Chapters 18
Life in the Universe: Are We Alone?

* Cosmic Evolution
  * Life in the Universe
    • Are we alone?
    • Earth is the only place we know of for certain that life exists
    • 7 stages in cosmic history
      – particulate
      –
      – stellar
      – planetary
      –
      – biological
      – Cultural
    • How do we define life?
      – React to environment often healing
      –
      – Can reproduce and pass on their genetic characteristics
    • Sometimes it’s difficult to discern between what’s alive and what is not
* Life on Earth
  * Chemical Evolution
    • Early Earth was washed out by volcanism, meteors, and erosion
    • Early earth structure
      – Lots of volcanic activity with expelled gasses producing our early atmosphere
      – Eventually Earth cooled and formed water in the atmosphere and on the surface
      – A shallow lifeless sea formed
    • In 1953 scientists simulated the early Earth by creating a mixture of the materials thought to be present on Earth long ago (“primordial soup”)
      – Water, methane, carbon dioxide, and ammonia
      – They energized the mixture with electricity and produced amino acids
      – No DNA was produced and life didn’t arise from the mixture
    • Recent theories suggest life came from interstellar impacts bringing the necessary organic material
  * Biological evolution
    • Evolution from single to multi-celled organisms
      – Fossils date back to 3.5 billion years ago
    • Survival of the fittest
    • Intelligence is favored by natural selection
* Earth was violent
  • Natural radioactivity
  •
  • UV radiation
  •

* Life as we know it
  * Carbon-based life in a liquid environment
  * Alternative bio-chemistries attempt to investigate why can’t life survive in other situations without water and carbon

* Life in the solar system
  * No other environment in the solar system appears suitable for Earth-like life
  * The Moon and Mercury
    • No atmosphere
    •
    • No magnetic fields
    • Constantly bombarded by meteors
    •
  * Venus
    • Too much atmosphere
    •
  * Jovian planets
    • Too cold with no solid surface
    •
  * Dwarf planets
    • Too cold
  * Comets and asteroids
    •
    • No life expected
  * Mars
    • Once warmer and wetter
    •

* Intelligent Life in the Galaxy
  * ____________________ - statistical estimate of the probability of life elsewhere
    – # of technological intelligent civilizations now present in the galaxy = rate of star formation, averaged over the lifetime of the galaxy X fraction of stars having planetary systems X average number of habitable planets within those planetary systems X fraction of those habitable planets on which life arises X fraction of those life bearing planets on which intelligence evolves X fraction of those intelligent-life planets that develop technological society X average lifetime of a technologically competent civilization.

  • Rate of Star Formation
– An average of 10 stars per year form in our galaxy
– Value = 10

• Fraction of stars having planetary systems
  – Other stars form by condensation
  – Our Sun is not unique
  – We have observed planetary disks
  – Earth size planet would be too dim to detect
  – Only Jupiter sized have been detected
  – We believe all stars have planetary systems
  – Value = 1

• Number of habitable planets per planetary system
  – Temperature is the most important factor
    – The distance from the host star and the atmosphere determine temperature
    – ______________________ - zone around star where conditions are suitable for life to exist
    – The Hotter the star, the larger the zone
    – Venus, Earth, Mars are in our Sun’s zone
    – One in 10 planetary systems have life
    – Value = 1/10

• Fraction of habitable planets on which life arises
  – Life is inevitable given proper chemicals, suitable environment, and a long enough time period
  – Value = 1

• Fraction of life bearing planets on which intelligence arises
  – Natural selection favors intelligence
  – One species will eventually become intelligent
  – Life remained single-celled for 2.5 billion years on Earth
  – Value = 1

• Fraction of planets on which intelligent life develops and uses technology
  – Probably some species will always fill the niche of technological intelligence
  – Value = 1

• Average lifetime of a technological civilization
  – Earth has only survived in its technological state for approximately 100 years
  – How long will we be around before a catastrophe
  – Value = 1000 years

* The reliability of each term decreases with each term on right hand side
* If advanced civilizations typically survive for 1000 years, there should be 1000 of them currently in existence scattered throughout the galaxy

* The Search for Extraterrestrial Intelligence
  * Meeting our Neighbors
    • Assume technological civilization will last for 1 million years
    • Average distance between civilizations is 150 light years
    • Sending a message will take about 300 years to go and get back
• It would take 25,000 years to reach closest star (Alpha Centauri)
• Going to the closest technological civilization would take 1 million years
• Our probes have carried proof of our existence with them (________________)
• It’s assumed that most technological civilizations are more advanced than us
  – We must be cautious because advanced life may think they can take us over

* Radio Searches
  * Radio energy allows us to listen in deep space because the longwaves can travel great distances with little distortion
    • We listen passively for signals
  * Natural radio signals are variable
  * Our radio and televisions broadcast out to space
  * If we only knew the right frequency we could listen
  *
  • Water emits radiation at around 21 cm
  • Water is the building block for Earth-life
  • Interval between ______________ is the best option for our searches and this interval is called the “______________”

* 

End of Chapters 18