Physics 2028: Great Ideas in Science:

The Exobiology Module

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Edition 1.0

Abstract

These class notes are designed for use of the instructor and students of the course Physics 2028: Great Ideas in Science. This edition was last modified for the Spring 2008 semester.

IV. Exobiology: Life in the Universe

A. What is Life?

1. These next two sections summarize what has been learned during this past semester.

2. Life is matter that can reproduce itself and evolve as survival dictates.

3. Life on Earth is carbon-based. Carbon can easily form long molecule chains.

4. Most life on Earth is composed of **cells** (viruses are not), which have **proteins** as their building blocks. Proteins have **amino acids** as their building blocks.

5. The molecule **DNA** is located in the nuclei of cells. This molecule carries all of the genetic information. It is through this molecule that life is able to reproduce itself.

6. **Evolution** takes place by **mutation** coupled with **natural selection** so lifeforms better adapted to the given environment will survive and reproduce more with these survival traits.

B. How Did Life Start?

1. In 1952, the **Miller-Urey Experiment** created amino acids from H_2O (water), CH_4 (methane), NH_3 (ammonia), and H_2 (molecules common in the early Earth's atmosphere) when an electric arc (to simulate lightning in the early Earth atmosphere) was passed through this mixture (see Figure IV-1).

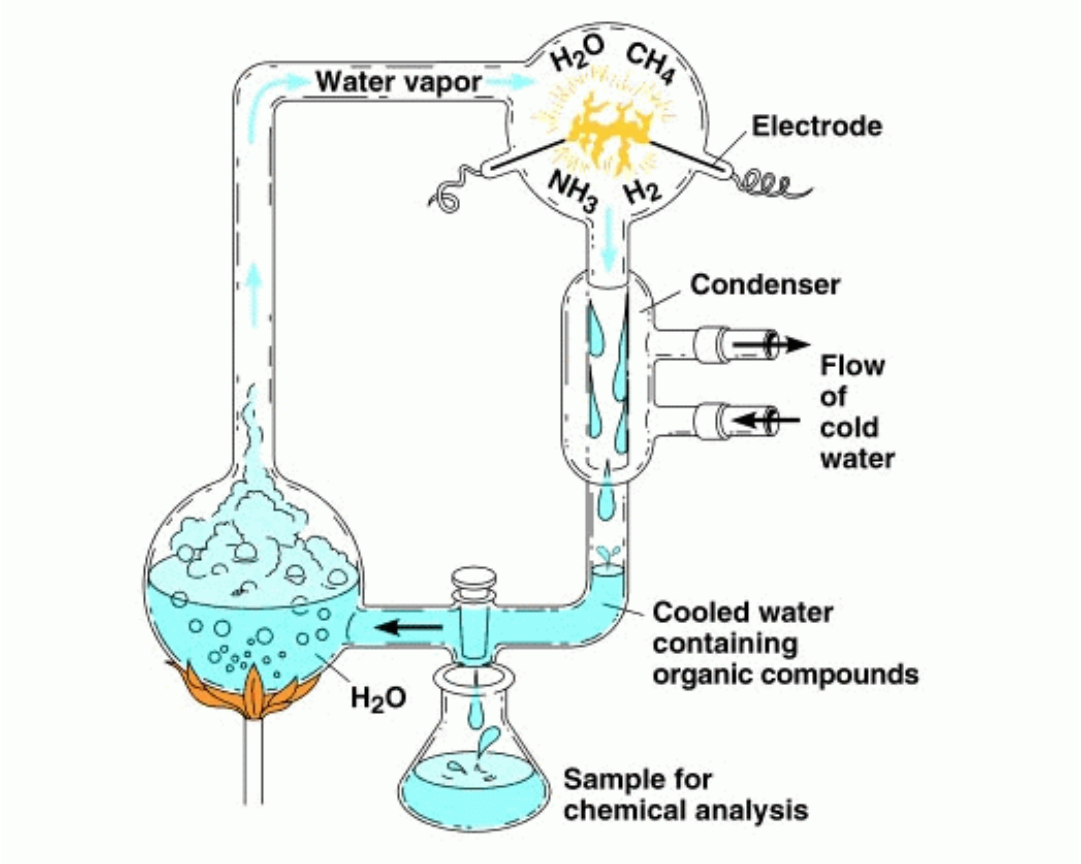

Figure IV–1: Experimental setup by Urey and Miller to simulate the early Earth atmosphere.

a) A few hours into the experiment, a brownish-orange film formed in the experimental apparatus.

b) This *film* was analyzed and was found to be amino acids!

c) The experiment was later repeated with ultraviolet light (to simulate sunlight) instead of an electric arc as the energy source and the same results were obtained.

d) This experiment showed that nature can make organic compounds out of simple inorganic molecules very easily.

2. Not only are organic compounds easy to make, we see them throughout the Galaxy!

a) Nonterrestrial amino acids have been found in meteorites.

b) The spectral lines from amino acids and other organic molecules also have been detected in the interstellar medium.

c) The spectral lines from organic molecules have been detected in the atmosphere of Saturn's largest moon Titan.

d) **The Universe has no trouble creating organic compounds in a very simple and natural manner!**

3. It's a big step however to go from organic molecules to self-replicating organic molecules (*i.e.*, life). Many experiments have been carried out since the Miller-Urey Experiment to try and understand how life got started from this building block material.

a) Biologists have been able to grow structures from amino acids that resemble proteins.

b) Long carbon-chained molecules are very fragile and are easily broken apart when left by themselves. However, experimentalists have found that long carbon-based molecule chains can form, grow, and survive in mud and clay.

c) This may suggest that we may owe our very existence to our large natural satellite — the Moon! The Moon raises tides on the shores of the continents. This moistens the dirt making mud and the organically rich oceans deposit amino acids and other organic molecules in this mud.

d) As the tides continuously raise and lower, long carbon-based molecules chains began to flourish. As time went on, electrochemical reactions between the chains started to take place forming more complicated molecule chains until one chain was made that was able to make copies of itself — micro-organisms arose and flourished in the

oceans as the tides swept this material back out.

e) There is no magic going on here, just chemistry being powered by an energy source (*i.e.*, the Sun). Mutations from cosmic rays and the UV radiation from the Sun cause further alterations to these long molecule chains $\Longrightarrow$ variation in lifeforms begin on Earth. Natural selection begins in earnest causing organisms that are successful in their environment to survive, be fruitful and multiply. And the rest is history!

C. The Demise of Lifeforms and Civilizations.

1. In this section we will discuss various types of mechanisms that could catastrophically wipe out civilizations (both terrestrial and extraterrestrial) and lifeforms in general. This will be useful when discussing the **Drake Equation** a little later in these notes.

2. Here we won't be talking about species extinction that occur gradually as a result of natural selection. Instead we will discuss events that lead to the demise of species over relatively short time periods (with a few longer duration events added in).

3. Local Catastrophes — those that occur over a specific region on a planet.

a) **Floods**: Here we do not mean the occasional local flooding that might affect a local community due to heavy rains since the loss of life is minimal for these events and they do not bring the end to civilizations. Instead, we focus on two catastrophic types of flooding:

i) Tsunami: A tsunami (pronounced tsoo-nah-mee) is a wave pulse, or series of wave pulses, generated in a body of water by an impulsive disturbance that

vertically displaces the water column.

- Tsunami is a Japanese word with the English translation, "harbor wave."
- Earthquakes, landslides, volcanic eruptions, and even the impact of cosmic bodies (see below), can generate tsunamis.
- Tsunamis can savagely attack coastlines, causing devastating property damage and loss of life.
- Over the past hundred years, tsunami events have not have any major impacts on loss of life or civilization. However, since humans like living near the sea, the early humans may have been devastated by such events.

ii) Snow Melt at the Ending of the Last Ice Age: This is the "big one" in this category since many civilization ending myths and stories are based on flooding in the area of the Mediterranean Sea basin which is surrounded by Europe, Asia (Middle East), and Africa.

- The following information is from the book *Noah's Flood: The new scientific discoveries about the event that changed history*, by William Ryan and Walter Pitman, published by Simon & Schuster (1998). This book outlines the evidence to support the timeline of events reported below. See http://www.religioustolerance.org/ev_noah.htm for more details.

— Five million years ago, the Mediterranean Sea was a largely dry valley. A narrow height of land between what is now Spain and Northern Africa held back the Atlantic Ocean. For some reason, this "highland" collapsed – perhaps due to an earthquake, and the Atlantic Ocean flowed in to form the Mediterranean Sea. Any land-based lifeforms there would have been annihilated.

— From 120,000 to 18,000 BCE, the Earth was experiencing its last ice age. Sheets of ice up to two miles thick covered much of the northern parts of North America, Europe and Russia. So much water had been withdrawn from the world's oceans that their level was about 400 feet (120 meters) lower than it is today.

— Around 18,000 BCE, the temperatures started to warm again to pre-ice age levels. The ice at the southern boundaries of the glaciers began to melt. Some of the water fed what is called the New Euxine Lake – a fresh water lake located within the area of today's Black Sea (evidence for the existence of this lake was found in the mid-1990s). It had a small outlet to the Sea of Marmara and then to the Aegean and finally the Mediterranean Seas.

— Around 13,000 BCE, the flow of freshwater from the glaciers into this lake had almost stopped.

— Between 10,500 and 9400 BCE, both the temperature and rainfall dropped in the region – an event called the *Younger Dryas*. The flow of fresh water into the New Euxine lake almost stopped. The lake level dropped, due to evaporation. Eventually, the lake level fell below its outlet to the Sea of Marmara. The New Euxine Lake then became a landlocked, fresh water lake. Various tribes in the Near East were experiencing drought conditions. They gravitated to the shores of this and other large lakes where the water supply was fresh and plentiful. They built villages, hunted, fished and learned to cultivate grain crops. They may even have experimented with primitive irrigation methods. At the end of this era, temperatures and rainfall both increased to "decent" levels

— Sometime between 5650 to 5500 BCE, the New Euxine Lake was still landlocked and fresh. But the Mediterranean Sea and Sea of Marmara had gradually risen to a level some 426 feet (130 meters) higher than the lake. It was held back only by a small rise of land at the Bosporus River – now the Bosporus Straight near present-day Istanbul, Turkey. Eventually, the ocean level rose high enough to slosh over into the Euxine Lake.

— Based on geological modeling, this water from the Mediterranean Sea would have cut a small channel down to the lake. In a short time, the flow would reach 10 cubic miles of water per day – 200 times the flow of the present Niagara Falls. Its velocity would have reached 50 miles per hour (over 80 km/hour)! Its noise would have been audible 120 miles (200 km) away. The lake level would have risen about six inches a day. The shoreline of the New Euxine Lake would have expanded up to a mile each day in some areas. The effect on the multiple cultures who had settled on the lake shore would have been catastrophic.

— The fields in all the villages which surrounded the lake would have been quickly inundated. Most or all of the fish life in the lake would die as the salt level became intolerable to the fresh water species. The salinity would eventually be high enough to support salt-water species. The people would have had to scatter immediately in all directions in order to survive. Ryan and Pitman suggest that groups of immigrants migrated into islands in the Aegean, and up the Dniester, Dnieper, Danube, Don and Volga rivers.

— This would have led them into much of Europe, the Balkans, and what is now Russia. Other groups migrated to areas of what is now Turkey, Egypt, the Levant (now Israel, Jordan, Lebanon, Palestine), northern Mesopotamia (now Iraq) and Anatolia (now Turkey). Within a few years, the lake level reached equilibrium, at more-or-less its present value. We now call this lake the Black Sea.

— Perhaps some of the flood stories from ancient texts originate from this formation of the Black Sea such as the Sumerian (the language of the first known writing, a language with no known roots and no known descendants) story, an Akkadia (one of the ancient tongues of the Semitic language group to which the Arabic dialects and Hebrew belong) story, the Babylonian flood myth in the *Epic of Gilgamesh* which is generally regarded as having been derived from these earlier flood stories. The *Epic* dates back to the third millennium BCE. And finally, the Noah flood myth which appears to be based upon the flood story in *Epic* (there are about 20 points of similarity between the Bible story and the flood story in the Epic of Gilgamesh).

b) **Droughts**: A drought is an extended period of months, or years, when a region notes a deficiency in its water supply.

i) Generally, this occurs when a region receives consistently below average precipitation.

ii) It can have a substantial impact on the ecosystem and agriculture of the affected region.

iii) Although droughts can persist for several years, even a short, intense drought can cause significant damage and harm the local economy.

iv) According to the UN, an area of fertile soil the size of Ukraine is lost every year because of drought, deforestation and climate instability.

v) Many droughts have occured over human history and some of these resulted in the spread of our species across the planet in search of wetter climates.

c) **Insect Invasion**: It's hard to feed a community when the bugs get to it before you do.

i) Once again, there are many historical stories and myths of insect invasions affecting civilization.

ii) One of the worse offenders are locus whose swarms can wipe out square miles of farmland in a few days time.

iii) This is the first of a few different ways to cause mass starvation.

d) **Disease**: The same as insect invasion, but these "bugs" are a lot smaller.

i) This is one of the biggest killers that have occured over human history.

ii) The Black Plague, or Black Death, was one of the most deadly pandemics in human history, widely

thought to have been caused by a bacterium named *Yersinia pestis* (Bubonic plague).

iii) The total number of deaths worldwide from the pandemic is estimated at 75 million people – there were an estimated 25-50 million deaths in Europe. The Black Death is estimated to have killed 30% to 60% of Europe's population.

iv) It may have reduced the world's population from an estimated 450 million to between 350 and 375 million in 1400.

e) **Overpopulation and Starvation**: Throughout much of the 20th Century, the Human Population grew at an exponential rate (just as viruses do). Since people need food to survive, will the day ever come when there is insufficient food to feed the masses?

i) The human population of Earth reached 1 billion in 1804.

ii) By 1927 it had reached 2 billion.

iii) The 3 billion mark was reached in 1959.

iv) There were 4 billion humans on the planet in 1974.

v) The 5 billion mark was passed in late 1986.

vi) At the end of the 20th century, the human population of Earth reached 6 billion.

vii) As people became aware of the problems of over-population in the latter part of the 20th Century, the growth in the population, though still expanding, has slowed a bit.

viii) Unfortunately, the Earth is a rather small planet and the question still remains, will the day come when the earth is no longer able to support the human population?

4. Planetary Catastrophes — those that affect the whole planet and arise from the planet itself (or its inhabitants).

a) **Ice Ages**: As mentioned earlier, the Earth experienced its last ice age from 120,000 to 18,000 BCE. Though humans were around during this epoch, civilization did not yet exist – humans were still hunter-gatherers. During this time interval most humans lived within the tropic zone where the cold weather was not as harsh. However, if another ice age was to occur, it would have a large impact on the human species due to higher energy needs and smaller areas of land capable of supporting farmland.

b) **Supervolcanoes**: A supervolcano is a volcano that produces the largest and most voluminous kinds of eruption on Earth. The explosivity of such eruptions varies, but the volume of ejected is enough to radically alter the landscape and severely affect global climate for years, with cataclysmic consequences for life. The largest volcanic events over the last 3 million years on the Earth are (estimates of the volume of erupted material are given in parentheses):

i) Lake Taupo, North Island, New Zealand: This eruption occured 26,500 years ago (1,170 km^3).

ii) Lake Toba, Sumatra, Indonesia: This eruption occured 75,000 years ago (2,800 km^3). The Lake Toba eruption plunged the Earth into a volcanic winter, eradicating an estimated 60% of the human population (although humans managed to survive, even in the vicinity of the volcano), and was responsible for the formation of sulfuric acid in the atmosphere.

iii) Yellowstone Caldera, Wyoming, United States: This eruption occured 2.2 million years ago (2,500 km^3) and 640,000 years ago (1,000 km^3). This supervolcano is now overdue to re-erupt.

c) **Nuclear War**: The effects of such an event are the same as those from a supervolcano, but the recovery from such an event will be far slower than the recovery from a supervolcano, mainly due to the slow decay of radioactive material.

d) **Global Warming**: This is a slower civilization demise event taking a century or two to severely affect the human population (or extraterrestrial populations if they experienced such a phenomenon). Since this topic was discussed last semester, we won't list the details of this problem here.

5. Astronomical Catastrophes — those that affect the whole planet but are caused by extraplanetary astronomical events.

a) **Asteroid and Comet Impacts**: Life on the planet Earth has experienced numerous **mass extinctions**.

i) There have been several times in the last 270 million years when there were very high levels of extinction.

ii) There were large peaks in extinction at the end of the Permian, Triassic, and Cretaceous periods.

iii) Particularly the Cretaceous-Tertiary (K-T) boundary stands out because there was considerable stratigraphic evidence that marine and continental extinctions occured at nearly the same time.

iv) In specific the marine biota was hit very hard: 15% of all marine and maybe 80-90% of all marine species.

v) At the same time, the continental biota was also hit hard: about 25% at the family-level became extinct but about 56% at the genus-level.

vi) In 1980, Nobel laureate Luis Alvarez, his geologist son Walter Alvarez, nuclear chemist Frank Asaro, and paleontologist Helen Michael published their discovery of high levels of the element iridium in a clay layer separating marine sediments of Cretaceous and Tertiary age. This iridium enhancement was seen in this layer of sediment over the entire planet.

vii) All of the planets and smaller bodies in the Solar System formed through an accretion process in a protoplanetary disk surrounding the protosun. The kinetic energy of this accretion resulted in the protoplanets being molten throughout. During this stage, the interior structure of the planets **differentiated** – heavy elements sinking towards the center, lighter elements rising to the outer layers. Of the heavy elements, iron is the most abundant in the Universe, whereas the related platinum group (iridium being one of these) have a much lower cosmic abundance. Most of these heavy elements sank towards the center, but there is still a substantial amount of iron in the crust due to its relatively high cosmic abundance. As a result of this, the platinum-group elements are rare and expensive minerals on the Earth surface.

viii) In lower mass objects in the Solar System (*e.g.*, asteroids and comets), their gravitational fields were not strong enough for this differentiation to occurs. hence the platinum group elements are evenly distributed through the interior of these objects.

ix) Platinum group elements are thus much more common in asteroids, comets, and space dust in general, than on the Earth's surface. These platinum-group elements would thus be a good signature for space dust in sediments. Better yet, platinum-group elements don't move around much once they are deposited. They are some of the so-called noble metals that tend to be unreactive and virtually

inert. Of the platinum-group elements, iridium is relatively easy to measure, detectable in parts per billion. Thus iridium proved to be the element of choice to measure as a proxy for space dust.

x) Something must have caused this sharp increase of space-dust iridium over a very short time period – an **asteroid impact**!

xi) The impact structure, discovered buried beneath the shore of the Yucatan Peninsula (Chicxulub), turns out to be from 150 - 300 km in diameter, one of the largest impact basins known on the Earth. At the present diverse lines of evidence have largely confirmed the asteroid impact theory of mass extinctions and the Chicxulub impact basin is considered to be the "smoking gun" by many scientists.

xii) Clay layers corresponding to earlier mass extinctions also have been found to contain enhancements of iridium. As such, **watch the skys!**

b) **Solar System Intruders: Inorganic**: Besides asteroids and comets from our own Solar System causing crises on the Earth, what would happen if a stellar mass object approached the Solar System too closely?

i) The average separation of stars in our local vicinity of the Galaxy is approximately one star per cubic parsec (note that 1 parsec = 3.26 light years).

ii) Most of the stars in our vicinity of the Galaxy are part of the galactic disk component of the Galaxy

and share a common orbital motion about the center of the Galaxy.

iii) There are a small group of stars in our part of the Galaxy that belong to the galactic halo and are currently moving through the disk at large angles with respect to the disk stars.

iv) When factoring all of these factors into account, the probably of another star system encountering the Solar System is negligibly small.

v) However, if such an encounter were to take place, it is not collisions that we would have to worry about, but instead perturbations in the orbits of the planets in the Solar System.

- Let's assume a black hole passed some 200 A.U. (*i.e.*, the average Earth-Sun distance) and ejected Jupiter from the Solar System. With the Solar System's vacuum cleaner gone, comet impacts on the inner planets would increase substantially, possibly causing mass extinctions on Earth.
- Or if Jupiter's orbit was altered into an elliptical orbit bringing it into the inner Solar System, Jupiter's gravitational field would scatter the inner planets, possibly sending some into the Sun and perhaps ejecting others out of the Solar System.

c) Solar System Intruders: Organic – Star Wars:

i) Science fiction is filled with extraterrestrial aliens visiting Earth. Prior to the 1968, most aliens were always presented as war like.

ii) In 1968, the movie 2001: A Space Odyssey presented aliens as very non-human who helped proto-humans survive and had no interest in attacking Earth.

iii) Then in 1977 and in 1982, the movies Close Encounters of the Third Kind and E.T. portrayed aliens as kind and friendly.

iv) However, if extraterrestrial aliens were to visit Earth (and no, U.F.O.s are not extraterrestrial spacecraft), would they be friendly or war like?

v) Certainly in the history human exploration, violence often occured when more advanced civilizations encountered less technical civilizations.

vi) Aggressiveness may be a driving force in sending lifeforms to the stars.

vii) As such, if we ever see a Death Star heading in our direction, our chances of a friendly encounter would not be very high.

d) Stellar Evolution:

i) As we have seen in the Astronomy Module, stars evolve over time. The lower the mass of a star, the

longer its core hydrogen burning lifespan on the main sequence.

ii) Stars of one solar mass last about 10 billion years on the main sequence. The Sun is now about 5 billion years old, half way through its main sequence lifespan.

iii) In the last half of a star's main sequence life, the luminosity of a star gradually increases due to a slight increase in temperature (remember $L \propto T^4$).

iv) The Earth has about 1 billion years left in the Sun's habital zone, the region around a star where liquid water can exist on the surface of a planet in orbit about that star.

v) After that time, the Earth's surface temperature will be high enough to boil away our oceans. If humans are still around, we will need to leave the planet by then.

D. The Search for Extraterrestrial Life (SETI).

1. The study of possible life off the Earth (*i.e.*, *extraterrestrials*) is called **exobiology**.

2. Are there simple lifeforms in the Solar System?

a) The best planets (besides Earth) suited for life in the solar system are Mars, Jupiter's atmosphere, Europa's submerged ocean, and Titan (although Titan may be too cold to support the formation of long molecule chains).

b) The *Voyager* spacecrafts observed organic compounds in Titan's atmosphere. The spacecraft *Cassini* is currently in orbit about Saturn. *Cassini* landed a probe called *Huygens* on Titan's surface in January 2005. Some ground-based observations have indicated the presence of oceans of liquid hydrocarbons. To date, *Cassini-Huygens* has not detected any of these hydrocarbon oceans.

c) *Vikings* 1 and 2 looked for life on the surface of Mars with negative results.

i) Images from the *Viking* orbiters and the recent Mars mapping missions have shown that liquid water did exist on the planet's surface early in its history.

ii) Indeed, recent evidence gathered by the *Mars Global Surveyor* suggest that Mars may still have a substantial amount of water in some areas less than 500 meters (1640 feet) below the surface.

iii) Did life have time to get started there before the liquid water evaporated from Mars' surface?

iv) A meteorite found in Antarctica was identified as originating from Mars a few years ago. Small nanometer sized *wormlike* structures were found inside this meteorite and NASA scientists speculated that it represented ancient Martian life. Continuing analysis of this meteorite now shows doubt that these structures are due to life, but instead, due to inorganic chemistry. The debate still continues.

v) If Mars did have microbial life early on, it is doubtful that this life is still present in the Martian soil today.

d) Observations from the *Voyagers* and the *Galileo* spacecraft (a Jupiter orbital mission) have shown that Jupiter's moon Europa has cracked water ice on its surface which suggests a liquid subterranean ocean beneath the ice crust. As the moon orbits Jupiter, it is tidally pulled in and out which heats the interior of the moon.

i) This may cause volcanism on the floor of Europa's ocean. On the Earth, such ocean-bottom *lava vents* are home to many organisms.

ii) As a result, Europa's ocean may be teaming with life.

iii) NASA is in the planning stages of developing spacecraft that will go to Europa (possibly by the late 2010's). Such a spacecraft will launch a *penetrator* into Europa's ice crust to gain access to the ocean below and conduct studies on possible life-forms there. (Though great precautions will have to be taken to prevent contamination from Earth microbes hitching a ride on the spacecraft.)

3. There are no other technological civilizations in the solar system. The search for extraterrestrial technological civilizations must look beyond the solar system. This search has been designated **SETI**: the Search for ExtraTerrestrial Intelligence.

a) A technological civilization is defined to be one that has developed **radio astronomy** — we have only been a tech-

nological civilization for 60 years!

b) The number of technological civilizations in the Galaxy can be estimated by **Drake's Equation**:

$$N_c = N_\star \, f_p \, n_{\ell z} \, f_\ell \, f_I \, F_s \ . \qquad \text{(IV-1)}$$

i) N_c = number of communicative (*i.e.*, technological) civilizations in the Milky Way Galaxy.

ii) $N_\star$ = number of stars in the Galaxy:

— this is the best known variable of this equation: about 2×10^{11} (200 billion) stars.

iii) f_p = fraction of stars with planets:

— new planetary systems are being discovered every year in the solar neighborhood.

— HST has discovered 100's of planetary systems forming around stars in stellar nurseries.

— stellar formation modeling give this fraction a value anywhere from 1/2 to 1!

— to be conservative, let's choose 1/2 for this fraction.

— $N_p = N_\star \, f_p = 1 \times 10^{11}$ planetary systems.

iv) $n_{\ell z}$ = number of planets per star that lie in the **habital zone** (also called the **life zone**) for at least 4 billion years:

— a habital zone is a region around a star where a planet can have temperatures that permit the existence of liquid water $\Longrightarrow$ F5 V – K5 V stars.

— only one system in which to do statistics.

— models predict from 0.01 to 1.

— 4 billion years chosen here due to length of time it took intelligent life to evolve on Earth.

— $N_{\ell z} = N_\star \, f_p \, n_{\ell z} = 10^9 - 10^{11}$ life zone planets.

v) f_ℓ = fraction of suitable planets on which life begins:

— not enough statistics.

— organic chemistry and the Miller-Urey Experiment suggests the answer is 1.

— we perhaps need to include the fraction of those planets that possess a large natural satellite at this point in order for stable long molecule chains to form.

— we will assume that this fraction ranges from 0.0001 to 1.

— $N_\ell = N_\star \, f_p \, n_{\ell z} \, f_\ell = 10^5 - 10^{11}$ planets with life.

vi) f_I = fraction of lifeforms that evolve to intelligence and develops radio astronomy:

— no statistics.

— 0.0001? – 1?

— $N_I = N_\star \, f_p \, n_{\ell z} \, f_\ell \, f_I = 10^1 - 10^{11}$ planets with intelligent life.

vii) F_s = fraction of star's life during which a technological society survives:

— completely unknown, destruction by nuclear war, mass extinctions from asteroid impacts (see §IV.C).

— if 100 years: $F_s = 10^{-8}$.

— if 1,000,000 years: $F_s = 10^{-4}$.

— $N_c = 10^{-7} - 10^{7}$ technological civilizations in the Milky Way.

c) If $N_c \leq 1$, we are the only technological civilization in the Galaxy.

d) If $N_c \gg 1$, technological civilizations are everywhere in the Galaxy.

i) If $N_c = 10^7$ civilizations, the average separation of each system is 120 ly.

ii) If this many exist, there should be many civilizations more advanced than us $\Longrightarrow$ where are they?

— UFO's not the answer! No scientific evidence that these *events* are extraterrestrial in origin.

— Also, travel time is too long (can't go faster than light) and it would be very expensive from a raw materials point of view.

iii) Von Neuman Machines (machines that travel to the next nearest star and reproduce themselves, sending their offspring to the next nearest stars, etc.) should be seeding the Galaxy by now $\Longrightarrow$ where are they?

iv) Maybe we are the first to achieve technology! (Somebody has to be first — *The First Ones* in the *Babylon 5* television show.)

e) We the listeners: radio astronomy.

i) Technological civilizations = ones that have radio telescopes.

ii) The laws of chemistry and physics are universal $\Longrightarrow$ water (H_2O) should be an important to all life-forms. As such, ET might broadcast between the H (*i.e.*, 21 cm) and OH (*i.e.*, 18 cm) lines $\Longrightarrow$ the **water hole**. There is little galactic noise in this part of the radio spectrum, hence a good place to send signals.

iii) Nothing found yet. The Horowitz experiment is now looking using a billion channel receiver (Project BETA). A few signals have been detected, but nothing has repeated. A detection cannot be confirmed unless it repeats and is verified by other scientists.

iv) If a signal is ever found, will it cause culture shock?

f) We the talkers:

i) Radio astronomy: we have sent messages. Dr. Frank Drake sent a binary signal with a variety of useful information off towards the globular star cluster M 13 in the 1960's. Unfortunately, the signal will not get to this cluster for another 30,000 years!

ii) Spacecraft emissaries: *say it better with Voyagers*:

— *Pioneers 11 & 12* have gold plaques on board with drawings of humans, our solar system, and our location in the Galaxy with respect to neutron stars.

— *Voyagers 1 & 2* each have a video disk and player on board — the disk contains pictures of our society and the Solar System. As well, it contains verbal greetings from all languages and songs including Chuck Berry's *Johnny Be Good*!

4. We are closer to answering this question of *whether or not we are alone in the Universe* than we ever have been throughout history. Humans seem to fear loneliness, so this question is very important to many people. Hopefully, with the aid of our current technology, we will discover the evidence of extraterrestrials in our lifetime.

5. Once they are found, it will be a "Herculean" effort to try a decode any signal that comes our way from another intelligence. It should be doable, however, since all technological civilizations will have one language in common — the language of *mathematics*! $\Longrightarrow$ The Universe behaves in a logical fashion, described by the laws of physics written in the language of mathematics. Let the search continue ...