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Are We Alone?

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Overview

One of the most pressing fundamental questions that face the philosophically minded human being is "Are we Alone in the Universe?" This question has been pondered for much of human history, but scientific, technological advances in Astronomy have added a tremendous amount of data to the discussion. Ever since the famous Drake equation was proposed in 1965, which attempted to determine the probabilistic factors that are primary to the existence of intelligent life, scientists have attempted to predict the likelihood of intelligent extraterrestrial life. It is my goal in this unit to explore the current data that exists regarding the requirements for life, the probability that such life could find a suitable existence elsewhere in the Universe and the physics required to detect it.

The debate ranges from those that claim that intelligent life is very rare to those scientists who believe that intelligent life is pervasive throughout the Universe. I will be considering the factors that are postulated to be prerequisites for life, the history of life on our planet that has resulted in our own existence and the relative significance of this fact, the scientific data that allows us to predict the probabilities of life elsewhere in the Universe and the reliability of these claims. I will be considering all of these issues in light of the physics involved in searching for extraterrestrial life and the technological advances that have recently improved our capacity to conduct this endeavor.

I intend to teach this unit in physics classes to explore probabilities in scientific claims, discerning the fundamental aspects of a problem, critical thinking, the physics of stars, rotation and thermodynamics relevant to establishing habitable zones, an analysis of the conditions necessary for life and estimates of time required for life to evolve, and the advantages to having space satellites to detect planets and any signals of intelligent life since this is the only real tangible way to detect intelligent life at this time. Using all of this information it is my intention to present a scientific discourse about the relative likelihood that intelligent life exists elsewhere in the Universe.

I will be teaching this to a variety of levels of physics classes in the urban Pittsburgh City school district. I will address this unit to general main stream first year physics classes, gifted first year physics classes and algebra based Advanced Placement second year physics classes. This is a broad range of mathematical and conceptual skill levels. However, I believe this unit is accessible on a variety of levels. Conceptually, I believe this unit is accessible to eleventh and twelfth grade students. Some of the specific scientific concepts might be too difficult for the general physics class but adaptations can be made to the unit by varying the level of explanation of the most difficult concepts. This is also true mathematically. The general physics students will be introduced to the formulas whereas the second year physics students will be expected to manipulate and in some cases, derive the formulas. This unit is intended to be broad enough to be applicable to a! ny physics course.

Rationale

My research has led me to the conclusion that simple life, like bacteria, is relatively pervasive in the Universe. The primary reason for this assertion is the rapidity within which life established itself on the Earth as soon as conditions made that possible. This occurred between 3.85 to 3.5 billion years ago as soon as the Earth ceased to be bombarded by devastating asteroids that would have sterilized the Earth and may have done so several times prior to this time. This is supported by Ward and Brownlee (2000) in Rare Earth: Why Complex Life Is Uncommon in the Universe, and by G.S. Kutter (1987) in The Universe and Life. Whereas both of these sources indicate that simple life is probably abundant in the Universe, they come to opposite conclusions on whether intelligent life exists elsewhere. As the title suggests, The Rare Earth hypothesis indicates that there are a plethora of factors that are required for a planet to be suitable for complex! life. Branching off of the Drake equation, Ward and Brownlee come to the conclusion that although simple life is probably abundant in our Galaxy, there are a multitude of factors that make it unlikely that intelligent life would evolve elsewhere. These factors include sterilizations of planets by meteor impact, the necessity of extremely stable conditions for complex life to evolve, including temperature, radiation levels, and water levels and the existence of a large moon to establish a beneficial and stable obliquity. In addition, the Earth's magnetic field helps to protect life from dangerous cosmic radiation. The presence of Jupiter helps to limit asteroid bombardment. They also believe that plate tectonics are an indispensable thermostatic process in the maintenance of a suitable global temperature and composition, and in establishing land masses. The rarity of plate tectonics on other planets greatly decreases the likelihood of life in the Universe. While simp! le life may well be pervasive, the time required with very tight environmental constraints that would enable simple life to survive and evolve into intelligent life is hugely significant. Based on the evolution of life on our planet, Ward and Brownlee suggest that billions of years are required for complex life to evolve. It is not a given as Darwin suggested that life will inevitable evolve into more complex forms. There is an indication in the fossil record of the Cambrian Explosion in which a tremendous number of "body types" evolved in a very short period of time. Actually, all of the body types that exist were developed by that time and no new body types have evolved since. How can this evolutionary "explosion" be explained? In the case of humanoid development there are other questions that are unresolved. In fact, very specific conditions are necessary for humanoid life to evolve, including a stretch of time living arboreally so that sensitive hands were developed and more unaccountably, the evolut! ion of the ability to be bipedal prior to leaving the trees. In addition, they suggest that very specific environmental demands are required for life to proceed to more complex life forms. In addition, more complex life forms are much more susceptible to extinction than simple life forms. All of these considerations lead Ward and Brownlee to propose the Rare Earth Hypothesis, that indicates that Earth is in fact very special and rare indeed and we may be the only intelligent life forms that exist in the Galaxy.

There are also discussions of habitability zones, the types of star systems that would be conducive to life, the inhospitable nature of parts of the Galaxy that are too densely populated, the development of the atmosphere, the necessity of having sufficient oxygen in the atmosphere for complex life to have more efficient energy conversion, the necessity of the existence of DNA or a suitable map, and how life began, including the possibility that life could have been "seeded" from space, most likely Mars. In the 3.8 billion years that life has had to evolve life has managed to propagate in incredibly diverse environments, including the extremophiles, which are organisms that live in extreme conditions. However it is surprising to me that all life is related in its DNA and came from the same source even though it has branched since. This strikes me as very difficult to assimilate that life is pervasive and yet in at least the 3.5 billion years that lif! e has been on Earth, only in the beginning did life originate? What special conditions existed to allow life to come into existence then but not to independently come into existence since? One strong suggestion for the lack of further evolution of life once it started is that life, once it formed, would have been able to out compete any other reproducing "cell" that came into existence. Another premise is that potentially multiple strands existed but all but one went extinct. Either of these hypotheses are plausible but not entirely convincing, so the question will remain, if simple life is as prevalent as Ward and Brownlee and Kutter suggest then why do all life forms on Earth, including the extremophiles share the same DNA source? In other words, why did life only produce one life form strand that survived or even left a record?

On the other hand, G.S. Kutter constructs his own Drake-like equation. In 1987, he predicted, based on a multitude of factors and the relative probabilities that could be assigned to those factors, that there are 100 advanced civilizations in our Galaxy. He is obviously much more optimistic, than Ward and Brownlee, that simple life will evolve into advanced life. His primary factors are 1) The probability that any given star in the Galaxy has planets suitable for supporting life, 2) The probability that on suitable planets life actually arises, 3) The probability that life, once it has arisen on a planet, evolves into complex multicelled forms, and 4) The probability that complex multicelled life evolves into intelligent beings with advanced technology. He states that "Life is not uncommon in the Universe. It probably has arisen tens of millions of times- perhaps even hundreds of millions of times- in our Galaxy alone. . .it appears conceivable that we are the ! only civilization with advanced technology presently existing in our Galaxy. However, just as likely, given the billions of galaxies that populate the observable part of the Universe, we are not entirely alone. Surely our kind has evolved, and survived, elsewhere also." (Kutter 1987) If, in fact, there were one hundred advanced civilizations in our Galaxy, this still presents a daunting problem. Given the size of the Galaxy, that means that the average civilization would still be 10,000 light years away. That means that having only been sending radio waves out for 80 years, and although they travel at the speed of light it would take another 9, 920 years before those first signals would reach them! That doesn't even address the fact that the radio waves would be so weak and dispersed that they would be undetectable. So in considering how we would detect advanced civilizations if they are out there we must consider the advantages of having space telescopes w! ith specialized detectors for receiving any extraterrestrial life signals.

Clearly, there are divergent points of view as to the likelihood that intelligent life exists. So in this unit, I propose to look at the likely probability of each of the factors that would be prerequisites for life as we understand it, and to analyze there relative merits based on current scientific data.

I also intend to introduce the recent discovery that there is a planet, Gliese 581c, that is an Earth like planet having 5 times the mass of the Earth and 1.5 times the diameter revolving around a red dwarf that is only 20.5 light years away. This is the first discovery of a terrestrial planet that is Earth like in the habitable zone of a star, and it greatly increases the probability of life existing in our Galaxy. In addition, scientists have indicated that a second terrestrial planet is also orbiting the Red Dwarf Gliese 581d slightly further out and eight time the mass of the Earth. Although it is slightly outside the habitable zone, scientists have suggested that Gliese 581d with its greenhouse gases may be the truly suitable planet, whereas Gliese 581c might have experience runaway greenhouse warming (W. Von Bloh, et. al, 2007).

It is only in the past decade or so that sensitive enough measurements could be made to prove the existence of planets outside our Solar System. The first extra solar planet was discovered in 1995 called 51 Pegasi by Marcy and Butler (although a radio telescope discovery around a dual star system may have indicated an inhabitable planet a few years earlier (Boss 1998)). The discover of 51 Pegasi was revolutionary and the 4.3 day orbit of the Jupiter sized planet convinced other scientists to reanalyze their six year old data for the existence of planets. And the revolution began. In the last 12 years 241 more planets have been discovered in over 181 solar systems, at an accelerating rate. As of April 2007 over 230 extrasolar planets had been discovered, but all of them were huge gaseous Jupiter-like planets circling far outside the habitable zones or too close to the stars that they revolve around. The difficulty of discovering planets exists because of the nature in wh! ich they are discovered. Most have been detected by their wobble which means that the planets must exert enough gravitational influence to detectably influence the motion of their star. In April two Earth-like terrestrial planet with masses five times and eight times the mass of the Earth respectively and with a diameter approximately 1.5 times that of the Earth were discovered that potentially with liquid oceans. The fact that these potentially habitable planets are so close to our Solar System and are able to be detected with our very limited technology, would seem to promise the existence of a plethora of such planets. There has been an explosion of extra solar planets and the technological advances are enabling astronomers to continue this tremendous advance. There are several NASA satellites in the process of being deployed or in the planning stages that promise the discovery of countless Earth like planets. It seems a simple matter of probability now that the first p! lanet has been found. If this is so, then it would seem all the more likely that advanced life forms would be able to evolve because our speculation about what is required for life could be reduced to verifiably similar environments. Gliese 581c and d basically guarantee that there are millions, and potentially billions, of Earth like planets.

There are four primary ways of detecting planets at the present time. The first two methods are dependent on the "wobble" in stars caused by the gravitational effects of action reaction which cause the stars position to move slightly when a planet revolves around it because only the center of mass moves in a straight line. The planet departs from the center of mass much more than the star but since the planet only reflects a minute amount of the starlight it is currently beyond our technology to detect. Therefore we must attempt to detect the very slight wobble of the luminous object, the star. The two methods of detecting this slight "wobble" are called the astrometric and the radial velocity method. The astrometric is a visual detection of the star's "wobble" when the orbital motion of the planet is perpendicular to ourselves. However, this change in motion is so small that it is extremely difficu! lt to detect, but current technology is advancing which is going to make this possible very soon. The advantage of detecting the EM waves directly is that this allows for spectography to analyze the spectra and determine the chemical composition of the atmosphere of the planets that are found. The second method that utilizes the stars "wobble" is called radial velocity. This method indirectly detects the change in the star's motion using the Doppler effect of the starlight when the orbits are parallel to ourselves. Since the star is oscillating slightly in its motion parallel to us, the motion towards us and away from us results in a change in the stars velocity which can be detected as the Doppler shift. Of the 242 planets that have been detected, the radial velocity method is how the majority of planets have been discovered, and it is the reason that all but two of those planets are huge Jupiter like planets because obviously more massive planet! s are going to cause stars to wobble more and therefore are detectible with our currently limited technology.

However, that technology is quickly evolving and there are many planned space satellites specifically designed to look for planets and search for extraterrestrial life. Satellites are far preferable to land based telescopes because of the undesirable effects of the atmosphere. Satellites avoid the distortions that prevent the precision measurements of the full spectrum of EM waves in space. The other two methods for searching for planets are the transit method and the coronagraphic method. The transit method is to use extremely sensitive optical satellites to detect the slight decrease of a star's luminosity when the planet crosses directly in front of the star. Although these occurrences are relatively rare they provide extremely accurate information about the planet's radius and mass and can determine if a planet is in the habitable zone of its star. The last method which is still being developed is the coronagraphic method. This extremely difficult opt! ical process involves the satellite blocking out the light of the star by optically eclipsing the star so that it can detect the planets which otherwise are too dim to be detected in the star's bright light. The impending deployment of satellites specifically with these capabilities will greatly increase our knowledge of the number of Earth-like or suitable planets there are for life in the habitable zones of stars in our Galaxy.

The only method for directly searching for intelligent life involves the attempt to detect intelligent electromagnetic signals. It is necessary to search as many different frequencies as possible so that the signals that might be sent are not missed. This is our best bet for verifying the existence of intelligent life because we simply do not have the technology to travel very far from this rock that we call home! Since the Galaxy is so huge, we are dependent on EM waves traveling at the speed of light to do the traveling for us. SETI (Search for Extra Terrestrial Intelligent life) is in the process of deploying a massive ground-based radio telescope to detect any possible signal from intelligent life.

This topic is very rich and timely. The greater our advances in technology, the more we will be able to discern about the cosmos. In recent decades science has seen the inclusion of cosmology as a verifiable science with tremendous amounts of data to offer to the scientific community. The advance of astronomy and cosmology has provided a boon of data for the entire scientific community in a time when high energy physics has been limited. It is my hope that the search for extraterrestrial life will gain the respectability that it deserves as a scientific endeavor. The search for intelligent life is the most compelling discovery that we could possible make. . . to know that we are not alone. Now that would be a truly awesome scientific realization.

Biological Considerations and Necessary Environmental Conditions

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One of the most compelling issue of whether or not life exists elsewhere concerns the factors required for the beginning of life. Since we only know of life on our Earth we do not have anything to compare so our investigation is largely speculative. However, biologists and astrobiologists have attempted to determine the factors necessary for life. The biologists are much more conservative and have suggested that as many as 10^{450} random trials would have been necessary for life to occur. However, experiments such as those done by Miller and Urey have demonstrated that when the compounds that made up the primordial soup (such as carbon dioxide, nitrogen and water vapor which were outgassed by volcanoes) were exposed to an electrical arc, which simulated lightning, amino acids and other compounds necessary for life were formed. Although that was established over sixty years ago, no one has been able to produce even the simplest life form. This is a conund! rum, however, the definitive establishment that life evolved so soon after conditions were possible for life leads astrobiologists to suggest that simple life is, in fact, pervasive although we do not know the mechanism that would have allowed life to come into existence. Let's consider the requirements of life.

For life to be self-replicating there must be a map. This would have to be in the form of DNA or RNA or some similarly complex molecule. This is the most difficult component of life. In addition, it is widely believed that life is likely to be carbon based. This is because carbon is a remarkably flexible element that forms very complex molecules and is abundant throughout the Universe. Another requirement appears to be the existence of liquid water because it is the universal solvent and allows cells to transport the necessary compounds to and from the cell. So in our search for extraterrestrial life we are looking for environments that satisfy these requirements.

There are two methods of searching for places where life could exist. We can attempt to visit sites within our Solar System, which so far has been fruitless, although Mars is still a possible candidate for life in the past and Europa, which is a moon of Jupiter, probably has liquid water below its ice cover, and could support life. The second method is to utilize spectroscopy to analyze the composition of atmospheres of planets once they are detected for relatively high concentrations of methane and oxygen which seem to be indicative of life processes, but this method is rather speculative, and currently beyond our technological abilities.

So as unlikely as it seems, our best prospect currently for detecting life in the Universe may be to specifically search for incoming EM signals that were produced by intelligent life. These signals are currently the only hope that we have of searching the Galaxy beyond our own Solar System. We will now consider the physics of attempting to find other Earth like planets because that drastically reduces the unknown factors regarding the requirements of life, and the methods of attempting to detect intelligent signals.

The Drake Equation

First proposed by Frank Drake, and known as the Drake Equation, although there are many variations of it, there is a probabilistic approach to addressing the likelihood of there being intelligent life in the Galaxy. This method involves determining the factors that would be essential for life to evolve and for that intelligent life to be detectable by us. Some of the factors can be determined but many of them are speculative. The original Drake equation considered the rate at which solar-type stars form in the Galaxy, the fraction of stars that have planets, the number of planets per solar system that are Earthlike or suitable for life, the fraction of those Earthlike planets on which life actually arises, the fraction of those life-forms that evolve into intelligent species, the fraction of those species that develop adequate technology and then choose to send messages out into space, and the lifetime of a technologically advanced civilization. All of these probabilities we! re multiplied to determine N, the number of technologically advanced civilizations in the Galaxy whose messages we might be able to detect. The formula is:

$N=R_{*}f_{p}n_{e}f_{l}f_{i}f_{c}L$ (Freedman and Kaufmann, 2005). Based on variations in the predictions, and variations in the basic parameters of the formula, the conclusion varies from 1 (our own) to millions. Future advances will enable us to calculate the relative probabilities of the factors with greater confidence.

Physics of Detecting Extraterrestrial Life

I intend to create a unit that highlights many aspects of physics in a manner that is current, engaging and enlightening for my students. This section will address the physics of extraterrestrial life and how we can detect it. SETI has identified a relatively noise-free frequency coined the "water hole" because it is in the neighborhood of the microwave emission lines of hydrogen and hydroxide, which would combine to form water. This frequency is our best bet for searching for a signal. In order to detect the signal we are looking for a focused signal most likely produced by a laser in the radio frequency range. The benefit of a laser is that the collimated beam does not disperse and can be detected at great distances. The detrimental aspect of this is that the signal is only detectable if you are in the narrow scope of the beam. In addition, it is essential to search millions of frequencies or channels to make sure that the signal is not miss! ed.

Methods of Detecting Extra Solar Planets

The "wobble" of stars is caused by the existence of planets. A star's wobble caused by the revolution of planets around it is the result of the fact that multiple bodies orbit around their center of mass. The center of mass moves in a straight line. The mass of a planet affects the wobble of the star although it is far less massive. In the case of the Solar System, the center of mass is located near the edge of the Sun in the direction of Jupiter. That is why this "wobble" is so difficult to detect and why it took thirty years of searching to identify the first verifiable planet. It also explains why the first several hundred planets were huge Jupiter like planets, since they would affect the motion of the star much more significantly than a small planet.

Although it is simplified, the one dimensional analogy is the situation in which a large adult sits on a see-saw with a very small child. In order for the child and adult to balance (which is equivalent to finding a stable orbit) the adult would have to sit in very close to the pivot point and the child would have to be as far away from the pivot as possible.

Astrometric Method

This method involves the visual detection of the motion of the stars wobble perpendicular to our own position. This is very difficult to do because the amount of motion is so slight relative to the size of the point sources of light. Often the wobble is less than the diameter of the star. This requires technological sophistication that is just now being developed.

Radial Velocity Method

This method of detecting the wobble is utilized when the star is moving parallel to us. It requires the use of the Doppler effect to determine the slight motion and resultant change in velocity towards and away from us. This motion causes a slight Doppler shift in the light emitted by the star. This is done by analyzing the spectrum of the light of the star. Two slices of a spectral line are analyzed comparing the Doppler shift in a slice of the rising curve to the Doppler shift of the falling light curve. When done with sufficient sensitivity, the variability of the stars oscillation can be detected. This oscillation is the result of an orbiting planet and the amount of Doppler shift enables the calculation of the mass of the planet. This method took thirty years to develop and it has been the method by which most extra solar planets have been detected including Gliese 581 c and d. This information is M_{planet}(sin i), where i is the angle of inclination to ! us, which is typically unknown.

Transit Method

As in the previous method of planet detection, the transit method is used when the motion of the planet is parallel to us. However, the transit method is the exact situation when the angle of inclination is exactly 90 degrees, or in our plane of sight. This results in the planet eclipsing the star. The planet is very small in comparison to the size of the star so only a small amount of the light is blocked. The method of analyzing this light data is known as photometry. It is only recently that the technology enabled the devices to be sensitive enough to detect this slight variation in luminosity. There needs to be an exquisite precision. The method of photometry has recently achieved this level and can detect 1 part change in luminosity in 10^5 difference. By continuing to detect for the next transit of the star the period and mass of the planet can be determined. Also, it is possible using this method to determine if the planet is in the star's ha! bitability zone.

Coronographic Method

This method which is still in development involves the direct observation of the planet by optically blocking out the star's light. This is equivalent to trying to detect a firefly next to a search light. The benefit of this method is that it would allow for the direct observation of the planet and therefore allow for spectral analysis of the atmosphere of the planet. This information could be utilized to potentially determine the existence of life based on the abundance of certain elements and compounds which we know are produced by life processes.

Interferometry

This method utilizes the wave characteristic of EM radiation to interact, thus creating constructive or destructive interference or perfectly canceling each other out. This is a method that enables extremely exacting measurement within the wavelength of the EM radiation utilized. As in waves in a pool created by multiple sources, the waves add and cancel resulting in patterns known as diffraction patterns. Interferometry is a powerful method that utilizes multiple smaller telescopes linked together by a detector. You achieve the same resolving power as a telescope that was the size of the separation of the small telescopes. However, in order to achieve this, the distance of separation must be maintained with incredible accuracy. You get great resolution but the distance must be maintained within a portion of a wavelength. Consequently, the first such telescopes were radio interferometers since the wavelength of radio waves can be miles. As the technology has progressed, thou! gh, we now have optical interferometers where the separation needs to be controlled within nanometers. Although interferometers offer incredible resolution, the amount of light collected is only the sum of the area of the telescopes. Therefore, for faint sources there are only a small number of photons collected. In addition to searching for planets, interferometery is useful in doing direct determinations of distances to astronomical objects and determining the Hubble constant with great accuracy.

Thermodynamics

The planetary equilibrium temperature, habitable zones and the greenhouse effect can all be determined. The temperature of a planet is based on the energy it receives from the luminosity of its star minus the energy that it radiates which is based on its surface area. A planet will achieve an equilibrium temperature. Greenhouse gases can raise the equilibrium temperature as a blanket raises the temperature of a body beneath it. The body radiates heat more slowly through the blanket material so a higher equilibrium point is attained at the lower atmospheric level, but regardless, equilibrium is achieved.

Electromagnetic Spectrum

The electromagnetic spectrum is the full spectrum of all energy photons as gamma rays, then x-rays, ultraviolet rays, visible light, infrared waves, and the lowest waves are radio waves. The velocity of all of this radiation is the speed of light. Therefore, the higher energy waves have higher frequency based on c=ΛY ; E=?Y; E=?c/Λ; ?=4.135 x 10^{-15} eV-s.

Doppler Effect

The Doppler effect is the phenomenon that results from a moving source. A wave that is continually generated by a moving source will increase in frequency if it is moving toward you and decrease in frequency if it is moving away from you. In sound this is known as a change in pitch, either higher or lower respectively. In light, the change in frequency is the result of the constancy of the speed of light and its relativistic effects are detected as a change in color. This is the method used to determine that the galaxies in the Universe are moving away from us.

Spectroscopy

The study of spectrum enables astronomers to analyze the electromagnetic waves that reach us. The light contains an incredible amount of information. The quantization of light is the result that photons come in discrete packets. In addition, from chemistry we know that EM waves are emitted in quantized amounts that indicate the different potential orbits of the atom. There are discrete orbits so there are a limited, and specific number of energy states that electrons can occupy. Therefore, when electrons transition between these energy levels they either absorb or emit very specific amounts of energy. From a knowledge of a these chemical states and the periodic table, the electromagnetic radiation from space can be analyzed to determine what the composition of the matter that it interacted with consisted of. Radiation is absorbed by matter in these discrete energy levels, but at all other energy levels the atoms are transparent. Therefore, the photons of these exact energy l! evels capable of exciting atoms are absorbed. This causes there to be "holes" or dark bands in the electromagnetic spectrum. These bands act as a fingerprint for each element. A careful analysis of this fingerprint enables the chemical composition of far away matter to be determined! In addition, this spectrographic finger print is used to determine how much the EM spectrum might have been Doppler shifted as the result of the velocity of the source towards or away from us. The EM waves that are absorbed by the atoms are eventually reradiated, but they are radiated in all directions therefore resulting in the dark band in the spectrographic spectrum.

Land Based Telescopes

The disadvantage of land based telescopes is that they must get all of their information from EM radiation that is distorted by the atmosphere. The atmosphere is made up of a fluid of particles that diffract the EM radiation. In large part this can be accounted for. However, the turbulence of the atmosphere, known as seeing, results in a blurring of point sources so it puts a definite limit on the amount of resolution that can be achieved. For exacting measurements that are required for these faint and far away sources that may only activate a pixel on the receiving device the seeing is a devastating effect and results in a blurring that spreads the light over several pixels. In part, as a result of the "Star Wars" program, scientists have been able to resolve the relative distortion of the atmosphere, by analyzing the effects on laser light, however, the effect of seeing, although it can be mitigated cannot be removed and it is the limiting factor of lan! d based telescopes. Another disadvantage is that land based telescopes can only operate at night because the sky is too bright, are affected by local city light, and are periodically obscured by cloud cover. The down time for the telescope due to daylight and cloud cover prevent continual data collection which is necessary for some observational purposes.

The benefit of land based telescopes is that they are much cheaper and can be maintained and upgraded easily. However, for extra solar planet searches they are reaching the limits of their capability. The Keck interferometer is an example of the best ground based telescope. More can be found out about this telescope at http://planetquest.jpl.nasa.gov/Keck/keck_index.cfm.

Allen Telescope Array- SETI

Array Telescopes are a method of interferometrically combining smaller telescopes together. It is possible if delicately coordinated to get the equivalent gathering aperture as significantly larger and monumentally more expensive telescopes. SETI, the Search for Extra Terrestrial Intelligence, has developed and begun deploying the ATA, Allen Telescope Array, which is a huge array of interlocking 6 meter satellites that are the equivalent of a one hectare telescope that will allow for the surveillance of tens of thousands of channels from 0.1 Hz to 16 GHz. For more information visit http://en.wikipedia.org/wiki/SETI#Allen_Telescope_Array.

Space Telescopes

The search for extra solar Earth like planets has become scientifically respectable as is indicated by the incredible amount of research being done in this field. The website dedicated to this field and the technological project underway is run by NASA and is called Planet Quest: the Search for Another Earth and can be accessed at http://planetquest.jpl.nasa.gov/index.cfm. This is an incredible site for specific information about existing and planned satellite projects, educational resources and background information.

SIM- Space Interferometery Mission

Interferometric telescopes utilize interferometry to make very exact measurements. The SIM telescope is an example of this type which is scheduled to be launched in 2012 and its sensitivity will enable it to detect planets as small as the Earth. Currently we can achieve 1 thousandth of an arc second. The SIM will be able to achieve 1000 times better resolution, or 1 millionth of an arc second. The website to find out more information is http://planetquest.jpl.nasa.gov/SIM/sim_index.cfm.

Transit- Kepler Satellite

The transit technique utilized by the Kepler satellite will enable scientists to determine whether a planet is in its star's habitable zone. Check out the website at

http://planetquest.jpl.nasa.gov/Kepler/kepler_index.cfm.

Coronagraph Telescope- TPF: Terrestrial Planet Finder

Coronagraphy is a method of attempting to detect planets directly by blocking out the stars EM radiation by "eclipsing" it optically. This is an extremely sophisticated method, but there is a satellite telescope being developed for deployment as the successor to SIM. By receiving EM radiation directly, it allows spectroscopy to be used to analyze the chemical composition of the planets atmosphere. Learn more about this mission at http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm.

Types of Orbits for Satellites

Low orbit

These satellites have a 90 minute orbit at about a few hundred kilometers and above and some need constant boosting or their orbit degrades and they reenter the atmosphere. The range is from 100- 1000 kilometers and above 700 kilometers there is no need to reboost. Our telecommunication satellites are in low orbit because the time for relaying the signal is short enough at the speed of light not to be problematic. These satellites experience high friction from the atmosphere and consequently require constant "boosting" to maintain their orbit.

Geosynchronous Orbit

Orbiting at the same rate as the Earth allows a satellite to stay above the same location. The orbit is 23 hours 56 minutes. These orbits are permanent which is great for us since they do not require energy to maintain their orbit, however, the detrimental side of this fact is that failed satellites in this orbit turn into space debris that stays there forever. This orbit is not used for telecommunication satellites because there is a quarter of a second delay in the two way transmission. This orbit is at approximately 23,000 miles altitude.

Inner-Lagrangian Orbit

This orbit maintains the same relative position between the Sun and the Earth. There are three of these positions. This orbit is in relative equilibrium and stays relatively stable.

Calculating Orbits

Kepler's Laws $P^2 = a^3$; "P" is the planet's sidereal period in years and "a" is planet's semimajor axis, in AU.

Strategies

I will utilize a constructivist approach in teaching this unit. Constructivism suggests that learners take in knowledge superficially and apply it to their existing framework even if that contains fundamental misconceptions and contradictions known as assimilation, or a learner can actively utilize the knowledge to reframe their world view which is known as accommodation. The goal is for the student to construct as comprehensive and consistent a world view as possible. This approach recognizes that the learner comes with a vast set of preconceptions about their world. In order to have some influence over how the information that we are presenting as educators is processed, we must actively attempt to understand the students' preconceptions and misconceptions. Then we must actively engage the students world view if we are to have a lasting impact on their thinking process. My main emphasis in teaching physics is to address my students' critical think! ing skills. Physics attempts to address the fundamental nature of our reality, but our experiential knowledge is often deceptive or contrary to the "Laws" of physics. Consequently, it is apparent to me as an educator that we must address the learner as a comprehensive being with a tremendous amount of inclination to sustain their current world view. This is natural in human beings. But the scientific pursuit requires that we are open to accepting the experimental evidence about the world around us and to have a more comprehensive understanding of the world we inhabit even when a large part of the knowledge is conceptual.

So how do we begin to affect our students' world vision? Well it is clear that first we must make learning an active process. It is essential that we engage our students as deeply and profoundly in the educational process as possible. How can this be done? It is my belief that we must stimulate their inherent desire to learn. It is only if we activate this passion for learning that students will invest enough of themselves to begin the process of allowing their learning to transform their vision of how the world is constructed. So students must be forced slightly beyond their comfort zone, known by Piaget as the "zone of proximal learning". This is the place where students are emotionally invested in what they are learning and in the space in which learning matters. It is my goal for my students to evaluate their views and to attempt to make their understanding as comprehensive and consistent as possible.

How do we get students to engage at this level? I believe that a constructivist, hands on learning is primary. Students must engage on a multitude of levels including a physical level. They must be presented with problems that are meaningful, relevant and which they are compelled to attempt to resolve. Thus the teacher must act as a facilitator acknowledging the role of prior knowledge to stimulate students to incorporate new learning into altering their world view. The students must be encouraged to construct their new world view and this is strongly based on motivation. It cannot occur passively.

This is where this unit comes in. I believe that students are most motivated by topics that are relevant to them, that stimulate their imagination and enable them to further their understanding of the world around them. I am convinced that the question, Is there intelligent life elsewhere in the Universe? is one such question. I think that it activates an innate curiosity about our relative place in the Universe and it allows me to frame many realms of physics knowledge in terms that are relevant, pertinent and digestible.

I intend to utilize the science in this unit to address the nature of the Universe and our place in it. I hope to consolidate my students' knowledge of physics concepts such as mass, gravity, astronomical scales, light and electromagnetic waves, optical characteristics and current technology, probability and the evolving nature of the scientific endeavor. I want to impress upon my students that the scientific approach is an extremely effective method to approach most issues with the intention of determining or evaluating truth claims. Science is a process, as is learning and our knowledge or understanding of the physical world is constantly evolving. Therefore, a constructivist approach is extremely complementary to the scientific pursuit. The goal is that our students become global citizens with an advanced capacity for discernment and critical thinking and it seems apparent to me that a constructivist approach is the best means to achieve this end. I will achieve! this with challenging mathematical problem sets, laboratory experiences in interferometry and parallax, gravitational analogies to a stars "wobble", spectroscopy, and optics, and guided questioning about the requirements, probabilities, and implications of searching for and potentially discovering intelligent life.

Objectives

My students will acquire an understanding of the issues related to the evolution of life, its likelihood of existing elsewhere in the Universe, the physical principles that are inherent to the search for extraterrestrial life and be able to incorporate that knowledge into a greater understanding of physical science (S2). Students will improve their capacity for making discerning judgments about issues related to science and will be able to appreciate the scientific method as a valuable and useful approach to decision making. The students will be able to use their observations to evaluate the veracity of knowledge and be able to identify issues that are still unknown (S1, S5). The students will be able to understand the evolving nature of science and the method that scientist use to make truth claims (S7). The students will appreciate the role that the advances in technology have played in the advances in scientific knowledge and be able to access internet resources (S9).! The students will acquire the terms and language to discuss their elevated ideas regarding space sciences (C5). The students will be able to communicate their ideas, express their opinions, and defend the relative reliability of different theories. The students will engage in higher level class discussions (C6,C7,C8). The students will improve mathematical skills in understanding formulas, calculating results, representing their data graphically and comprehending the implication of mathematical expressions (M1, M2, M4, M5,M6).

Classroom Activities

Lesson 1 - Planet Quest - Interactive Drake Equation, What is Life and What is an Intelligent Signal?

After having begun a discussion on the factors that determine the prerequisites for life, the probability of life being able to exist elsewhere and how we would go about detecting intelligent life that may exist, we will visit the interactive website, http://www.alienearths.org/. From this scientific site my students will be able to determine the factors that scientists consider to be the most relevant for calculating the probability of how many intelligent civilizations might exist in our Galaxy. From this interaction, the students will be able to make actual calculations and receive scientific explanations for those determinations.

In the life section of this site, the students will be able to decipher the distinction between that which is alive and that which is not. Specific examples are given for the living and non-living substances. This will enable students to explore the difficult distinctions between what makes up life. It is my hope that my students will come away with the understanding that living organisms must be able to replicate using some type of "map" and they must be able to get the materials to sustain their existence.

The last section of this interactive site will provide my students with examples of signals so that they can begin to decipher intelligent signals from natural ones. This is the endeavor of SETI and although we have not detected an intelligent signal yet, there is hope and it is our best chance of discovering that we are not alone.

Lesson 2 - Interferometry Lab and Parallax- Determining Distances

Parallax is the technique utilized to directly determine distances. We use it all the time and it is the reason that we have depth perception. Our two eyes detect differences between objects and how much the background changes relative to them. Our brain is able to utilize this information to calculate how close or far away objects are. The more that the background changes relative to the object of focus the closer the object is. Conversely, the less the background changes, the farther away the object is. We will conduct labs using this concept and geometry to determine the distances to far away objects. The website that we will use to help us conduct this lab is

http://.jpl.nasa.gov/PDF_Examples/04_28_05_1.pdf.

We will also conduct a lab on interferometry. This concept, as has been described involves the wave nature of the EM spectrum. We will visit the site,

http://planetquest.jpl.nasa.gov/SIM/experiments.cfm to conduct our lab.

Lesson 3- Calculate the different Orbits and Calculation of EM wave frequency and energy

We will mathematically calculate the different orbits. We will calculate their distance and period, which is the time it takes to make one complete orbit. The website that we will utilize for this purpose is, http://csep10.phys.utk.edu/astr162/lect/light/waves.html. All of these activities are meant to complement the discourse that has been initiated about whether or not life exists elsewhere in the Galaxy. These are the methods that scientists utilize to determine whether or not life could exist elsewhere, so it is important that students have hands on knowledge of the scientific methods used to pursue this knowledge.

Lesson 4- Temperature of the planets and Greenhouse gases

(the equation for the temperature of a planet)

To calculate the temperature of the Earth you use the following equation

$$\frac{L_s}{4\pi d_S^{\,2}} \bullet \pi r_E^{\,2} \bullet (1-A) = 4\pi r_E^{\,2} \sigma T^4$$

L_s- luminousity of Sun= 3.86 x 10^{33} erg/sec

A - albedo = 0.39

d_s - distance of Earth from Sun = 1.496 x 10^{13} cm

r_E - radius of Earth = 6,378 km

Σ - Stefan-Boltzman constant = 5.67 x 10^{-5} erg/cm ^{2} deg ^{4} sec

1 st term -"energy flux"

2 nd term - cross-sectional area of the Earth

3 rd term- amount of energy absorbed

Equals:

Surface area of the Earth x Boltzman constant(energy per meter) x temperature to the fourth power

Solving for temperature: (Πr_E^2 cancels leaving:)

$$T^4 = \frac{\frac{L_s}{4\pi d_S^{\,2}} \bullet (1-A)}{4\sigma}$$

Substituting in the values gives:

$$T^4 = \frac{4x10^{33}\,x0.61}{16\pi x5.7x10^{-5}x(1.5x10^{13})^2}$$

T= 248K = -25°C

the same equation is used to determine the habitable zones of planets. The temperature must be between 0 to 100C. However, as with the Earth and Gliese 581d the greenhouse gas effect may bring some planets into the habitable zone and like Venus and Gliese 581c may force them out!

$$T^4 = \frac{\frac{L_s}{4\pi d_S^{\,2}} \bullet (1-A)}{4\sigma}$$

Distance of distance of Venus from the sun: d= 0.72 AU

Although the albedo of Venusis currently 0.76, if no clouds were there (no atmosphere), the albedo should be similar to Earth, 0.39

A simplified formula is:

$$T_{planet} = 278\left(\frac{(1-A)}{d_s^{\,2}}\right)^{\frac{1}{4}}$$

where d is the distance from the planet to the sun in units of AU (the mean distance between the sun and Earth)

Derive this formula and solve for T_{Venus}=

The students discuss the implications of their calculations of the temperature of the Earth from the Sun's luminous heat and the temperature of Venus. Without the greenhouse effect we could not live on the Earth. Then the students will discuss how the greenhouse gases may have affected the temperatures on Gliese 581 c and d.

Cited Works

Boss, Alan (1998) *Looking for Earth: The Race to Find New Solar Systems*. New York. Johh Wiley & Sons, Inc.

Freedman, Roger A. and William Kaufman (2005) *Universe*. Seventh edition. New York. W. H. Freeman and Company.

Kutter, G.S (1987) *The Universe and Life: Origins and Evolution*. Boston. Jones and Bartlett Publishers, Inc.

Ward, Peter and Donald Brownlee (2000) Rare Earth: Why Complex Life is Uncommon in the Universe. New York. Copernicus Books.

"Gliese 581 c" Retrieved June 15, 2007 from Wikipedia.

http://en.wikipedia.org/wiki/Gliese_581_c#Discovery

W. Von Bloh, et. al. The Habitability of Super-earths in Gliese 581. May 25, 2007.

http://arxiv.org/PS_cache/arxiv/pdf/0705/0705.3758v1.pdf

(Discusses the proposal that 581c might have runaway greenhouse gases therefore making 581d in the habitable zone)

Reading List

http://en.wikipedia.org/wiki/Constructivism_%28learning_theory%29

(An explanation of constructivist learning theory)

Minkel, JR. Scientific American.com. Retrieved June 15, 2007.

www.sciam.com/article.cfm?articleID=25A261F0- E7F2-99DF-313429A4883E6A86. April 24, 2007. "All Wet? Astronomers Claim Discovery of Earth-like Planet. Not too hot and not too cold means just right for water.

Galaxies and Cosmology. Ed. Mark H. Jones and Robert A Lambourne. 2004. UK. Cambridge University Press.

http://sciencenow.sciencemag.org/cgi/content/full/2007/611/1?eaf

"New Earth or Planetary Hothouse?" Phil Berardelli. *Science*NOW Daily News.11 June 2007

(An article about the implications of W. Von Bloh et. al. scientific article)

http://www.princeton.edu/~willman/planetary_systems/Gliese581.html

Gliese 581 Planetary System Data

(A table about Gliese 581 planets)

http://www.alienearths.org/

"Alien Earths: Beta" 2006 Space Science Institute

(A great interactive site that deals with the issues of finding intelligent life in the Universe)

http://planetquest.jpl.nasa.gov/SIM/experiments.cfm

(Possible interferometery experiments)

Mallory, Michael (2005). *Our Improbably Universe: A Physicists Considers How We Got Here...*. New York: Thunder's Mouth Press.

Planet Quest: the search for another Earth. Retrieved July 7, 2007, from NASA Web site: http://planetquest.jpl.nasa.gov/index.cfm

(Awesome site that includes links to numerous educational resources, current information about satellite missions, and even has a current planet count)

Citation Machine. Retrieved July 11, 2007.

http://citationmachine.net/index.php?callstyle=2&all=yes

(Provides specific information on how to cite references)

Retrieved July 9, 2007.

http://csep10.phys.utk.edu/astr162/lect/light/waves.html

(Provides information on light and waves)

Allel Telescope Array. Retrieved July 10, 2007 from Wikipedia.

http://en.wikipedia.org/wiki/SETI#Allen_Telescope_Array

(Information about the ATA telescope)

Appendix-Content Standards

PENNSYLVANIA SCIENCE STANDARDS

S1. All students explain how scientific principles of chemical, physical, and biological phenomenon have developed and relate them to real-world situations.

S2. All students demonstrate knowledge of basic concepts and principles of physical, chemical, biological and earth sciences.

S5. All students construct and evaluate scientific and technological systems using models to explain or predict results.

S7. All students evaluate advantages, disadvantages and ethical implications associated with the impact of science and technology on current and future life.

S9. All students demonstrate basic computer literacy, including word processing, software applications, and the ability to access the global information infrastructure, using current technology.

PENNSYLVANIA MATH STANDARDS

M1. All students use numbers, number systems, and equivalent forms (including numbers, words, objects and graphics) to represent theoretical and practical situations.

M2. All students compute, measure, and estimate to solve theoretical and practical problems, using appropriate tools, including modern technology such as calculators and computers.

M4. All students formulate and solve problems and communicate the mathematical processes used and the reasons for using them.

M5. All students understand and apply basic concepts of algebra, geometry, probability and statistics to solve theoretical and practical problems.

M6. All students evaluate, infer, and draw appropriate conclusions from charts, tables and graphs, showing the relationships between data and real-world situation.

PENNSYLVANIA COMMUNICATION STANDARDS

C5 All students analyze and make critical judgments about all forms of communication, separating fact from opinion, recognizing propaganda, stereotypes, bias and recognizing inconsistencies and judging the validity of evidence.

C6 All students exchange information orally, including understanding and giving spoken instructions, asking and answering questions appropriately, and promoting effective group communications.

C7 All students listen to and understand complex oral messages and identify the purpose, structure, and use.

C8 All students compose and make oral presentations for each academic area of study that are designed to inform, persuade, and describe.