Life in Universe

ASTRON 1141 – Chapter 2 & 3 Space, Time & Energy

Our Place In Space

1. The Solar System is big. It's 150 million kilometers or 1 astronomical unit (AU), from the Earth to the Sun
2. The Milky Way Galaxy is really big. The center of the Milky Way Galaxy is 27,000 light-years away
3. The universe is really, really big. The most distant galaxies we can see are 13 billion light-years away

- The circumference of the Earth is 24,900 miles, or 40,000 kilometers
- The kilometer was first defined so that the distance from the equator to the north pole was 10,000 kilometers

- **Scientists often use the metric system of units**
  - Length in meters
  - Mass in kilograms
  - Time in seconds

- **Standard prefixes are used to express large and small numbers**
  - 10^3 = kilo (kilograms, kilometer)
  - 10^6 = mega (megawatt, megayear)
  - 10^9 = giga (gigabyte, gigayear)
  - 10^{-3} = milli (millisecond, millimeter)
  - 10^{-6} = micro (microsecond, micron)
  - 10^{-9} = nano (nanosecond, nanometer)

- **Earth – Moon System**
  - Distance: 380,000 kilometers
  - 9.6 times Earth's circumference

- **How do we know distances in the Solar System?**
  - By radar (reflecting a radio signal)
  - Round trip travel time / 2 = one-way travel time
  - One-way travel time x c = distance to object
  - Light travels through a vacuum at a constant speed (c)
  - c = 300,000 kilometers/second
  - 1 light-year = 63,000 AU = 9.46 trillion kilometers

- **Solar Interstellar Neighborhood**
  - The Sun's nearest neighbor among the stars is Proxima Centauri
  - The distance form the Sun to Proxima Centauri = 270,000 AU = 4.24 light-years

- **How do we know the distance to a star?**
  - From stellar parallax

- **Milky Way Galaxy**
  - We live in a galaxy called the Milky Way Galaxy

- The distance from the Solar System to the center of the Milky Way Galaxy is 1.7 AU = 27,000 light-years
- The Milky Way Galaxy is part of a cluster of galaxies called the Local Group
- The galaxy M31 (Andromeda) is also in the local group; it is 2.5 million light-years away
- Distance to Proxima Centauri = 600,000 x distance to Mars
- Distance to Andromeda Galaxy = 600,000 x distance to Proxima Centauri
- Clusters of galaxies are strung together in long superclusters
- The Local Supercluster is 100 million light years long

Our Moment in Time

1. Geological evidence indicates the Earth has a large, but finite, age
2. Radiometric dating indicates the age of the Solar System is 4.57 billion years
3. The universe has been expanding since the Big Bang, 13.8 billion years ago

- In Europe, before the 18th century, biblical chronology was the accepted method of finding the Earth's age
- Archbishop James Ussher (1650): "The beginning of time… fell on the beginning of the night which preceded the 23rd day of October, in the year 4004 BC
- 18th century: Geologists realized that the Earth is much more than 6,000 years old

- **Best method for finding the age of rocks:**
  - Radiometric dating
  - Some atomic nuclei are unstable
  - They undergo radioactive decay, emitting particles to become a smaller, stable nucleus
    a) Uranium has 92 protons and 146 neutrons
    b) Lead has 82 protons and 124 neutrons
  - Decay of unstable nuclei is a random process
  - You can only give the half-life: the time it takes half the nuclei in a lump of material to decay
    a) The half-life of uranium-238 is 4.5 billion years
  - Start with an ingot of solid uranium-238
    a) After 4.5 billion years (1 half-life), ½ of the uranium ingot will have turned to lead
    b) After 9 billion years (2 half-lives), ¾ of the uranium ingot will have turned to lead

- **When it comes to radiometric dating, zircons are a geologist's best friend**
  - Zircon = zirconium silicate, with various impurities
  - Newly formed zircon crystals are frequently contaminated with uranium, never with lead
  - Zircons crystals are difficult to destroy, easy to detect
    1. Grind up a zircon, do a chemical analysis, find the relative amounts of lead-206 and uranium-238
    2. Compute the number of half-lives that have elapsed

- **Zircons**
  - Caveat: if the zircon melts, the chemically incompatible lead is locked out when the zircon re-solidifies
  - The age of a rock found by radioactive dating is the time since the rock solidified
    a) Oldest Earth zircons: 4.4 billion years
    b) Youngest Earth zircons: 0 years

c) Oldest Moon rocks: 4.4 billion years
d) Oldest meteorites: 4.57 billion years

- Best estimate of age of the Solar System: Sun, meteorites, planets all formed 4.57 billion years ago
- However, the Solar System condensed form a gas cloud when the universe was already old

- The Big Bang model was confirmed by the discovery of a Cosmic Microwave Background
- The cosmic microwaves have a thermal spectrum, of the sort produced by hot, dense, opaque objects
- Extrapolation = 13.8 billion years ago
- Conclusion: the whole universe, in its initial stages, was hot and dense enough to be opaque
- The Big Bang Theory: the universe began in a hot, dense, opaque state about 13.8 billion years ago. As the universe expanded, it cooled and became transparent. Galaxies formed, containing starts, planets and (at least one case) life.

Matter and Energy

1. Atoms are made of protons, neutrons and electrons: atoms can bond together to form molecules
2. Energy cant be created or destroyed, it can only change form
3. Disorder, or entropy, has a natural tendency to increase

- Democritus (ca. 400 BC) believed that matter is made of tiny unsplittable atoms
- Atomic theory was revived (ca. 1800) by John Dalton: every element is made of atoms of a single, unique type
- In 1869, Dmitri Mendeleev (Russian scientist) arranged the 63 elements then known into the first periodic table. Noting gaps in the table, he predicted previously unknown elements, like gallium and germanium

- **An atom as now defined, has a nucleus of protons and neutrons surrounded by a cloud of electrons**
  - Proton: massive, positive charge
  - Neutron: massive, neutral charge; uncharged
  - Electron: low in mass, negative charge

- The elements are defined by the number of protons in the atomic nucleus
- **Number of protons = Atomic Number of the elements**
  - 1 Proton = Hydrogen
  - 2 Protons = Helium
  - 3 Protons = Lithium… and so on

- **The Eight Most Abundant Elements in the Universe are**
  - Hydrogen (H)
  - Helium (He)
  - Oxygen (O)
  - Carbon (C)
  - Nitrogen (N)
  - Neon (Ne)
  - Silicon (Si)
  - Iron (Fe)
- The main elements of life on Earth are C, H, O and N
- The Earth itself is largely Fe, O and Si

- Most atoms (though not helium or neon) join to form molecules
- Organic molecules, by definition, are molecules that contain carbon
- **Matter consists of particles that have mass**