Astrobiology: The Search for Extraterrestrial Life

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Abstract

The purpose of this paper is to outline the main concepts of astrobiology and explore the possibilities for extraterrestrial life. This research document will highlight the importance of how studying the formation of life on earth is a key component of searching for life on other planets. The bulk of this paper will focus on the primary means for the detection of exoplanets; specifically those that could potentially harbor life. The purpose and functionality of the satellite, Kepler, will be thoroughly discussed.

Background

Astrobiology is defined as the study of the origin, evolution, distribution, and future of life in the universe. This diverse scientific field encompasses the search for habitable environments within our Solar System as well as planets outside our Solar System that could potentially harbor life. A major part of astrobiology is trying to locate evidence of prebiotic chemistry that may give us hints as to how life formed here on Earth and how life may form on other planets. Astrobiologists strive to answer the question of whether life exists beyond Earth, and if so, how to locate it. In order to provide answers to this question, astrobiologists utilize several different scientific fields, including physics, chemistry, astronomy, biology, geography, and many others.

As of now, Earth is the only known place in our universe to contain life forms. However, advances in astronomy and planetary science have increased the span of what we consider to be habitable zones around other stars. Additionally, advancements in these fields have uncovered a large variety of organisms with the capability to thrive in very harsh environments on Earth. These discoveries have led to a great deal of speculation surrounding the possibility that life may be thriving on numerous different extraterrestrial bodies.

One of the most important aspects of trying to locate life on other planets is to first understand how life formed here on Earth. The knowledge of how organic life forms can form from inorganic materials would facilitate the process of understanding the myriad of ways in which life can form on other planets as well as the identification of potentially hospitable planets outside our Solar System. As of now, there are several different methods for the detection of these exoplanets.

1 Origin of Life

The origin of life is a perplexing and heavily researched field, completely separate from the study of the evolution of life. Trying to solve the mystery of life involves a substantial amount of focus on prebiotic chemistry. This branch of chemistry primarily involves researching the conditions of early Earth and attempting to understand how organic compounds may have formed from the inorganic elements present during that time period. This process of biological life arising from inorganic matter is known as abiogenesis or biopoiesis. An alternative theory, known as panspermia, suggests that the first elements of life could have potentially formed on another planetary body or asteroid which then could have transferred these elements to Earth via collision. In October 2011, scientists found that the cosmic dust permeating the universe contains complex organic matter that could be created naturally, and rapidly, by stars. [1] This research suggests that this complex organic matter may have been related to the development of life on early earth.

Although the exact method of how the first instance of life was formed remains unknown, it is clear that life on Earth can be traced back approximately 3.8 billion years ago to a period in Earths history in which heavy bombardment of comets containing organic chemicals was common. During this time, amino acids, often referred to as the building blocks of life, would have formed through natural chemical reactions as demonstrated in the Miller-Urey experiment and other experiments like it that simulated some of the hypothetical conditions of early Earth. [2] Other essential biochemicals, including nucleotides and saccharides, can also form in similar ways. When located within organisms, these chemicals are organized into more complex molecules, such as proteins, polysaccharides, and nucleic acids. These three molecules make up all living organisms on this planet and are essential for all life functions. As to which of these organic molecules was first produced, and how they were later able to form life, is a heavily researched part of abiogenesis.

The first organisms on Earth are believed to have been single cell prokaryotes (lack a cell nucleus) which could have potentially evolved from organic molecules surrounded by a membrane-like structure.[3] The oldest fossil microbe-like objects are dated to be approximately 3.5 billion years old. Around 2.4 billion years ago, the ratio of stable isotopes of carbon, iron, and sulfur seem to indicate the process of photosynthesis, thus demonstrating that life on Earth during this time was fairly widespread. [4]

2 Formation of Life on Other Planets

When searching for life on other planets, it is beneficial for astrobiologists to make several simplifying assumptions to the help narrow down the search. The first assumption is to assume that the vast majority of organic life forms in our galaxy are, for the most part, based on carbon chemistries similar to life forms of Earth. [5] This assumption is important because carbon, being the fourth most abundant element in the universe, is well known for the wide variety of molecules that can be formed around it. Additionally, the fact that atoms of carbon are able to bond to other carbon atoms quite readily provides the construction of long intricate molecules.

Another important assumption is that in order for life to be present on an exoplanet, the presence of liquid water is of vital importance. Water is a common molecule that allows for the existence of an environment suitable for the formation of complicated carbon-based molecules that could potentially lead towards the production of different life forms.

A third assumption is to focus the search for potential life containing extraterrestrial planets on planetary systems containing sun-like stars. This assumption arises from the notion of planetary habitability.[6] Very big stars tend to have a relatively short lifespan, indicating that life would probably not have a sufficient amount of time to form and evolve on any nearby orbiting planets. On the opposite end, very small stars provide little heat and thus only planets with very small orbits would receive enough heat to not be completely frozen. It is currently estimated that around ten percent of the stars in our galaxy are similar to our sun and that there are approximately a thousand such stars within a distance of 100 light-years from our sun.

The last assumption mentioned above, however, may not be entirely that accurate. In 1977, during an exploratory dive to the Galapagos Rift, scientists discovered colonies of worms, clams, crustaceans, mussels, and other different creatures clustered around undersea volcanic features. These types of organisms thrive in an environment in which there is no access to sunlight. In fact, these creatures comprise an entirely independent food chain in which instead of plants, the basis for this chain is a form of bacterium that derives its energy from the oxidation of reactive chemicals; a process known as chemosynthesis. These reactive chemicals consist of hydrogen and hydrogen sulfide which bubble up from the Earths interior.[7] This discovery was extremely important to the field of astrobiology because it illustrated the fact that the formation and sustainment of life is not dependent on the sun. As far as we know, life only requires water and an energy source in order to survive.

[1] Pace, “The Universal Nature of Biochemistry”.
[2] Rubin, ”Miller-Urey Experiment: Amino Acids & The Origins of Life on Earth”
[3] Wilde, ”Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 Gyr ago”
[4] Cavalier-Smith, ”Introduction: how and when did microbes change the world?”
[5] ”Polycyclic Aromatic Hydrocarbons: An Interview With Dr. Farid Salama”. Astrobiology magazine. 2000
[6] ”Stars and Habitable Planets”. Sol Company. 2007
[7] Chamberlin, ”Black Smokers and Giant Worms”. Fullerton College.

3 Searching for Hospitable Planets

A significant part of astrobiological research is dedicated towards the detection of exoplanets with the inclination that life should be present on other planets with similar characteristic to Earth-like organisms. Currently, there are several different projects aimed at detecting Earth-like exoplanets, including NASAs Terrestrial Planet Finder (TPF: recently canceled) and Kepler, launched in 2009. The goal of these missions is both to detect Earth-sized planets as well as to directly detect light from the observed planet so that it can be examined spectroscopically. By examining planetary spectra, it is possible to determine the basic composition of an exoplanets atmosphere and surface. With this information, it could potentially be possible to ascertain the probability of life being found on that particular planet.

An estimate for the number of planets with intelligent extraterrestrial life is roughly outlined by the Drake Equation. This equation is a mathematical approach taken to attempt to express the probability of intelligent life as a product of different factors, including the fraction of planets that might be habitable and the fraction of planets on which life might arise.[8] :

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L \tag{1}$$

Where:

N = the number of communicative civilizations

R^* = the rate of formation of suitable stars (like our Sun)

f_p = the fraction of those stars that contain planets

n_e = the number of Earth-like worlds per planetary systems

f_l = the fraction of those Earth-like planets where life actually develops

f_i = the fraction of life sites where intelligence develops

f_c = The fraction of communicative planets (those on which electromagnetic communications technology develops)

L = The lifetime of communicating civilizations.

However, it is extremely unlikely that this equation can be constrained to any concrete span of reasonable error limits any time soon due to its inclusion of terms that are not able to be verified. Additionally, the Fermi paradox proposes another counter argument against the Drake Equation that states: if life is so common in the universe, then there should be obvious signs of it. Despite the complex problems posed by the Fermi paradox, there is no reason to halt our search for life beyond the scope of our planet. With the constant discovery of new planets and different kinds of life forms, we would be naive to think that life on Earth is one of a kind.

4 Exoplanet Detection Methods

Any given planet serves as an extremely faint light source compared to its parent star and thus it is very difficult to directly observe exoplanets. In fact fewer than five percent of all discovered exoplanets have been observed directly. Luckily, there are several different methods for the detection of exoplanets that are currently being utilized by a variety of scientific projects that prove to be much more successful and efficient then direct observation. The goal of the remaining portion of this paper is to accurately describe these detection methods and provide examples of how they are being used today.

[8]Ford, ”What is the Drake Equation?”. SETI League.

4.1 Radial Velocity

Any given star containing an orbiting planet will tend to move in a small orbit of its own as an effect of the planets gravity. This movement produces a change in the speed with which the star moves toward or away from the Earth. These variations in speed are the radial velocity of the star with respect to the Earth. This radial velocity can be obtained from the displacement in the parent star's spectral lines caused by the Doppler Effect. The radial velocities of the host star and an orbiting planet with respect to the center of mass are obtained from the following equations:

$$V_{r(star)} = \frac{2\pi a_1 sin(i)}{P\sqrt{1-e^2}}[cos(\theta - \omega) + e \cdot cos(\omega))] \tag{2a}$$

$$V_{r(planet)} = \frac{2\pi a_2 sin(i)}{P\sqrt{1-e^2}}[cos(\theta - \omega) + e \cdot cos(\omega))] \tag{2b}$$

Where:
P = The orbital period of the host star (typically in days or years)
a = Half the length of the major axis
θ = the angle between the periastron and the position of the planet
ω = the angle between the line of nodes and the periastron

Note:

- The periastron is defined as the point at which an object, in this case a planet, is closest to the star it is orbiting.
- The line of nodes refers to the line connecting the point where the planet passes from below the plane of the sky to above the plane of the sky and the point where the planet passes from above the plane to below it.

The method of using radial velocity measures these speed variations in order to confirm the presence of an orbiting planet. Modern spectrometers are able to detect velocity variations down to approximately 1 m/s. The radial-velocity method, also known as Doppler spectroscopy, has been the most productive technique used to locate exoplanets. This method is independent of distance, but requires high signal-to-noise rations in order to obtain high precision and so it is generally used for nearby stars within a distance of 160 light-years from Earth. Most commonly, scientists and equipment using this method tend to locate massive planets that are close to their parent stars. Locating planets with larger orbits requires many years of observation. One of the main disadvantages of utilizing the radial-velocity method is that it is only able to estimate a planets minimum mass. However, when used in combination with the transit method (described below), the planets true mass can be estimated.

4.2 Pulsar Timing

Another useful method of detecting exoplanets is Pulsar Timing. A pulsar, also known as a neutron star, is the small and dense remnant of a star that has undergone a supernova. These pulsars regularly emit radio waves as they rotate rapidly. Due to the regularity of the rotation of the pulsar, slight discrepancies in the timing of its observed radio pulses can be utilized to track the pulsars motion. Just like an ordinary star, pulsars will move in a small orbit of their own if it has a planet circling it. Pulse-timing calculation can reveal certain parameters of that particular orbit. Although this method was not originally intended to detect exoplanets, it is extremely sensitive and is even capable of locating planets that are far smaller than planets found by other means. The Pulsar-Timing method is also able to detect gravitational perturbations between different objects of a planetary system and thus can ascertain further relationships and orbital parameters of the planets. Unfortunately, pulsars are relatively scarce, making it difficult to locate any significant number of exoplanets. Additionally, it is believed that life would not be able to survive on planets orbiting pulsars due to the high-energy radiation emitted by the star.

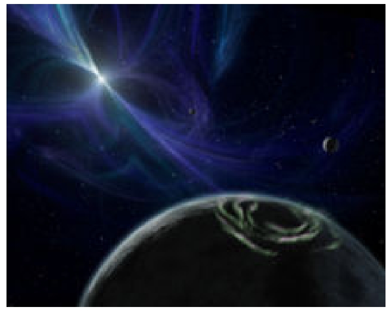

Figure 1: Artist's impression of the pulsar PSR 1257+12's planetary system

4.3 Transit Method

The previous methods mentioned above are able to provide information about the mass of detected planets. The transit method, however, is a photometric method that can determine the radius of a planet. When a planet crosses in front of the disk of its parent star, the observed visual brightness of this star decreases by a small amount. This drop in brightness is directly related to the relative size of both the star and the planet as shown in the equation below:

$$\frac{\Delta L}{L_*} \approx (\frac{R_{pl}}{R_*})^2 \tag{3}$$

Where:
$\Delta L =$ the depth of the brightness drop
$L_* =$The luminosity of the star

Unfortunately, this method has two substantial disadvantages. Planetary transits are only observable if the exoplanet has an orbit that is perfectly aligned from the astronomers vantage point. The probability of a planetary orbital plane being perfectly on the line-of-sight to a star is given as the ratio of the diameter of the star to the diameter of the orbit. To put this into perspective, for a planet orbiting a sun-like star at a distance of 1 AU, the probability of a random alignment producing a transit is roughly 0.47 %. Thus while this method is not useful for determining if any particular star contains orbiting planets, it is useful if one is scanning large areas of the sky in which thousands of stars are in view. The transit-method is theoretically capable of finding exoplanets at a rate that exceeds that of the radial-velocity method.[9] Several sky surveys have taken this approach, such as the ground-based MEarth Project and the space-based COROT and Kepler missions. Another disadvantage of this method is that it produces a fairly high number of false detections and so typically any exoplanet detected using the transit method requires additional confirmation, usually from the radial-velocity method. The main advantage of using the transit-method is that the size of the planet can be determined from the produced light curve. When combining both the radial velocity method and the transit method, one can identify the density of the planet and thus gather information about the planets physical structure. Another advantage of the transit-method is that it produces information about the atmosphere of the transiting planet. When a planet passes in front of a star, light from the star passes through the upper atmosphere of the orbiting planet. By carefully examining the stellar spectrum, elements present in the planets atmosphere can be detected. The atmosphere can also be detected by measuring the polarization of starlight as it is reflected off the planets atmosphere. When used in reverse, (when the planet is blocked by its parent star), the transit method allows for direct measurement of a planets radiation. From this measured radiation, one can determine the planets temperature and possibly detect the presence of cloud formations.

[9]Hidas, M. G.; Ashley, M. C. B.; Webb, et al. (2005). "The University of New South Wales Extrasolar Planet Search: methods and first results from a field centred on NGC 6633"

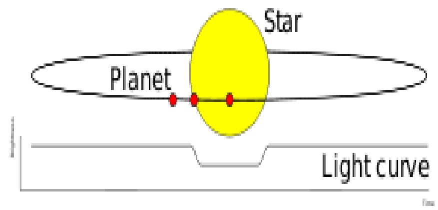

Figure 2: Transit method of detecting extrasolar planets.

4.4 Transit Timing Variation Method (TTV) and Transit Duration variation method (TDV)

If an exoplanet has been located through the use of the transit method, than variations observed in the timing of the transit can provide an extremely sensitive method capable of detecting additional planets within the system with sizes potentially as small as the Earth. Transit duration variations accounts for the amount of time a transit takes and may hint at the existence of an exomoon.

4.5 Orbital Phase Reflected Light Variations

Giant planets with short periods and relatively close orbits around their parent stars will tend to undergo reflected light variation due to their shift in phases from full to new and back again (Similar to that of the Moon). Since telescopes are not able to resolve a planet from its star, the brightness of the host star seems to vary over each orbit in a periodic manner thus revealing the existence of an orbiting exoplanet. The main advantage of this method is that, unlike the transit-method, it does not require the planet to pass in front of the disk of the star and is largely independent of the orbital inclination of the planets orbit. Additionally, the produced phase function of the detected giant planet is also a function of the planet's thermal and atmospheric properties. The first planets discovered by this method are KOI 55.01 and 55.02, found by Kepler.[10]

4.6 Gravitational Microlensing

Gravitational microlensing is produced when the gravitational field of a star behaves like a lens, thus magnifying the light of a distance background star. This effect only occurs when the two observed stars are almost perfectly aligned. These lensing events are extremely short lived, only lasting for weeks or days due to the relative motion of the two stars and our planet Earth. Over the past ten years, more than a thousand such events have been observed. If the foreground lensing star contains an orbiting planet, then the gravitational field of that planet is able to produce a detectable contribution to the observed lensing effect. For the detection of an exoplanet using this method, a very improbable alignment is required and so a tremendous number of distance stars must be continuously monitored in order to identify planetary microlensing contributions at a reasonable rate. This method is most heavily applied in a direction towards the center of the galaxy due to the relatively large number of background stars provided. This method was first proposed to look for exoplanets by astronomers Shude Mao and Bohdan Paczynski of Princeton University in 1991. Detection of exoplanets using gravitational microlensing dates back to 2002, when a group of Polish astronomers developed a workable technique to locate exoplanets. Since then, at least four confirmed exoplanets have been detected using microlensing. As of 2006, this was the only method capable of detecting planets with Earth-like masses.[11] One of the major disadvantages of using this method is that follow-up observations of detected planets are for the most part impossible. This is due to the fact that the detected exoplanets are typically several kilo parsecs away and the lensing cannot be repeated because the chance alignment never occurs again. Despite this weakness, gravitational microlensing, if applied to enough background stars, should eventually reveal how common earth-like

[10] Charpinet, S. and Fontaine, G. and Brassard, P. and Green, EM and Van Grootel, V. and Randall, SK and Silvotti, R. and Baran, RH and Kawaler, SD and others (2011). "A compact system of small planets around a former red-giant star"

[11] J.-P. Beaulieu; D.P. Bennett; P. Fouque; A. Williams; M. Dominik; U.G. Jorgensen; D. Kubas; A. Cassan; C. Coutures; B. Paczynski (2006) and others. "Discovery of a Cool Planet of 5.5 Earth Masses Through Gravitational Microlensing".

planets are in the galaxy.

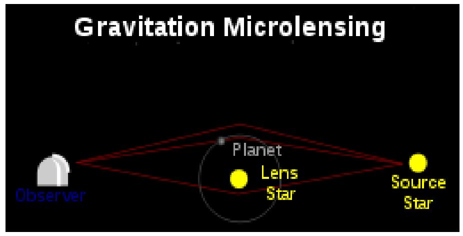

Figure 3: Gravitational Microlensing

Observations using gravitational microlensing are typically performed by utilizing networks of robotic telescopes. In addition to the NASA/National Science Foundation-funded OGLE (Optical Gravitational Lensing Experiment), the Microlensing Observations in Astrophysics (MOA) group is working to perfect this approach. The PLANET (Probing Lensing Anomalies NETwork)/RoboNet project allows for nearly continuous coverage of the sky by a world-spanning telescope network that provides the opportunity to detect microlensing contributions from planets with masses as low as Earth. This strategy was successful in detecting the first low-mass planet on a wide orbit, designated OGLE-2005-BLG-390Lb.

4.7 Direct Imaging

As mentioned above, planets serve as faint sources of light compared to their parent stars and any of this light emitted from the planet is typically lost in the glare of its star. This makes direct imaging extremely difficult but not impossible. In fact, several projects equip their telescopes with planet-imaging-capable instruments. The projects include, but are not limited to: The Gemini Telescope (GPI), the VLT (SPHERE), and the Subaru telescope (HiCiao). Up until approximately 2010, telescopes were only able to directly image exoplanets under extraordinary circumstances. Such conditions typically involved especially large and hot planets that were widely separated from their parent stars. During the year 2010, a team from NASAs Jet Propulsion Laboratory demonstrated that a vortex coronagraph could potentially enable small scopes to directly image planets by directly imaging previously imaged HR 899 planets using just a 1.5 meter portion of the Hale Telescope.[12]

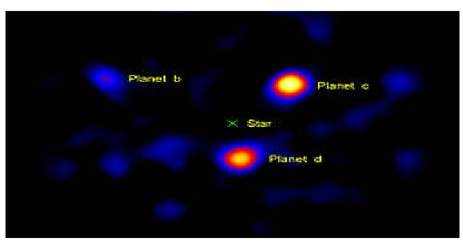

Figure 4: Direct image of exoplanets around the star HR8799 using a vortex coronagraph on a 1.5m portion of the Hale telescope

4.8 Astrometry

This method is comprised of the precise measurement of a star's position in the sky and the observation of how that position changes over a certain period of time. If the star being observed contains an orbiting planet, then like previously mentioned, the gravitational influence of the planet will cause the star to move in a tiny elliptical orbit. Thus the star and its planet are actually orbiting around their mutual center of mass, or barycenter. Due to the enormous ratio of the stars mass to that of the planet, the mutual center of mass typically lies within the radius of the star.

[12]"msnbc.com, "Technology Science and Space"

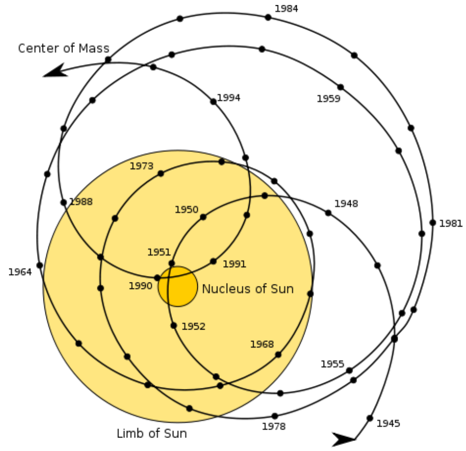

Figure 5: Motion of the center of mass (barycenter) of solar system relative to the Sun.

4.9 Eclipsing Binary Minima Timing

In the case where a double star system is aligned such that, from the perspective of the Earth, the stars pass in front of each other in their orbits, the system is then referred to as an eclipsing binary star system. The time when the minimum amount of light is observed, during which the star with the brighter surface area is at least partially obscured by the disc of the other star, is called the primary eclipse. Approximately half an orbit later, the secondary eclipse occurs during the instance when the star with the brighter surface area obscures some portion of the other star. These observed times of minimum light constitute a time marker on the system, similar to the pulses observed from a pulsar. If a planet is present in circum-binary orbit around the binary stars, these stars will be offset around a binary-planet center of mass. While these stars are displaced by the planet back and forth, the times of the eclipse minima will tend to vary in a periodic way (i.e. late, on time, early, on time, etc). This periodicity is one of the most reliable methods of detecting exoplanets around close binary systems.[13]

4.10 Polarimetry

When light is given off by a star, it is considered to be un-polarized (meaning that the direction of oscillation of the light wave is completely random). However, if the light is reflected off the atmosphere of a nearby planet, the light waves will interact with the atmospheric molecules and become polarized. If one analyzes the polarization of the combined light of the planet and its parent star, one can detect the presence of an atmosphere on an exoplanet and potentially detect an exoplanet itself.

4.11 Communication

Although this area of astrobiology is quite controversial, research on communication with extraterrestrial intelligence is being conducted throughout the globe. This research primarily focuses on composing and deciphering messages that could theoretically be understood by another technological civilization. Attempts at communicating with extraterrestrials have included the broadcasting of mathematical languages, pictorial systems such as the Arecibo message, and computational approaches to detecting and deciphering natural language communication. The SETI program utilizes both radio and optical telescopes to search for deliberate signals that would have been emitted by extraterrestrial intelligence. While some scientists strongly advocate for the continual transmission of messages to outer space, some scientists, such as Stephen Hawking, advise against it, suggesting that aliens might simply raid Earth for its resources.

[13] Doyle, Laurance R., Hans-Jorg Deeg, J.M. Jenkins, J. Schneider, Z. Ninkov, R. P.S. Stone, J.E. Blue, H. Gtzger, B, Friedman, and M.F. Doyle (1998). "Detectability of Jupiter-to-brown-dwarf-mass companions around small eclipsing binary systems".

5 The Kepler Spacecraft

The Kepler spacecraft is an American space observatory with the objective of discovering Earth-like planets in orbit around other stars. This spacecraft, named after Johannes Kepler, was launched in March 2009 with an expected mission lifetime of at least 3.5 years. [14] The Kepler mission has been designed to survey a portion of our sector of the Milky Way galaxy with the goal of discovering Earth-size planets in or near the habitable zone. Kepler will also be used to determine approximately how many of the billions of stars in our galaxy have such planets. The Kepler satellite relies solely on its photometer that continually monitors the brightness of over 145,000 main sequence stars in a fixed field of view. [15] This data is then analyzed to detect the periodic dimming of the emitted starlight caused by exoplanets transiting in front of their parent star.

Figure 6: Kepler Satellite

By applying the transit method to scan hundreds of thousands of stars in the constellation Cygnus for planets, it is hoped that by the end of its mission, Kepler will have collected enough data to reveal planets even smaller in size than the Earth. On February 2, 2011, the Kepler team released a list of 1,235 exoplanet candidates, including 54 planets that could potentially lie in the habitable zones of their parent stars. As of now it appears that there are three major types of exoplanets; gas giants, hot-super-Earths, and ice giants. However, the goal of Kepler is to now locate terrestrial planets (half to twice the size of the Earth) that are preferably located in the habitable zone where liquid water and life could potentially exist or theoretically form over time. Another benefit of the Kepler mission is that it will allow us to determine how common or how unique our own solar system is in the context of our galaxy.

[14] BBC Staff (7 March 2009). "Nasa launches Earth hunter probe". BBC News. http://news.bbc.co.uk/2/hi/science/nature/7926277.stm. Retrieved 2009-03-14

[15] AS Staff. "Meeting Program and Block Schedule". American Astronomical Society. http://aas.org/node/651. Retrieved 2011-04-20.

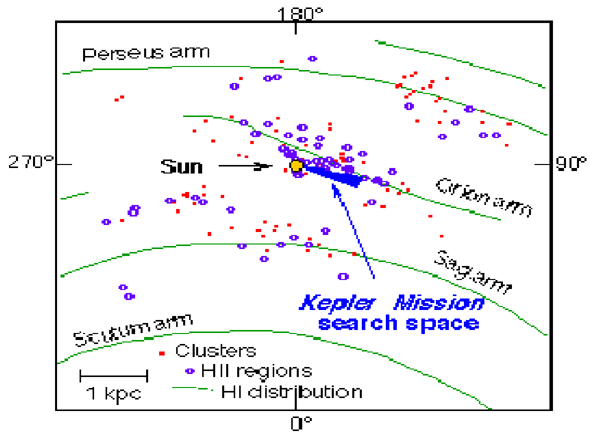

Figure 7: The figure shows what we believe to be the local structure of our Galaxy, the Milky Way. The stars sampled are similar to the immediate solar neighborhood. Young stellar clusters, ionized hydrogen (HII) regions and the neutral hydrogen (HI) distribution define the arms of the Galaxy

In order to accurately locate planets in the habitable zones of their stars, Kepler is looking for a time between transits of about 1 Earth year. In order to reliably detect a sequence, it is necessary to record four transits, and so the duration of the Kepler mission is required to be at least 3.5 years. If this mission is kept running past this time marker than it will become possible to detect planets even smaller and more distant in orbit than the Earth.

The Kepler Instrument is a specially designed 0.95-meter photometer. This telescope has a substantially large field of view of 105 square degrees (approximately the area of your hand held at arms length). In comparison, the field of view of most telescopes is typically less than 1 square degree. Kepler's large field of view is necessary to observe a large number of stars. The diameter of the telescope is required to be large enough so that it reduces the noise from photon counting statistics. This enables it to accurately measure the small change in brightness of an Earth-like transit. The design of the entire system has been constructed such that the combined differential photometric precision over a 6.5 hour integration is less than 20 ppm (parts per million) for a 12th magnitude solar-like star. However, these values are the result of a worst-case scenario. In reality, the central transit of the Earth crossing the Sun lasts about 13 hours and roughly 75% of the stars older than 10 billion years are less variable than our Sun on the time scale of a transit. The photometer of Kepler must be oriented in space in order to obtain the proper photometric precision needed to reliable observe an Earth-like transit while also avoiding disturbances caused by day-night cycles, seasonal cycles, and atmosphere perturbations.

5.1 Expected Results

Upon completion of the Kepler mission, it is expected that about 50 planets with similar sizes to Earth will be detected and roughly 185 planets with a size of 1-1.3 Re will also be identified with one year orbits. Other expected results include the detection of around 135 inner-orbit giant planets as well as 30 outer-orbit giant planets. The densities for several of these planets are also expected to be calculated.[16]

Conclusion

The field of astrobiology is a continually expanding area of science with many new discoveries being made on a daily basis. With the constant improvement of exoplanet detection methods and advancements of projects, such as Kepler, the search for Earth-like planets outside our solar system is growing at a rapid rate. The Astrobiology Science and Technology Instrument Development Program (ASTID) has recently approved 15 proposals for funding, including mission concept studies for small payloads and satellites. These newly funded projects were chosen out of 97 different proposals submitted to NASA. These projects include astrobiology investigations on future planetary

[16] http://kepler.nasa.gov

exploration missions, prototype artificial-gravity platforms for small satellites and planetary landers, nanosatellites designed to search for Earth-like exoplanets, and many others.

As more and more planets are uncovered, astrobiologists are eager to analyze satellite pictures, spectrum data, and any other evidence that may hint at planets that could potentially harbor life. With the right tools, scientists working in the field of astrobiology may one day be able to detect, for the first time in history, the existence of life beyond Earth.

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