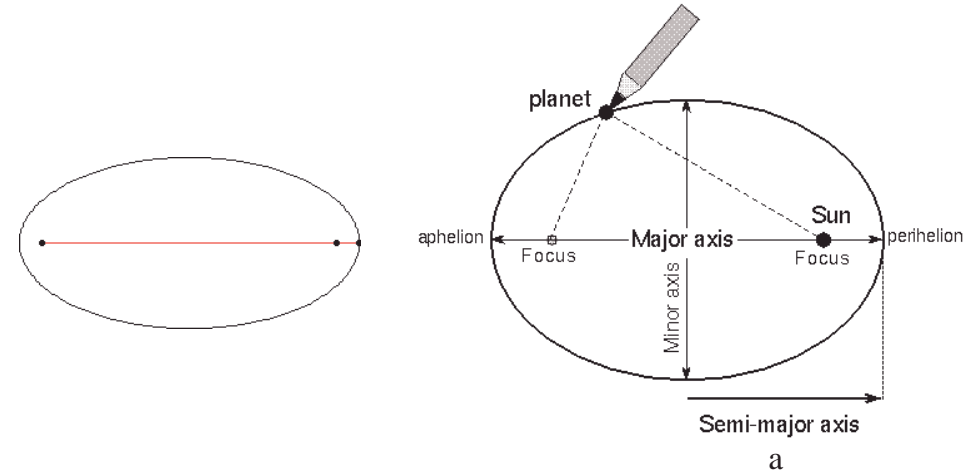
- Tycho's assistant in Prague
- After Tycho's death, succeeded Tycho's position and had access to the excellent data
- How to fit the Heliocentric model to accurate data of Mars?
- Circles didn't work.
- Ellipses!



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



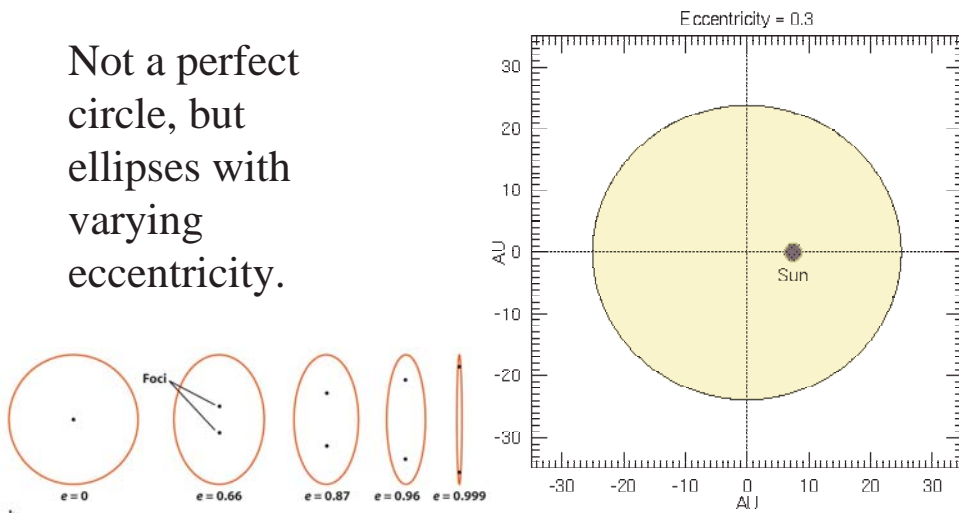
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Orbits of planets are ellipses with the Sun at one focus



Not a perfect circle, but ellipses with varying eccentricity.



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Implications



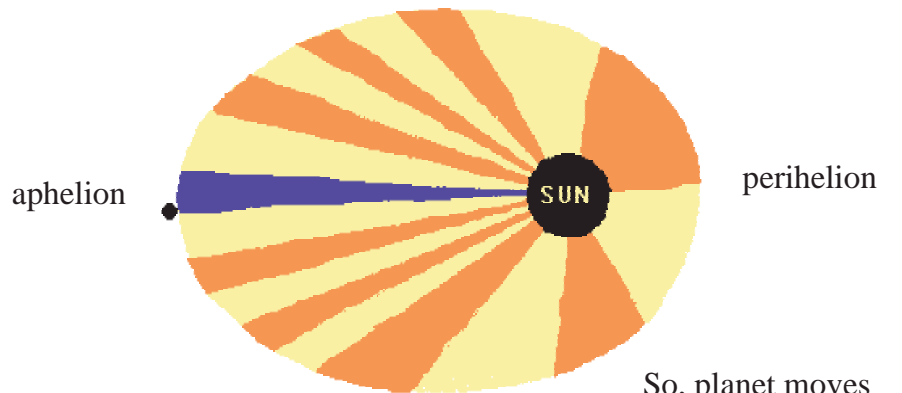
New Twist— even the Sun isn't at the center of the solar system now. How does that change our view of the Universe and our place in it?

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Kepler's 2nd law:

The Line that connects the planet to the Sun sweeps out equal areas in equal time



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Kepler's 2nd law:

The Line that connects the planet to the Sun sweeps out equal areas in equal time



Example: Note the inequality of the seasons: spring & summer have 93 days, autumn has 90 days, and winter has 89 days

Earth moves faster during autumn and winter (when it's closer).

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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.

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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.

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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)

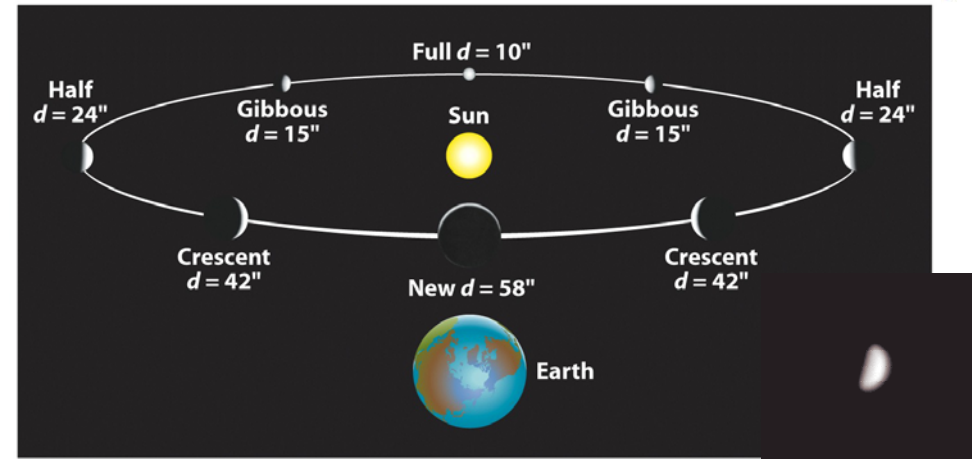
Wow! Big stuff. The moons of Jupiter did not orbit the Earth!



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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/venus/venusb.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?

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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 many other galaxies.



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Development



- Cultural evolution, technology, and worldview are essential components of f_c
- Extra-somatic storage of info crucial.
- Copernican revolution played an important role.
- Are we typical?
- Seems reasonable that to understand quantum mechanics, astronomy must also be well developed.
- ET has to realize that they are not the center of the Universe and that there might be other life.
- Is it inevitable $f_c = 100\%$ or a fluke $1/10000$?