Life On Mars: Detection, Habitability, and Biosignatures

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Abstract

Astrobiology is the study of life outside Earth. The quest for life beyond the earth requires an understanding of life and the nature of its supportive environments, as well as of the planetary and stellar processes. One of the first steps in searching for life outside Earth is to find an exoplanet that presents a supportive environment for all sides of life by various methods. When such a planet is detected, the scientific challenge is to determine how it can accommodate life through the great distances of interstellar space. Scientists evaluated and restricted the conditions of habitability at each of these stages in their research on Mars' terrestrial analogues, surface geochemistry, and the likelihood of organic and inorganic biosignature conservation. Studying these analog environments provides crucial information for a better knowledge of past and current mission results, as well as for the design, selection, and planning of future Mars exploration missions.

Keywords: Habitable zones, Mars, Life, Earth, Microorganisms, Habitability, Detection, Biosignatures

I. Introduction

When we hear the term Astrobiology the first thing that comes to our minds is space and extraterrestrial life; however, astrobiology is a scientific field that not only discusses extraterrestrial life but also focuses on the environmental factors that enabled life on Earth. The Universe contains an infinite number of planets; nevertheless, not all of them are habitable.

Scientists refer to the area in which a planet lies and contain the factors necessary for life (like water and suitable temperature) as habitable zone. Habitable zones differ from a star to another due to several factors like stars' sizes.
Mars is inevitable when discussing astrobiology and extraterrestrial life. Mars, being the closest to Earth, was the first place that scientists looked for life. However, Mars isn't a perfect planet and many obstacles faced scientists, the main are the absence of oxygen (due to its thin atmosphere), absence of liquid water and the wide temperature range.
The focus of searching for life was in our solar system; however, there are many planets that lay beyond our solar system that can be habitable, these planets are called exoplanets. Detecting exoplanets has been a challenge to scientists because of their distance from Earth. Several methods for detecting exoplanets, the most important of which are radical velocity and transit methods, have been developed, and they all rely on AI. But how to predict life on a distant planet without visiting it? To address this problem scientists, use scientific models.

i. Factors that allowed life to emerge on Earth:

Many factors allowed life to emerge on Earth among them are water, atmosphere, ozone layer, location in the universe, magnetosphere, the moon, distance from the sun, and temperature. We will explain two of these factors in detail.

1) Water:

Water is the second most abundant molecule in space. Water ice is widely distributed in space and can be observed by many telescopes. Distant galaxies have water proving that water was already present in the early universe. Our solar system is rich in water in different places and forms such as: in the poles of telluric planets (e.g. Earth and Mars) or small celestial bodies like comets (contain a significant fraction of water). In addition, liquid water oceans may be present under ice crusts of several moons of outer planets (e.g. Jupiter & Saturn).[1]

There are multiple hypotheses for the origin of water on Earth including planetary cooling (when the planet cools, the outgassed components were trapped in an atmosphere of adequate pressure to condense them into liquid water); extraplanetary resources such as asteroids, comets, and water-rich meteoroids; leakage of water stored in hydrate minerals, and volcanic activity (water vapor resulted from eruption condenses and turn to rain). [2]

2) Atmosphere:

The atmosphere is one of the most important factors that allowed life to emerge on Earth. Its main importance is the presence of oxygen which is crucial for all kinds of living organisms. Other importance of Earth's atmosphere includes: blocking some of the Sun's harmful radiations such as ultraviolet rays (which is done by the ozone layer); moderating Earth's temperature and weather; maintaining the water cycle (when water evaporates, it condenses in the atmosphere) and burning down asteroids thus reducing their impact when hitting Earth's surface.

Most scientists describe 3 phases in the evolution of Earth's atmosphere:

1at phase: Earth's original atmosphere isn't like today's atmosphere. It was probably just hydrogen and helium and it was extremely hot with hydrogen and helium molecules moving too fast. Their speed made them escape Earth's gravity and drop to space.

2nd phase: Earth's second atmosphere was originated from Earth itself; it came from volcanoes. The volcanoes released water vapor (H_2O), carbon dioxide (CO_2), and ammonia (NH_3).

3rd phase: most of the CO2 dissolved in the oceans. A simple form of bacteria developed so that it could live in water on Sun and CO2 and produce oxygen as waste material. Meanwhile, the ammonia molecules were broken by sunlight into nitrogen and hydrogen. This hydrogen, due to its low density, rose to the top of the atmosphere and dropped into space leaving today's known atmosphere that primarily contains nitrogen, oxygen, and carbon dioxide. [3]

II. Habitability of Mars

At the end of the 20th century, scientists have used the term "stellar habitable zone" to identify which planets are mostly habitable [4]. It simply states that any planetary surface that can allow the exitance of liquid water is habitable according to the distance from a star and the atmospheric pressure [4][5]. Each habitable zone differs from one star to another according to the star's mass and temperature [5]. For example, if a star has a massive mass and high stellar effective temperature, its habitable zone will mostly be located farther out from the star, and if a star has a small mass and low stellar effective temperature, its habitable zone will be closer to the star as shown in fig (1)[5].

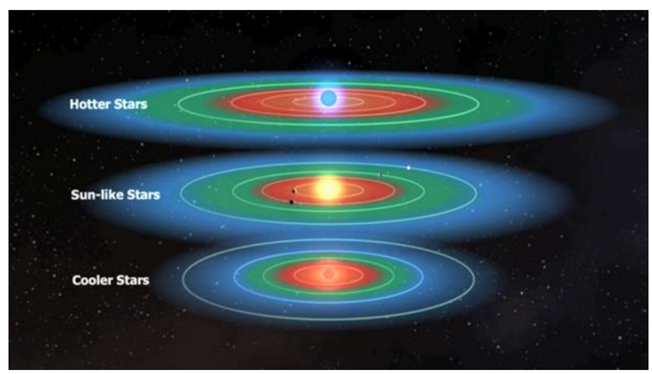


Figure 1:Different habitable zones of stars that have different stellar temperature.

To calculate any habitable zone of any star, the radius of a planet (R_p), the radius of the star (R_s), the distance between the star and the planet (d), the temperature of the star (T_s), and the area of the star should be known (A) [6]. By gathering all this data, the Stefan–Boltzmann law can be used to calculate the predicted temperature of the planet, and from it, we can know the range of the habitable zone. The Stefan-Boltzmann law states that:

$$P = \sigma * A T^4$$

, where P is the power emitted from the star and σ is Stefan–Boltzmann constant [6]. If the power emitted from the star, which the planet absorbs, is assumed to be equal to the emitted power of the planet, this assumption gives:

$$\sigma 4\pi R_s^2 * T_s^4 * (\pi R_p^2/4\pi d^2) = \sigma 4\pi R_p^2 * T_p^4$$

$(\pi R_p^2/4\pi d^2)$ is the radiated power from the star over a spherical area $(4\pi d^2)$ that is absorbed by the cross-section area of the planet (πR_p^2) [6]. After simplifying the previous equation, the temperature of the planet can be calculated by the following equation:

$$T_p = T_s * (R_s/2d)^{0.5}$$

Our sun's habitable zone has been estimated to be 0.5 AU as close to the sun and 3 AU as far from the sun [6]. this was calculated by using the sun's radius and temperature. In this range of the habitable zone, Mars (1.52 AU away from the sun) and Venus (0.72 AU away from the sun) are considered to be located at a very optimistic position [6]. However, by using a range of water temperatures (from 373K to 273K), the habitable zone was reduced to approximately 0.52 AU to 1.04 AU, where Mars is not included [6].

III. From Earth to Mars

one source of life on Mars could be Earth. It's far feasible that sun winds placing, ejecting, and propelling microbe-laden dust and particles in the stratosphere and mesosphere, and microbes residing in rock ricocheted into space from Earth with the aid of meteor strikes, have again and again infected Mars and distinctive planets and the opposite is correct. Moreover, due to tropical storms, monsoons, or even seasonal upwellings of columns of air, microbes, spores, fungi, (at the side of the water, methane, and different gases) may be transported to the stratosphere and mesosphere wherein they may continue. As it was proposed, solar winds and photons must disperse place-borne organisms during the cosmos. consequently, it may be really assumed that microbes not handiest flourish in the troposphere, however, while lofted into the stratosphere and mesosphere many continue to be feasible and may then be blown into space by means of effective sun wind in which they can stay. Even although innumerable meteorites collapse upon striking Earth's top atmosphere, those at the least ten kilometers across will punch a hollow within the surroundings and hold their descent. at the same time as meteors this duration or massive strike the ground, tons of dirt, rocks, (microbes, fungi, algae, and lichens can be, too), and other debris may be propelled over 100 km above the planet and ejected into space [7].

i. Life on Mars

Spacecraft that landed or crashed on Mars could also transfer life from Earth to Mars. for example, after sterilization, between 300 to 540 different colonies (typically) alongside thousands of organisms, including fungi, vegetative microorganisms, Bacillus, and coccigram-positive, and micro-organisms of the genus Streptococcus and Corynebacterium Brevibacterium survived the outer space of Mars Vikings Landers and another spacecraft. of non-cultivated species, and the abundance of germs and fungi even growing inside the equipment, the number of survivors is unknown. Bacilli are still reproductive and tolerate long-term exposure to deep radiation in areas like Mars. Many species of Micrococcus have also escaped extinction by living sterilized and living on the Earth's crust, simultaneously with several traces of staphylococcus and Corynebacterium, tolerating similar conditions (Corynebacterium) created by Martian habitats and cannot be eliminated from space. Streptococcus maybe a few other species that oppose NASA's sterilization efforts and remained active after 30 months. As a result, microorganisms could have been present in all shipments to Mars. For instance, because it was detected using NASA's Ultraviolet Imager aboard polar spacecraft, a magnetosphere explosion was caused by coronal mass ejection (CME) sequences and strong solar rays. As a result, polar regions had enough pressure to push oxygen, helium, hydrogen, and other gases from the Earth's surface into the atmosphere. typically, the weight is around or three nano pascals. while CME hit, it jumped into 10nano pascals. therefore, it is expected that other nutrients in the air, mold, moss, and algae have arrived at Mars to replicate themselves.

ii. Microorganisms on Mars

Many researchers have found that the proliferation of species, including microorganisms, algae, mold, and mildew can continue to exist in an artificial environment such as Mars. these survival rates increase when supplied with water or protected by rock, sand, or gravel. It was discovered that the Bacillus subtilis survived conditions of UV irradiation performed by Martian, while it is suggested that cyanobacteria collected on cold and warm islands survived “conditions like Mars including atmospheric composition, gravity, changing humidity (full and dry conditions) and strong UV rays.” It has been reported that six subspecies of the genus Carnobacterium collected in a permafrost building in northeastern Siberia - considered analogs of the Mars underground and nine additional species of Carnobacterium were present all capable of thriving and growing under conditions like Mars. In another case, four types of methanogens (Methanosarcina barkeri, Methanococcus maripaludis, Methanothermobacter wolfeii, Methanobacterium formalism) survived exposing low-pressure conditions. Cyanobacteria are also tolerant of Mars conditions. Akinetes exposed (dormant cells are formed by filamentous cyanobacteria) in outdoor conditions, including demolition periods, extreme temperatures (-80 to 80 ° C), and UV rays (325-400 nm), and showed high levels of efficiency in these places like Mars. Eukaryotes (fungi, moss) are also survivors. it was reported that microcolonial fungi, Knufia perforans and Cryomyces antarcticus, and Exophiala jeanelmei (a type of black yeast), survived, designed, and showed no evidence of subsequent stress prolonged exposure to conditions such as thermo-physical Mars. After developing the dried colonies of Antarctic cryptoendolithic black fungus Cryomyces antarcticus and exposure 16 months mimicking scenarios like Mars on Earth's space station determined that "C.C. The antarcticus was able to tolerate the combined stress of external variability substrates, space, and conditions such as Mars Survival, DNA, and structural stability. Martian world radiation is rated at "0.67 millisieverts a day”. This is much lower and deeper under radiation tolerance levels of various prokaryotes and simple eukaryotes, including resistant fungi radiation, doses up to 1.7 × 104Gy. Fungus, moss, and many microbes are species they are attracted to and thrive in highly radioactive environments. Mold and radiation tolerance bacteria will seek out and grow in radiation sources that act as a source of energy of metabolism. Or their DNA is damaged by radiation levels in addition to their tolerance levels, and they can easily fix these genes due to the genes with repair functions [7].

ii. Lichens

Lichens are consisting of a symbiotic relationship involving algae/cyanobacteria and fungi, the latter of which is responsible for the lichens' thallus, mushroom shape, and fruiting bodies. The specimens were observed on Mars andidentified by experts as lichens closely resemble Diabetes baeomyces, a fruticose lichen belonging to the Icmadophilaceae family characterized by stalks that may grow to 6 mm. Dibaeis baeomyces have been found growing on rocks, in the desert sand, dry clay, and in the arctic [7]. Scientists took photos on Mars that might be lichens, as shown in figure 3 and made a comparison between these photos and the others on Earth, as shown in figure 2.

Figure 2: Terrestrial Lichens, Ranging from 2 mm to 6 mm in size.

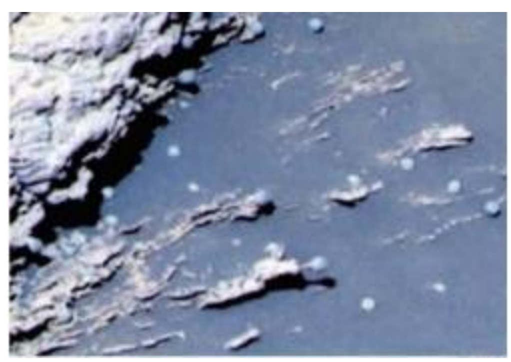


Figure 3 : Most experts agreed these may be lichens. The average size of these lichen-like specimens is estimated to be 2 mm to 7 mm and are like terrestrial lichens. However, if these

are living organisms, or unusual sediments fashioned by the alien environment of Mars is unknown [7].

The compact morphological structure of C. gyrosa (kind of lichens), together with its thick cortex and cortex acts as an endogenous protective defend against UV radiation. The presence of solar-screening pigments in diverse lichen species is set up amongst those dwelling in Arctic habitats and excessive mountain regions. For example, the cortex protects R. geographicum from the harsh environmental characteristics of high mountain areas whilst meteors strike Earth's atmosphere, they may be subjected to extremely high temperatures for only some seconds. If of sufficient length, the interior of the meteor will stay surprisingly cool. The interior may also never be heated above 100°C while spores can live to temperatures of over 250°C. Mars has a very thin atmosphere. consequently, many species of microbe have developed the ability to survive a violent hypervelocity effect and excessive acceleration and ejection into space, the frigid temperatures and vacuum of an interstellar environment, the UV rays, cosmic rays, gamma rays, and ionizing radiation they could stumble upon, and the descent via the surroundings and the crash touchdown onto the surface of a planet [7].

iv. BIOMEX experiments

To do some BIOMEX experiments, many preflight checks had been completed to figure whether the chosen samples are able to face up to severe conditions close to space and Martian environments. After a group of experiments on Mars-like regolith and desiccation exams, the organisms were exposed to experiment Verification exams (EVTs) and medical Verification exams (SVTs). Among (EVTs) exams, vacuum, low-strain Mars-like CO2 surroundings, extreme temperature cycles from ways under zero to more than 40C, and UVC irradiation were applied. The (SVTs) experiments had been conducted inner hardware with conditions that approached the ones of the gap surroundings at the ISS. The results explained that the lichen C. gyrosa exhibits high resistance and survival capacity. Neither Martian atmosphere and surface UV climate combinations nor LEO vacuum conditions induce a significant decrease in the activity of lichen after exposure for 120 h. It is important to emphasize that in our experiment the lichen thalli were exposed to simulated Mars and real space conditions. Many the chosen archaea, bacteria, and heterogenic multilayered biofilms formed via many species had been observed to be the most resistant to simulated or direct space and Mars-like conditions. Less resistance and a considerably lower cellular number and power regarding the Mars-like surroundings were proven for multicellular lifestyles-forms inclusive of the examined fungus Cryomyces antarcticus and the lichens Buellia frigida and Circinaria gyrosa as some studies show that the test lichen survived the 30-day incubation in the Mars chamber particularly under niche conditions [8]. However, the photobiont was not able to photosynthesize under the Mars-like conditions, which indicatesthat the surface of Mars is not a habitable place for C. gyrosa [10]. From my point of view, the photos that were taken were just sediments, were not lichens. The Results so far indicate that present Mars seems to be habitable for archaea and bacteria over longer timescales [9].

IV.Machine learning methods

About 4600 million years ago our solar system was formed. We know this from the study of meteorites and radioactivity. But you have ever contemplated a question, "Are we alone?" Or "Is there life beyond the earth?", This is the topic of exoplanets which are planets beyond our solar system, these planets come in a wide variety of sizes and orbits. Some are ginormous planets, some are rocky, some are icy and hugging close to their stars. But how do scientists detect whether there are exoplanets? It's not a simple task to detect exoplanets. We may have imagined life in books and films on other planets for centuries, but it has been a recent phenomenon to detect actual exoplanets. Planets emit very little or no light on their own so subsection I details methods for detecting exoplanets. While subsection II analyzes the advantages and drawbacks of each of these methods [11].

i. Exoplanets detection methods

Artificial intelligence (AI) and advanced vision technologies are being used to strengthen instrument capabilities and expand possibilities for detecting exoplanets.[12] Since then, different methods have been derived to detect exoplanets, with the two most prolific radial velocity and transit methods. Other methods like direct imagery, timing and gravity are not as prevalent, but have unique advantages and play an important role in searching for exoplanets. [13]

ii. The Radial Velocity Method

The radial velocity (Doppler spectroscopy) method was one of the first methods of discovering exoplanets, with scientists using it to discover a large number of planets since 1988. It searches for exoplanets by using stellar wobble, or the small orbit of a star around its star-planet center of mass. The visible light emitted by a star is split up into a rainbow by astronomers. This is referred to as the star's spectra, and the gaps between the normally smooth bands of light aid in determining the elements that comprise the star. However, if a planet orbits the star, the star wobbles back and forth slightly. As the star wobbles slightly away and toward us, the lines in the spectra will shift slightly towards the blue and red ends of the spectrum. This is caused by the blue and red shifts of the planet's light (FIG 4) [14].

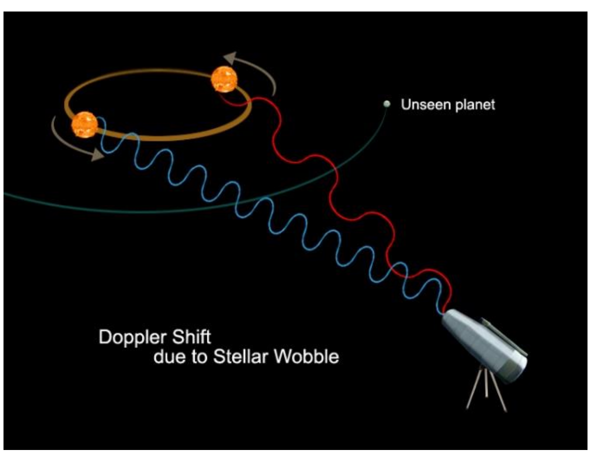


Figure 4: Radial Velocity

This wobble, though very small, can be measured as a variation in radial velocity by modern spectrometers such as the European Southern Observatory's (ESO) High Accuracy Radial Velocity Planet Searcher (HARPS) spectrometer at the La Silla Observatory in Chile, which has observed more than 451 wobbles during its Guaranteed Time Observations (GTO) planet search program. Scientists can determine the velocity of the star v* and the period of the orbit T by observing this wobble. With an estimate of the star's mass M* by spectral type and the inclination of the orbit j(orbit) by stellar photospheric absorption lines, the star's velocity can be expressed as follows:

$$v_\star = \frac{m_p sin(i_{orbit})}{M_\star + m_p}\sqrt{\frac{G(M_\star + m_p)}{a}}$$

where M(p) denotes the planet's mass and a denotes the radius of an assumed circular orbit. Kepler's third law of planetary motion also provides the period:

$$T = \frac{4\pi^2 a^3}{GM_{sys}}$$

where the mass of the system M(sys) = M* + M(p). The orbit radius of the planet is unknown, but can be solved for by combining Equation 1 and Equation 2:

As a result, scientists can determine the mass of an orbiting planet indirectly. Scientists have had great success detecting planets using the radial velocity method, especially when the planet's mass was large in comparison to the mass of the star, causing an easily detectable stellar wobble. This method, however, has limitations. Because stellar wobbles are typically small, radial velocities are difficult to observe at great distances and are thus only used to study nearby stars. Furthermore, false signals are

$$v_\star = \left(\frac{2\pi G}{T}\right)^{1/3} \frac{m_p sin(i_{orbit})}{(M_\star + m_p)^{2/3}}$$

common when observing multi-planet and multi-stellar systems where the system's center of mass is unknown and long, continuous observations are required to distinguish stellar bodies. Despite these difficulties, the radial velocity method remained the most common method of detecting exoplanets until

2014, when it was surpassed by transit photometry method [15].

vi. Transit method

The transit method has now surpassed radial velocity searching in several new planets since it was first used in the mid-2000s[16]. Planets don't emit light, but host stars they orbit do. Taking this into consideration, NASA scientists conceived the Transit method, in which a digital-camera-like technology is used to detect and measure tiny dips in a star's brightness as a planet crosses in front of a host star, the light from the star dips very slightly in brightness. By detecting these incredibly tiny dips in brightness, scientists can confirm that a planet exists as shown in figure 5. By observations astronomers can calculate the ratio of a planet's radius thereto of its star.

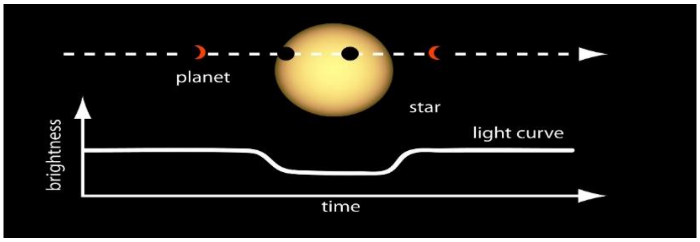


Figure 5: transit method

By changing the stellar flow F* and estimating the stellar radius R* of other measurements, the radius of the planet Rp can be determined [17] 2002.

$$\frac{F_\star - F_{\star,transit}}{F_\star} = \frac{\Delta F_\star}{F_\star} = \left(\frac{R_p}{R_\star}\right)^2$$

Figure 3 planet Radii in the Habitable Zone

Over multiple observations, the period T can also be observed, which enable us to estimate the radius of planetary orbit using the third law of Kepler:

$$a^3 = \frac{M_{sys} G T^2}{4\pi^2}$$

Although transit photometry has been extremely successful in discovering large numbers of exoplanets through missions, such as the Kepler mission, which identified three hundred forty planetary systems with 851 planets that were validated for more than 99%, it still has limits. Whilst transit surveys can scan large areas of the sky that contain thousands of stars at once, they can only observe planets that intersect astronomer and star perfectly, thus lacking many stellar systems which could contain planets of interest. False positives are also common when small variations in stellar brightness occur due to natural phenomenon such as pulsations of red giant branch stars, and studies have found that up to 35% of transit candidates turn out to be false-positives [18]. On balance, the transit photometry method has been used effectively in missions with the 2005 Spitzer Space. Also, there are other opinion says that the instruments required for this minor blip seem to be very susceptible. You can see how difficult it is to detect a planet from light-years away if you can imagine the dip in light from a massive searchlight when it crosses a small ant. Another drawback of the transit method is the fact that the distant solar system must be in a preferable angle to our own Earth perspective, If the angle of the distant system is only slightly askew, no transits will happen![19]

vii. Planetary detection Less prolific methods

Other methods for detecting exoplanets, in addition to radial velocity and transit photometry, including direct imaging, timing, and gravitational microlensing. In direct imaging, scientists use infrared imaging to examine the thermal radiation of exoplanets. Typically, we can only observe large, hot planets both close to and far from their stars, and imaging Earth-like planets necessitates high levels of optothermal stability. Timing methods take advantage of niche properties of certain exoplanets and can involve pulsars (neutron stars) that emit radio waves on a regular basis, changes in eclipsing binary minima that detect planets far from their host star [20], and transit timing variations caused by interplanetary gravitational pull [21], this method is also limited in applicability since so few exoplanets acquire those characteristics. Finally, gravitational microlensing examines the marginal effect of a planet on the gravitational lens behind a star. When a foreground star is between the observer and the source star, the foreground star magnifies the light from the source star, which allows the planet to make

an observable contribution to the lens. This method is actually more susceptible to the detection of large orbital exoplanets and is most effective for planets between the Earth and the center of the galaxy where many background stars occur, but the required gravity alignment is rare and cannot be repeated. Though these detection methods are more specialized and are not applicable to as many stars, they can give high-
detailed data compared to the methods of radial velo city and transit photometry.

iii. Analysis and Comparison of Methods

Each detection method uses different concepts of astronomy to deduce the characteristics of exoplanets. Whilst the most proficient methods to date have been radial velocity and transit photometry (FIG. 6), other methods have also been important in the search for a habitable planet (TABLE I). The radial velocity method is extremely versatile and applicable to a wide range of planets, though they must be close to the observer. The transit photometry method has observed a large number of stars, but it has a high false positive rate. direct imaging though only applicable to a small number of stars, reveals explicit, unequivocal evidence of exoplanets. Timing methods are similarly limited in their applicability, but they can provide accurate data for planets that are extremely distant. Planets with large orbital radii can be detected using gravitational microlensing, but measurement alignments are unlikely and cannot be repeated. In terms of observed properties, the transit photometry method provides the radius of an observed planet. Though all methods can be used independently, more than one technique is used to collect multifaceted data on planets of interest in the most accurate searches. The radial velocity and transit methods used on the same star can for determine mass and radius, yielding density that indicates the composition and habitability of that planet; and the transit timing can be used to validate exoplanets found through the transit photometry method in multi-planetary systems. Discovering a planet with one method can often make it easier to observe its other properties with another.[22]

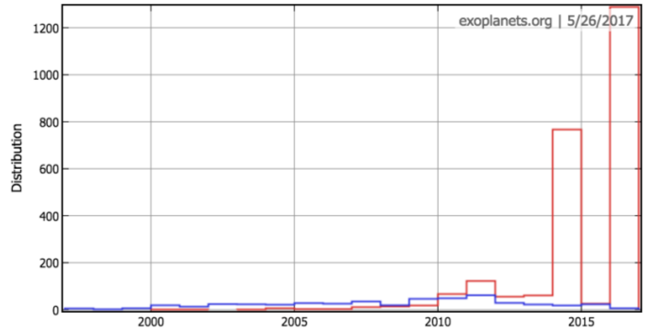


Figure 6 Radial velocity and transit exoplanetary discoveries by year through 2017. Radial velocity, blue; transit photometry, red. In 2014, the number of planets observed by transit photometry surpassed the number of planets observed by radial velocity. Figure created using exoplanets.org.

Method	Measurements	Advantages	Drawbacks	Best Case	Instrumentation
Radial Velocity	m_p, T, a	Can be used to observe many stars	Planet must be close to observer	Small cool star, large planet	Telescope spectrometer
Transit Photometry	r_p, T, a	Observe thousands of stars at once, possible atmospheric data	False positives, only observe intersecting planets	Large planet, low noise	Space Observatories (CoRoT and *Kepler*)
Direct Imaging	m_p, T, a	Detect planets with face-on orbits	Optothermal stability needed, glare	Planet close to observer, large size, large a, hot	Infrared telescope
Timing	m_p, T	Detect small planets far from observer, multi-planetary systems, accurate	Few stars	Pulsars, multi-planetary systems, binary star systems	Telescopes, *Kepler*
Gravitational Microlensing	m_p	Detect planets with wide orbits	Unlikely alignment, single trial	large a, background toward center of galaxy	Robotic telescopes (OGLE)

TABLE 1. Measurements, advantages, drawbacks, best cases, and instrumentation for the radial velocity, transit photometry, direct imaging, timing, and gravitational microlensing methods of detecting exoplanets. M(p), mass of planet; R(p), radius of planet; T, period of orbit; a, length of semi-major axis of orbit.

V. Exoplanet Hunting: Using Machine Learning to Predict Planetary Atmospheric Chemical Reaction Rates

We have known that thousands of exoplanets could host life, But the skeptic in us says “How can we make predictions about exoplanets?” Or “How can we know that these exoplanets can host life without being able to visit them or having such a limited information about them?” The answer is scientific models. Scientists use models to interpret data and explain what kinds of conditions might exist on planets that could explain their observations. Atmospheres are important potentially observable features of exoplanets, so atmospheric models are one of the most important types of models for exoplanets. Their composition can reveal biological activity as well as information about other planetary processes and events. Exoplanetary atmosphere models will aid in understanding of observations.

However, these models are heavily reliant on input parameters such as reaction rate constants or how fast species react. Unfortunately, databases of such rate constants are insufficient and only contain information for a limited set of reactions that have been studied in isolation in laboratories. These known reaction rates may not be sufficient to accurately model planetary atmospheres containing reactions with unknown rate constants or that are impractical to measure in the lab. To address this problem, Scientists applied a series of machine learning techniques to STAND-2019, an atmospheric chemical network detailed in Rimmer et. al, 2019, to explore how well machine learning can predict reaction rate this is not a substitute for actual data, but these forecast or estimated constants could help scientists to see more in the right direction. First, they use known reaction rates (FIG 7) and then feed those into an algorithm to predict reaction rates using an atmospheric chemical reaction dataset called STAND-2019, and because the model is highly dependent on the type of data given to it, it will be better at predicting things it has seen before. By determining what is in the dataset on which the algorithm is based, there are approximately six thousand reactions and 11 different types of elements, as shown in (FIG 8) As a result, the dataset is skewed heavily toward hydrogen, carbon, and nitrogen. It also includes reactants, products, variables for calculating the rate constant, and reaction flags that indicate the type of reaction.[23]

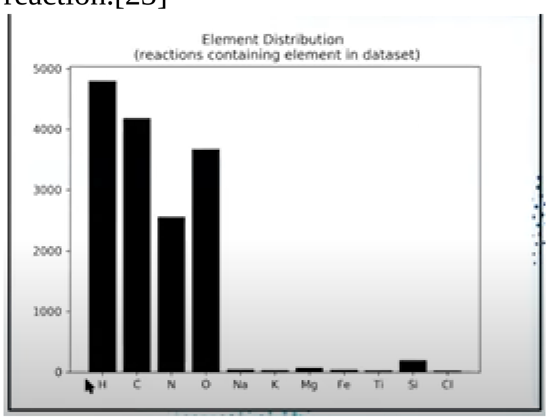


Figure 7 : Elements in data set [P. B. Rimmer and S. Rugheimer, "Hydrogen cyanide in nitrogen-rich atmospheres of rocky exoplanets," Icarus , vol. 329, pp. 124-131, Sep. 2019.]

Following that, they add useful features to the data, such as information about each reaction gleaned from chemistry knowledge. After creating features for the dataset such as reaction mass, number of species involved, and type of species involved, all of them are converted to numbers so that the algorithm can read them and use them to make predictions. But how are these features used? As a result, the entire dataset is divided into two parts: a training set (which is typically larger) and a testing set (which is smaller). In the training set, the algorithm sees both features and constants; in the testing set, the algorithm only sees features and then predicts constants based on those features. But how does this help with predicting? Scientists used the decision tree algorithm, which is part of the supervised learning algorithm family, to accomplish this. The decision tree algorithm, unlike other supervised learning algorithms, can also be used to solve regression and classification problems. The goal of using a Decision Tree is to build a training model that can predict the class or value of the target variable by learning simple decision rules from prior data (training data). As a result, it divides the data into more machine-readable sections, such as is this column less than or equal to this value. Because the values and splits are chosen at random, this algorithm performs well. The algorithm generates many of these trees using the training set, then runs the testing set through all these trees and averages the values from each tree to create the final prediction (FIG 9) [24]. Using this method can lead scientists to preliminary results, which show that the algorithm works better than using the mean of the data to predict rate constants(TABLE 2), but there is still room for improvement.[25]

RMSE (train)	RMSE (test)	R^2 (train)	R^2 (test)
3.402 +/- .162	7.472 +/- .121	0.946 +/- .008	0.748 +/- .007

Table 2: To measure how good are their prediction

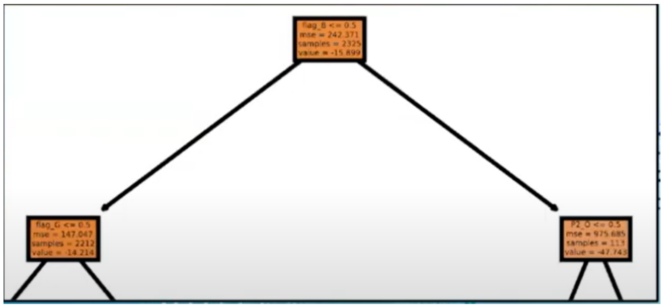
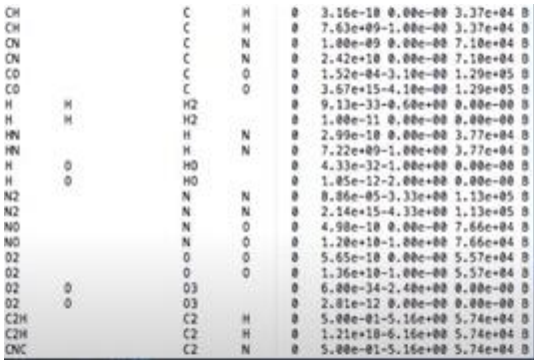


Figure 9 Decision Tree Algorithm [P. B. Rimmer and S. Rugheimer, "Hydrogen cyanide in nitrogen-rich atmospheres of rocky exoplanets," Icarus , vol. 329, pp. 124-131, Sep. 2019.]



CH		C	H	0	3.16e-10	0.00e-00	3.37e+04	8
CH		C	H	0	7.63e+09	-1.00e-00	3.37e+04	8
CN		C	N	0	1.00e-09	0.00e-00	7.10e+04	8
CN		C	N	0	2.42e+10	0.00e-00	7.10e+04	8
CO		C	O	0	1.52e-04	-3.10e-00	1.29e+05	8
CO		C	O	0	3.67e+15	-4.10e-00	1.29e+05	8
H	H	H2		0	9.13e-33	-0.60e+00	0.00e-00	8
H	H	H2		0	1.00e-11	0.00e-00	0.00e-00	8
HN		H	N	0	2.99e-10	0.00e-00	3.77e+04	8
HN		H	N	0	7.22e+09	-1.00e+00	3.77e+04	8
H	O	HO		0	4.33e-32	-1.00e+00	0.00e-00	8
H	O	HO		0	1.05e-12	-2.00e+00	0.00e-00	8
N2		N	N	0	8.86e-05	-3.33e+00	1.13e+05	8
N2		N	N	0	2.14e+15	-4.33e+00	1.13e+05	8
NO		N	O	0	4.98e-10	0.00e-00	7.66e+04	8
NO		N	O	0	1.20e+10	-1.00e+00	7.66e+04	8
O2		O	O	0	5.65e-10	0.00e-00	5.57e+04	8
O2		O	O	0	1.36e+10	-1.00e-00	5.57e+04	8
O2	O	O3		0	6.00e-34	-2.40e+00	0.00e-00	8
O2	O	O3		0	2.81e-12	0.00e-00	0.00e-00	8
C2H		C2	H	0	5.00e-01	-5.16e+00	5.74e+04	8
C2H		C2	H	0	1.21e+18	-6.16e+00	5.74e+04	8
CNC		C2	N	0	5.00e-01	-5.16e+00	5.74e+04	8

Figure 8: Chemical reaction rates they know

i. A Machine Learning Approach to Forecasting Weather on Mars

After all that, does this mean that Mars is unhabitable? A destructive Cosmic event could at any given moment completely erase all life on Earth. Extinction may be inevitable as well as pressure on earth's biosphere. Going beyond our domain, far beyond the sun and the Earth's planet, Mars can be a means of reducing the risk of human extinction. Despite this high goal, hostile Martian weather conditions vary considerably from those on earth and it would be inestimable for successful colonization to predict these conditions. In particular, the extremely wide temperature range (20°C to -73°C) is a significant barrier to implementing human infrastructure. Traditional weather prediction techniques used on Earth, such as numerical weather prediction (NWP), are extremely computationally intensive and, due to the volatile physical conditions of the Earth's atmosphere, are not always stable. Beyond that, NWP cannot be easily applied to forecast Martian weather. To overcome this barrier, supervised machine learning—a method resistant to an incongruity of atmospheric conditions that leads to uncertainties of NWP—is ideal for the Martian atmosphere, which is even less understood. The Mars' Gale Crater weather data has been collected and available via their Planetary Data System by a NASA Curiosity Rover. To predict a mean temperature using Curiosity's data two types of machine learning algorithms will be implemented: linear regression and artificial neural networks. These paradigms have been selected due to the ability of each to take into account the mixture of nonlinear and linear weather reactions. The weather data will be used in the two models of ~3 Mars years to predict ~1 year of test data. The medium and medium absolute errors are calculated, and the models are compared. for the mean temperature prediction [7].

In conclusion, not all planetary surfaces in the habitable zone have a hospitable environment, and there might be worlds outside the habitable zone that could have a hospitable environment [4]. From what is known from the collected reports, there was some evidence collected from instruments in orbit and on Mars's ground that liquid water existed on its surface. In addition, detected evaporite minerals show at least ephemeral liquid water at Mars's surface. However, the present thin atmosphere of mars cannot support the existence of liquid water on its surface. If Mars was more massive than it's now, providing a thicker atmosphere, and experienced more greenhouse effects, it would have been more habitable and suitable than the Earth [6].

VI. Conclusion

By identifying the past and potentially current environments in our solar system, detecting planets around other stars will be inevitable. In addition to understanding the origin of life, its evolution and diversification on Earth much more closely. Combined with the measurement of the host star's radial velocity, it can produce the planetary density that can be indicative of its development history. In the following years, the discovery of new transiting planets through land and space projects will increase understanding of these objects. Scientists are beginning to conduct comparative planetology and soon new insights will be provided into the genuine mass distribution of these objects. There is also a scope to improve chemical reaction rate prediction. It is humankind's nature to explore surroundings if it is possible. Spacecrafts were first sent to the planets forty years ago, and since then, the art of space exploration has become increasingly refined, and discoveries have multiplied. Theoretically, scientists now can reach and explore any object in the solar system. Mars is at the top of the list of exploration targets. Most hospitable, and most intriguing of the planets.

VII. **References**

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