

Cultural Evolution, II

Evolution of Concept of Universe

“Interest” part of f_c

Requires the following:

1. Understand the size and nature of Universe
2. Understand our place in Universe (*not* the center)
3. Optimistic Drake Equation

Are ability and interest linked?

Both are very recent developments

Is this a coincidence?

Evolution of Worldview

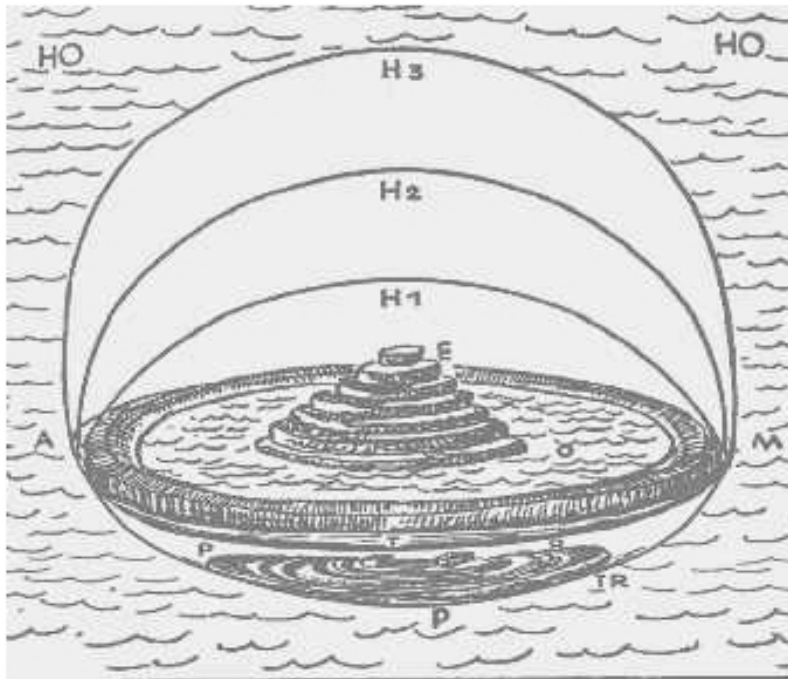
- Early astronomy had dual nature
 - Calendar Astronomy (observations)
 - Precise calendars in agricultural societies
 - Dates back to at least 3800 BCE
 - Mayans: length of year to 0.001% accuracy
 - Cosmic Myth (theory)
 - Tied to religion, origin stories

Oyster World



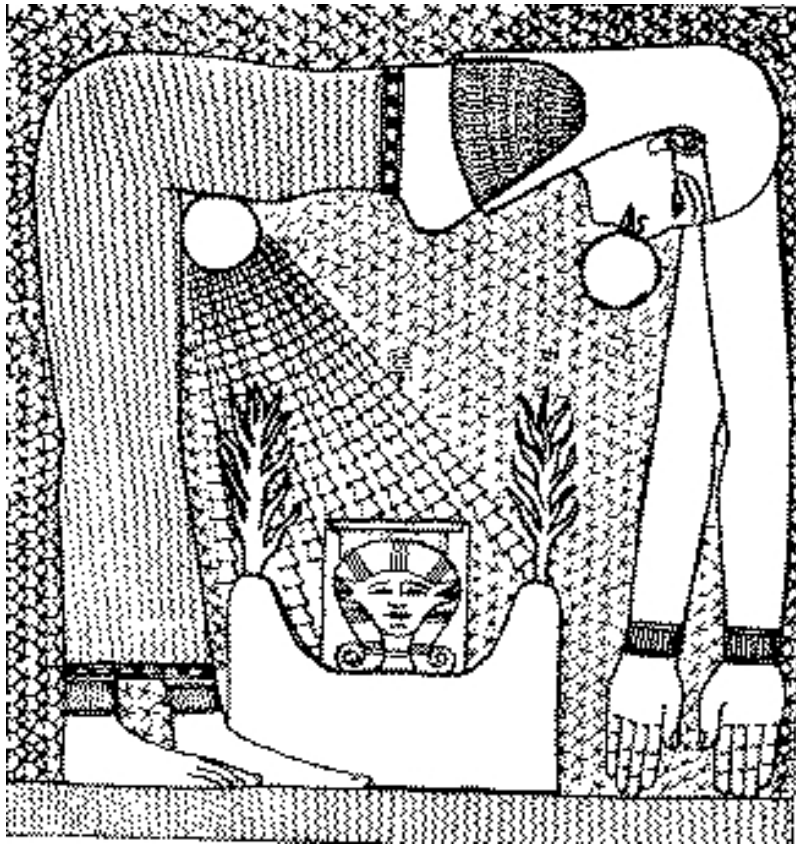
- Flat Earth
- Dome of Heavens
- Waters above
- Waters below
- Stars fixed to the dome
- Sun moves across the sky
- Earth is fixed

Late Babylonian World



- Three heavens
- Underworld
- Babylon is center
- Created by Marduk
 - City god of Babylon
 - Sliced up Tiamat
 - Separated waters above and waters below

Egyptian World



- God of the Air (Shu)
- Separated his parents
- Sky and Earth
- Mother was sky
 - Unusual choice

Origin of Natural Philosophy

- Around 500 BCE, Greeks on Ionian islands
- Thales and others
- Search for universal substance
 - Tried water, air, earth, fire
- Key feature is search for **natural** explanation
- Distinguished planets from stars
- Began to think about larger Universe

One group of Greek philosophers (the Atomists) believed in other worlds.

Epicurus 4th Century BCE

Infinite atoms implies infinite worlds, living creatures

In contrast: Aristotle

“The world must be unique”

Lucretius (Roman poet and philosopher)

“It is in the highest degree unlikely that this Earth and sky is the only one to have been created...”

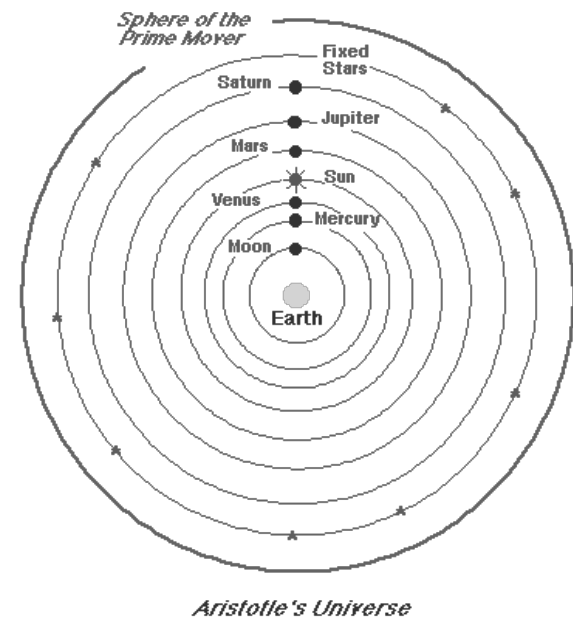
But even the Atomists did not have a correct vision of the nature of the Universe, stars

Plato and the dominance of the circle

- Plato chose the circle – the most symmetric
 - “And he gave the universe the figure which is proper and natural...”
 - “... he made it move with circular rotation”
 - Both from Timaeus

Aristotle and the two spheres

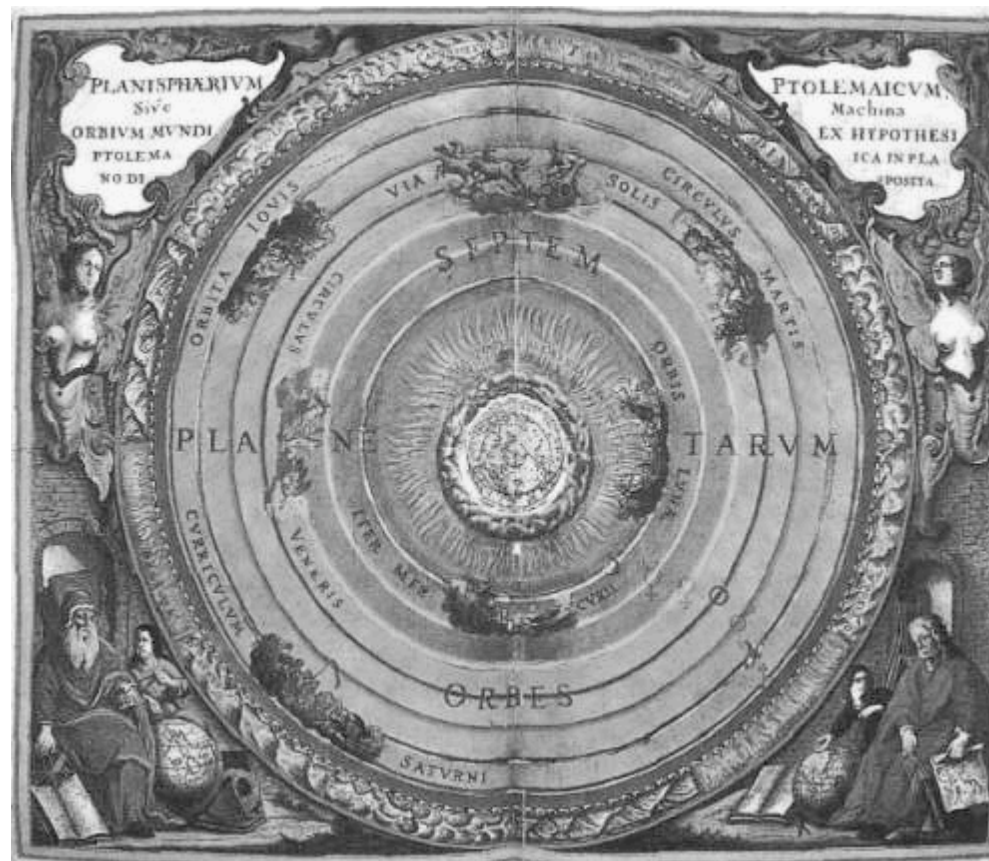
- Aristotle distinguished the two spheres
 - Sub-lunary
 - Four elements, natural motion dictated by nature
 - Unnatural motion requires constant force
 - Celestial
 - Quintessence
 - Eternal, uniform, circular motion
 - Crystalline spheres
 - Moved by Prime Mover
 - All motion centered on Earth



Saving the phenomena

- Ptolemy's Earth Centered model
 - Size: 19,865 Earth Radii
 - No voids (but cheated)
 - To match observed motions of planets,
 - Eccentrics, epicycles, equants
 - Extremely contrived

Ptolemy's model



For moving models, check
<http://faculty.fullerton.edu/cmcconnell/Planets.html> - 7

Model showing Ptolemy's "tricks"

Images and Animated Prepared by Tommy Huerta and Craig McConnell

Astronomy & Religion

Augustine (420 CE)

Neo-platonism incorporated into Christianity

Ignore Observation

World-view regressed

Aquinas (13th Century)

Aristotle incorporated into Christianity

Ptolemaic system

Heretics

e.g. Giordano, Bruno

Stars are Suns with Planets, Life

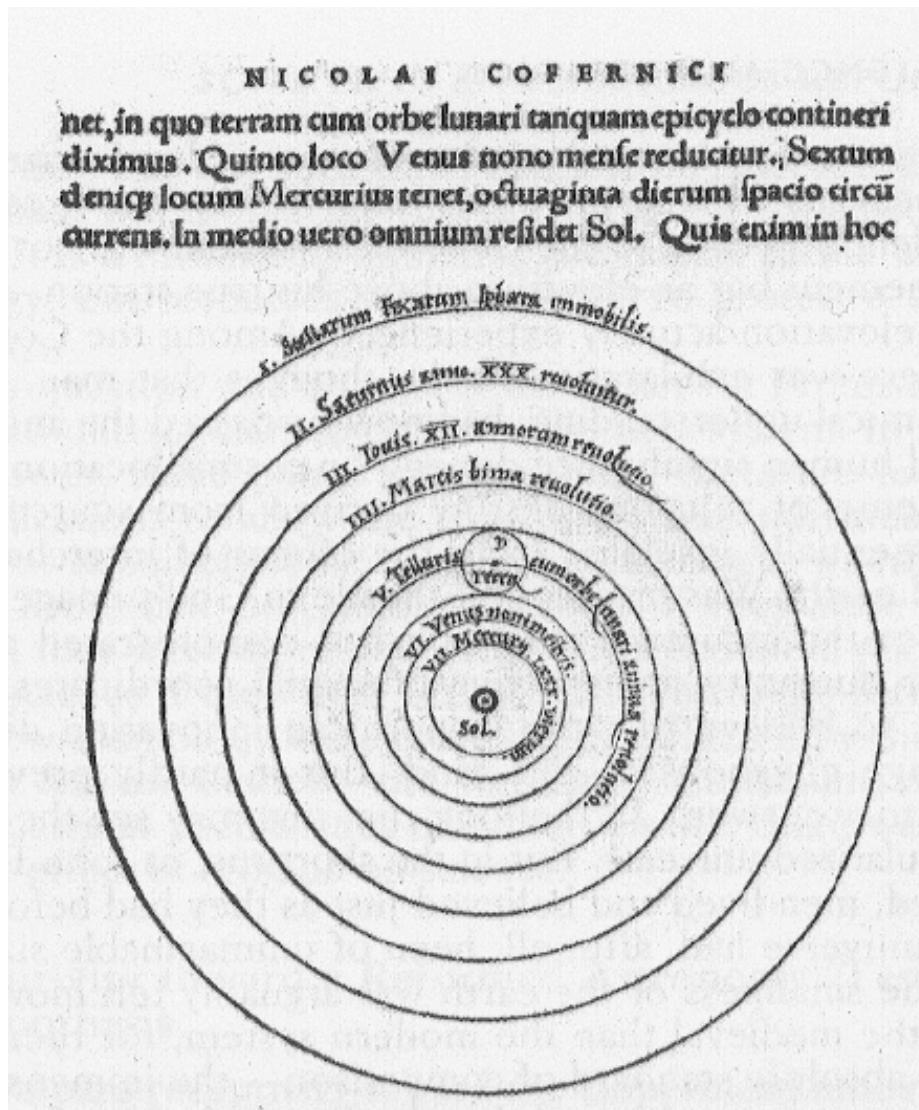
Two Thousand Years of Error

“There is perhaps no other example in the history of thought of such dogged, obsessional persistence in error, as the circular fallacy which bedevilled astronomy for two millennia.”

Arthur Koestler, in *The Sleepwalkers*, pg. 58)

Example: the supernova of 1054 was recorded in China, American southwest, ..., but NOT in Europe. It did not fit the theory.

Copernican Model (1540)



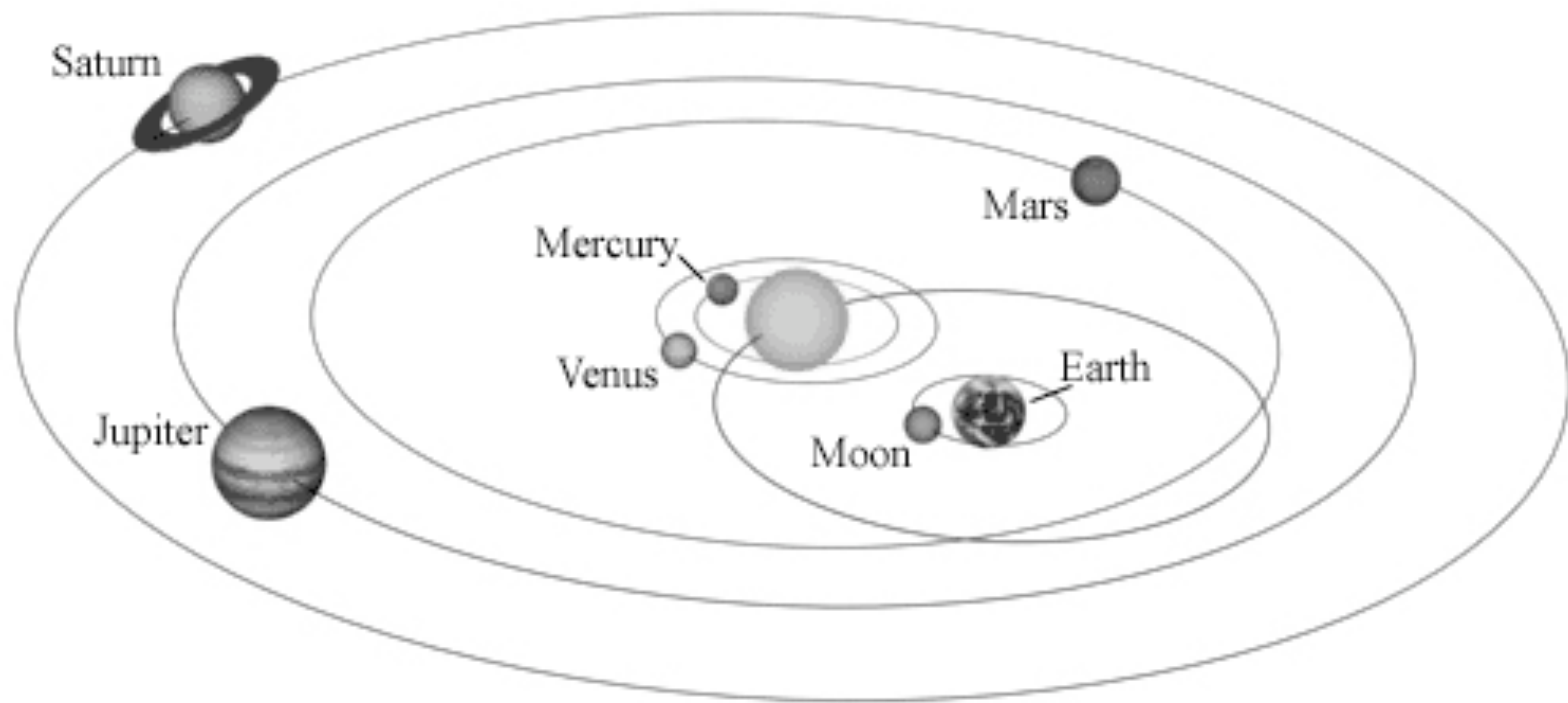
- Sun at center
- All planets orbit around Sun
- Circular motion
- Uniform speed
- To explain planets:
 - Still need:
 - Epicycles
- To avoid apparent motion of stars
 - Much bigger universe
 - 7,850,000 Earth radii
 - voids

Tycho Brahe (late 1500s)



- Before the telescope
- Very large circles for sighting positions of planets
- Observed supernova
- Careful records
- Hired Kepler
- Compromise world view

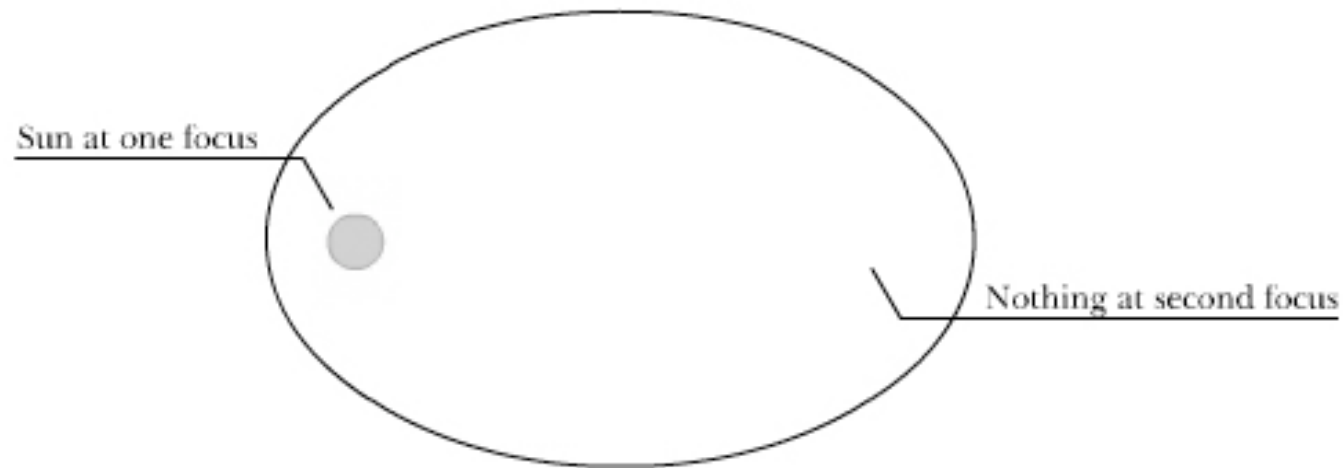
Brahe's Compromise World View



Kepler

- Worked with Brahe's data
- Found that he could fit the Mars data if
 - 1. Planets moved in elliptical orbits
 - 2. At different speeds at different places
 - 3. $P^2 = a^3$
 - P is period (how many years to complete orbit)
 - a is semi-major axis ~ radius of orbit
 - P in Earth years, a in earth orbit radii (AU)

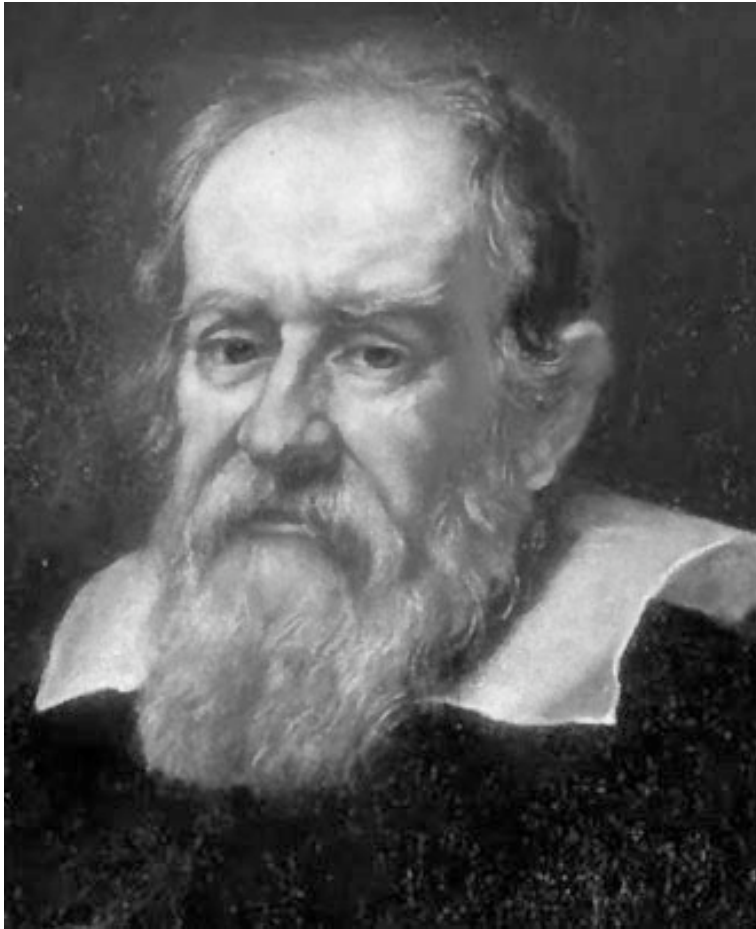
Elliptical Orbits



The size of the Sun is greatly exaggerated in this diagram

This would be an extremely elliptical orbit.
In fact, orbits in Solar system are nearly circles.

400 Years from Galileo



Portrait of Galileo Galilei by Giusto Sustermans

Clarified dynamical laws
Applied the telescope to the sky
Discovered “new planets” (moons of Jupiter), craters on the Moon, confirmed phases of Venus.

Endorsed Copernicanism...
And paid a price!

New observational tools drive
progress in astronomy

Galileo

- Used telescope (recently invented)
 - New “planets” (moons of Jupiter)
 - Sunspots
 - Craters on Moon
 - Many more stars
- New physics
 - No force needed to keep a body in motion

Conflicts with Religion and Philosophy

- Copernicus was careful about his “model”
- Galileo relations with church hierarchy varied
 - Accepted by some, but ran into trouble
 - Questioned by inquisition
 - Forced to recant idea that Earth moves
 - Excommunicated and placed under house arrest
 - That was corrected in 1992 (359 years later)
 - Now a statue of Galileo in Vatican courtyard
- Even stronger objections from the natural philosophers than from the Church

Newton completes the revolution

- Newton (1687, Principia)
 - Unifies celestial and sublunary physics
 - Newton's Laws of motion
 - Theory of Universal Gravitation
 - Together these explain both
 - Motion of planets
 - Motion on Earth

Newton's Laws of Motion

- 1. A body in motion tends to remain in motion unless acted upon by external forces.
 - Momentum ($p = m v$) remains constant
- 2. The rate of change of momentum with time is equal to the force.
 - $F = (dp/dt) = m (dv/dt) = m a$, if m constant
- 3. An object exerting a force on a second object experiences an equal and opposite force.
 - $F_{12} = - F_{21}$

Newton's Law of Gravity

- Every object with mass exerts a force on every other object with mass.
 - The force is proportional to the product of the two masses
 - The force is inversely proportional to the distance between the two masses.
 - $F = (GM_1M_2)/r^2$

Pause for Demo

- Galileo and the leaning tower story
- Squash ball about 1 ounce
- Basketball about 20 ounces
- Which falls faster?

The Copernican Revolution

- Copernicus (heliocentric but circular)
- Tycho Brahe (meticulous observations)
- Kepler (ellipses, not circles!)
- Galileo (constant motion needs no force)
 - The Earth can move but we don't feel it.
 - The inquisition was not persuaded.
 - “eppur, si muove”
- Newton (unified physics)

Copernican Principle

- Removal from the center
 - geocentric before 1543 (Copernicus)
 - heliocentric 1543 to 1915 (Shapley)
 - galactocentric 1915 to 1923 (Hubble)
 - nowherecentric 1923 to present (Einstein, ...)
- Nothing special about us
- No “fine-tuning” to allow us

The Universe as we see it now

- The Observable Universe (Horizon)
- Very large (about 48 billion light years)
- Very clumpy on “small” scales
 - planets, stars, galaxies, clusters, superclusters
- Very empty on average
 - about one atom every 40 cubic meters
- Expanding (galaxies moving apart)
 - velocity proportional to distance

Evolution of World View

- Need for a correct world view
 - If solar system is whole Universe
 - No possibility of other civilizations
 - Need to learn how big Milky Way is
 - (Note that we consider only the Milky Way)
 - Time to communicate with other galaxies is too long

Evolution in other fields

- Geology
 - Earth much older than 4500 yrs
 - Lyell (1860s)
 - Radioactive dating
- Biology
 - Species all evolved from common ancestor
 - Darwin (1859)
 - Natural origin of life
 - Miller Urey experiment (1953)

Connections

| Time | Information | Technology | World View |
|-----------|--------------------|-------------------------|--------------------------|
| 2 Myr ago | | Stone tools | |
| ?? | Oral Language | Collective hunting | |
| 6500 B.C. | Clay tokens | Agriculture, cities | |
| 6500 B.C. | | Wheel | |
| 4000 B.C. | | Copper tools | |
| 3000 B.C. | Clay tablets | | Oyster World |
| 3000 B.C. | Syllabic alphabet | | |
| 2800 B.C. | | Bronze tools | |
| 1500 B.C. | Letter alphabet | Iron tools | |
| 500 B.C. | | | Natural Philosophy |
| 200 | | | Ptolemaic Model |
| 1456 | Printing Press | | |
| 1540 | | | Copernican Model |
| 1610 | | Telescope | Kepler, Galileo |
| 1665 | | | Newton |
| 1700s | | Industrial Revolution | |
| 1859 | | | Darwin |
| 1895 | Radio | | |
| 1924 | | | Other galaxies |
| 1936 | First TV Broadcast | | |
| 1950s | Computers | Transistors, microchips | Miller-Urey |
| 1960 | | | First Search for Signals |
| 1990s | Internet | | |

How to Estimate f_c

Consider both “capability” & “interest”

Are these coupled?

Yes - Science and Technology closely linked

No - Technology without Astronomy?

Cloudy planet?...

Does correct worldview favor a civilization?

Yes - European domination

No - Germs more important than weapons?