

## Cosmology and the Birth of Earth

= Where do we come from? = Where do we fit in the Universe? = Why are we here?

### Cosmology

- Study of the structure and evolution of the universe
- Cosmology is a complicated science
- Requires thinking in unfamiliar scales of space and time
- Spatial Scales
  - -Attometers ( $10^{-21}$  meters to
  - -10s of billions of light years ( $9.46^{22}$  meters +)
- Temporal scales
  - -attoseconds ( $10^{-21}$  seconds) to
  - -10s of billions of years ( $3.15^{17}$  seconds +)

### Earth changing place

- 3,000 years ago, humans knew the heavens well
- Stars were fixed relative to other stars
- Stars moved predictably across the sky
- They saw retrograde motion separating planets from stars
- They did not think of Earth as a planet, however
- Movement in the heavens was attributed to deities

### An evolving image of Earth

- The ancients thought the universe was geocentric
- Heavenly bodies circle around a motionless central geocentric
- Proven by Ptolemy, the idea was still wrong
- Yet it held as doctrine for 1,400 years during the dark ages
- It became religious dogma supporting the importance of Earth in the Scheme of heaven

### The Renaissance

- A rebirth of rational thinking in 15<sup>th</sup> century Europe
- Galileo -observed moons orbiting Jupiter
- Copernicus- published evidence for heliocentricity
- Kepler-his elliptical planetary orbits refuted Ptolemy

### Heliocentric ideas

- Earth didn't center the universe
- Planetary orbits weren't circular
- Not all bodies orbited earth
- Planes, including earth orbit the sun

## The enlightenment

- Sir Isaac Newton devised....
- The law of universal gravitation
- The three laws of motion
- The mathematics of change (calculus)
- He proved that natural law governs natural events
- Geocentricity faded away

## Earth as a sphere

- A flat was dispelled by 250 BCE
- Abundant evidence suggested a spherical earth
- A curved shadow crossed the moon during eclipses
- Only the tops of distant sailings ships were visible
- In 1520, Magellan circumnavigated this sphere

A flat earth will receive light at a right angle at noon everywhere during summer solstice

A round Earth will receive light at diminishing angles toward the poles at noon during summer solstice

Eratosthenes measured Earth to be 252,000 (Egyptian) Stadia or 39,630km in circumference 1% error!

## Earth Rotation

How do we know that Earth Rotates

- Clearly visible in a time lapse photograph of the night sky
- Foucault's pendulum (1851) proved Earth's rotation

## Distance from Earth

We must consider huge expanses of space and time

- The speed of light is 186,000 miles/s (300,000 km/s)
- The moon is 1.3 light seconds (-237,00 miles) away
- The sun is 8.3 light minutes (-93 million miles) away
- A light year measures a distance of 5.87 trillion miles
- Alpha Centauri, the closest star is 4.3 light years away
- The visible universe is >13 billion light years away

## Modern view of the Universe

- Current concepts differ wildly from 100 years ago
- Earth is one of eight planets in the solar system
- The solar system is on an arm of the milky way galaxy
- Our Sun is one of 300 billion stars in this galaxy

## The Doppler effect

- Waves compress or relax with relative motion
- Applies to waves of both sound and light
- The stopped train sounds the same to Anna and Bill
- Anna hears a higher pitch from compressed sound waves
- Bill hears a lower pitch from expanded sound waves
- As the train passed Anna, the pitch would drop (higher to lower)
- This is commonly heard as cars whiz on a road

Light waves behave like sound waves

Visible light is electromagnetic radiation

- Visible wavelengths range from 400 to 700 nanometers
- 400 nm - blue=higher frequency
- 700 nm - red= lower frequency

A moving star displays Doppler shifted light

Light from an approaching star is compressed

- This causes a shift to higher frequencies, so that...
- Stars moving toward Earth are shifted toward blue

Light from a receding star is expanded

- This causes a shift to lower frequencies, so that...
- Stars moving away from Earth are shifted toward red

## The Expanding Universe

- Light from distant galaxies appeared "red shifted"
- In 1929, Hubble recognized this as a Doppler shift
- He concluded that galaxies were moving away rapidly
- No galaxies were found to be moving toward Earth
- This led to the development of the expanding Universe Theory, analogous to expanding bread

## Origin of the Universe

### The Big Bang Theory

- When did the expanding Universe begin?
- The best answer so far? The big bang
- All of the mass and energy in the Universe was packed into a single small point
- It exploded 13.7 Ga and has been expanding ever since
- The 1<sup>st</sup> atoms (hydrogen and helium) of the universe developed soon after the big bang. These atoms formed vast gas clouds, called nebulae