Part I: The Dawn of Time

Topics within Part I.

1. Origins of the Universe: from the Infinite to the Subatomic.
2. Planets and Meteorites: Neighbors in Space
3. Birth of the Earth and Moon: a Coupled System
4. Segregation of Earth Layers: Building a Dynamic System
5. Radioactive Clocks and Geological Time: Absolute and Relative Time

Origins of the Universe

Thematic Questions

- Beginnings of the Universe
  - How was it formed?
- The Age of the Universe
  - How old is it? How can its age be determined?
- History of the Universe
  - How has the universe changed over time?
- Composition of the Universe
  - What is it made of? How is it configured?
- Dimensions of the Universe
  - How expansive is it? Is it finite or growing?
Origins of the Universe

From the Infinite to the Sub-Atomic

- The Big Bang theory
- Evidence for the origins of time
- The Age of the Universe
  - Approaches to dating the universe
- History of the Universe
  - Sequence of events that created matter
  - Evidence for these events
- Size of the Universe
  - Assessment of its finite dimensions

Origins: The Big Bang Theory

Evidence for Expansion

- Expansion and age of the universe
- Evidence from recession of distant galaxies
- Hubble’s law

Systematic Expansion: growth like the 2-D surface of a Balloon
**Doppler Effect:**

**Wavelength Shift**
- A: Approaching wavelengths are blueshifted (shortened)
- B: Receding wavelengths are redshifted (lengthened)
- Absorption lines of stars are shifted

- Reference spectrum
- Absorption lines from star

**Expansion of the Universe:**

**Red Shift**
- Wavelengths of discrete spectral lines are shifted by stretching (Doppler effect)
  - Blue → red
  - Red → infrared.
- Shift increases with distance of object from observer
**Evidence for Universe Expansion**

**Hubble’s Law**
- \( V = H_0 \cdot r \)
  - \( V \) is recessional velocity
    - (calc.from Doppler red shift)
  - \( H_0 \) is Hubble constant
  - \( r \) is distance
    - (in megaparsecs)
- **Assumes**
  - Expansion is uniform throughout the universe
  - Recessional velocity is proportional to distance

**Analogy for Expansion**

**Raisin Bread**
- Distance between the raisins increases uniformly as the bread expands
  - Changes are proportional to original distances
Age of the Universe

**Observations**
- Velocities
  - Red shift
- Distance
  - Cepheid variables
  - Stars that 'blink'
  - Luminosity is related to period
  - Distance can be calculated from luminosity and measured brightness

![Image from Hubble telescope]

Hubble's law
Billion years (Ga) after Big Bang

Events at the Beginning of Time

**Sequence of Events**
- Singularity
  - Single, infinitely small point of infinite mass or energy
  - Cannot be observed, surrounded by event horizon
- Planck era ($10^{-43}$s)
  - Quantum physics begins
- Spacetime foam
  - Black holes and wormholes
  - Spatial variability
- Forces and subatomic particles

![Spacetime foam: Spatial variability]

G302 Development of the Global Environment
Sequence of Events (continued)

- Primordial fireball (1s; temperature >10^{10} K)
- Radiation era
  - Only elementary particles
  - Protons (p), electrons (e), positrons, photons, neutrons (n)
- Formation of matter (1s; temperature 4000K)
  - Simplest atom H (1e,1p) from neutron decay
  - Deuterium ^2H (1p, 1e, 1n), ^3He, ^4He (2p, 2e, 1n or 2n)
- Cosmic Microwave Background Radiation
  - Atom formation: ~0.5Ma after Big Bang (afterglow)
  - Expanding gas cloud of H and He, gathers in gravitational clusters to form galaxies
Cosmic Microwave Background Radiation (CMB)

Remnant Radiation from Formation of Atoms

Events in the Early Universe

Sequence of Events

- Inflation
- Formation of $^2$H and He
- Cosmic Microwave Background
- Matter forms
- Last Scattering of CMB

Temperature decreases with time
**Vision of Cosmic Microwave Background Radiation (CMB)**

**Analogy: Surface of Last Scattering**

- The cosmic microwave background radiation’s “surface of last scatter” is analogous to light passing through clouds.

**History of Universe Expansion**

**Non-Uniform Rate of Expansion**

- Initial Rapid Expansion (Inflation)
- Subsequent Progressive Growth
Galaxies and Star Clusters

Formation of Stars and Galaxies

- Evidence for early firestorm of star birth
- Galaxies created by merging of gas clouds and star clusters or perhaps remnant colossal clumps from the break-up of the early universe?
- What was the role of gravity? Gathered early stars?

Dimensions of the Universe

Olber’s Paradox

- Night sky is not uniformly bright
- Conclusion: the number of stars cannot be infinite

If infinite a star would occur in every direction
Olber's Paradox (continued)

- Light blocked by dust? *the dust would glow*
- Non-uniform distribution? *perhaps, but no direct evidence in support of this idea*
- Expanding? *distant stars red-shifted into obscurity*
- Young? *light from distant galaxies hasn't reached Earth*
- Finite number of active stars? *limits on available light*

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**Observation of Ancient Galaxies**

*Hubble Ultra Deep Field Image*

- Young Galaxies
  - Formed in a universe only 0.4 to 0.7 Ga old