Exoplanets: The Next Stop for Human Future Settlement

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Abstract— The traditional planetary science faced challenges upon the discovery of thousands of planets which are not same as the planets present in our solar system. These planets which are outside our solar system are called as exoplanets. These planets are different as they revolve around stars and not the sun. The search and discovery of exoplanets has changed our perspective, understanding of the cosmos, and have given us new hope to find a habitable planet other than the earth. Exoplanets are very interesting to study, are also very diverse in terms of their size, temperature, atmospheres, and their distance from earth. Scientists are observing and monitoring the exoplanets from various ground observatories that gives them unprecedented opportunities to probe and study the atmosphere and surfaces of potentially habitable exoplanets for existence of life. Different kinds of problems will arise in future as we go further in exploring these exoplanets, for this many advance technologies are being developed by different space organizations. In this paper we are going to study a viable list of exoplanets and select the best one for hosting life. The benefits of settling life on other planets is also discussed. The scope of this paper also includes a comparative study of the temperatures, atmospheres of various exoplanets to identify a suitable exoplanet for future life settlement.

Keywords: Planetary Science, Observatories, Atmosphere, Technologies, Temperature, Habitable Place, Benefits of Future Settlement, Distance from Earth

I. INTRODUCTION

With each passing decade many discoveries and progress has been made in planetary science, from finding water ice on the moon to evidence of water on asteroids to finding of phosphene on Venus. There was much curiosity for searching life in our solar system and beyond it. The development of various technologies led to the discovery of more than 4000 exoplanets, using different kinds of observatories on ground and in orbit. The study of these exoplanets is important part of modern-day astronomy as it provides a new scope in the field of exoplanetary science [3]. The exoplanets have extremely diverse properties from size to mass to their distance from earth. Now, the focus of humans is in finding the habitability of these exoplanets by studying the atmospheres, temperatures, and ability to host life which is done by using many advanced observations [8]. Current telescopes are not yet powerful enough to characterize and detect habitable exoplanets. However, the next generations of telescopes will have this capacity when built. Scientists are trying hard to overcome the limitations in travelling to these exoplanets. In this paper, a detailed study of best-found candidates Kepler22b, HD 85512 b, TOI 700 d, Gliese 667Cc is carried out. We compare their properties like the temperature, mass, atmospheric composition, distance from earth and distance from host star [4]. Using these comparisons, the selection of the best habitable exoplanet which can host life in future for the humans can be reached. We also discuss the benefits of settling life on exoplanets [3].

II. HABITABLE ZONE AND CONDITIONS WHICH MAKES A PLANET HABITABLE

Planets that orbit too close to their stars will be too hot, and planets that orbit too far away from their stars will be too cold. The planets that orbit, not too far away and not too close are orbiting their star's habitable zone that is also called "Goldilocks zone". The habitable zone is the region around a star in which an orbiting planet, having the right size and composition, could have the proper temperature range to support liquid water on its surface and hence it can possibly harbor life [5]. Earth is present in habitable zone and due to this, it has existence of water and sufficient atmospheric pressure. However, if earth were at the positions of Pluto then, all oceans and atmosphere would freeze. Also, if earth were at the place of mercury then water would get evaporated and boil quickly. Earth is present at a perfect distance from the sun that makes it a planet in the habitable zone of the sun. Water is very essential for life on earth as life started in water [13].

Based on the statements as mentioned above, we can justify that the some of the properties that make a planet habitable are availability of water, temperature, distance from the host star, mass, and radius [7]. As we are unaware about the habitability of the exoplanets, numerous calculations and observations are made to determine this. These observations and studies are based on various properties and factors which involve certain astrophysical, astrological, geochemical, and geophysical criteria. One factor that makes the planet habitable is the temperature, we can say life seems to be limited between the range of -15°C to 115°C, also water can maintain its liquid form under certain conditions. Low temperatures freeze the water and can slow down the chemical reactions that interferes with the other necessary reactions for life. At about 125°, protein, carbohydrate molecules and genetic material like DNA, RNA, etc., start to break apart and high temperatures cause the water to evaporate quickly [5]. Atmosphere provides chemicals needed for life such as carbon dioxide and nitrogen that protects life from harmful radiations. Suppose a planet is too small, it would be having insufficient gravity to hold the atmosphere as gas molecules escape into space. Magnetic field is also an important factor as the magnetic field protects life from radiations [11]. One of the parameters, such as the radius plays an important role in the planet's habitability as planet must be between 0.5 and 2.5 times of Earth radius to make the planet habitable. It is important that the star around which the planet revolves must be stable in terms of its luminosity, although luminosity of every star increases with time [5]. As our earth is a terrestrial planet, assuming that a habitable planet must be made up of rocks and not gases. For instance, Jupiter, Saturn and Uranus are the gas giants in our solar system where there is no life expectancy, and their gravity is

also very high due to their larger size and mass and so the gravity and mass needs to be reasonable for a planet to be habitable [3]. All these conditions contribute for a planet to be declared as a habitable planet for life to prevail on it [4] [5] [8].

III. PROPERTIES WHICH MAKE EARTH A HABITABLE PLANET

Earth is a habitable planet where life exists, and many factors and conditions are responsible to make earth as a perfect fit for hosting life. Different properties like earth's position in Milky Way galaxy, its distance from the sun around which it revolves. Sun is a long-lasting and stable star. Earth is having its own natural satellite that is the moon that can stabilize its axial wobble as it is having a magnetic field and ozone layer which protects earth from various hazardous radiations. The interior layers of earth also contribute to the habitability of earth [12]. The molten core plays an important role in this by creating the magnetosphere that protects life from sun's harmful rays. Earth has a stable rotation. Atmosphere has all the gases which are needed for life to exist on the planet. The temperature of earth is also favorable for the presence of life. As earth rotates on its axis and revolves around the sun, it holds a gravity that helps life to survive on earth [13]. The star of the earth is also at a correct distance from earth as it can emit a perfect amount of energy required for the process of metabolism on earth. Earth is having the holding capacity of atmosphere because of its perfect mass and gravity and due to this, it not only provides oxygen for living organisms, but it also keeps planet warm by trapping carbon dioxide and other gases. All these factors and properties make earth a habitable planet for life to survive and develop on it [12][13].

Properties of Earth	Value of properties
Water	71%
Gravity	9.807 m/s²
Surface temperature	288 k
Mass	5.972 × 10^24 kg
Atmospheric pressure	1 atm. (at sea level)
Distance from its star	148.58 million km
Magnitude of magnetic field	25 to 65 μT (0.25 to 0.65 gauss) (at surface)
Luminosity	3.828×10^26 W
Radius	6,371 km

Table 1: Properties which contribute to earth's habitability.

There are many properties of earth which make it habitable and above in the table 1 are some of those properties given with their approx. amount present on earth.

The four exoplanets that we are going to study in detail are Kepler 22b, TOI 700d, Gliese667Cc, HD 85512B. The detailed study will compare the four exoplanets for their radius, mass, temperature, distance from earth, luminosity, surface gravity, distance from host star and orbital period. We have chosen these exoplanets for our study as these are one of the best candidates in the habitable zone of their respective host stars in the various constellations that has shown signs of habitability and existence of water. By studying these four exoplanets we are going to select one of the best exoplanet candidates among them to host life in future.

IV. PROPERTIES WHICH MAKE EARTH A HABITABLE PLANET

A. Kepler 22b

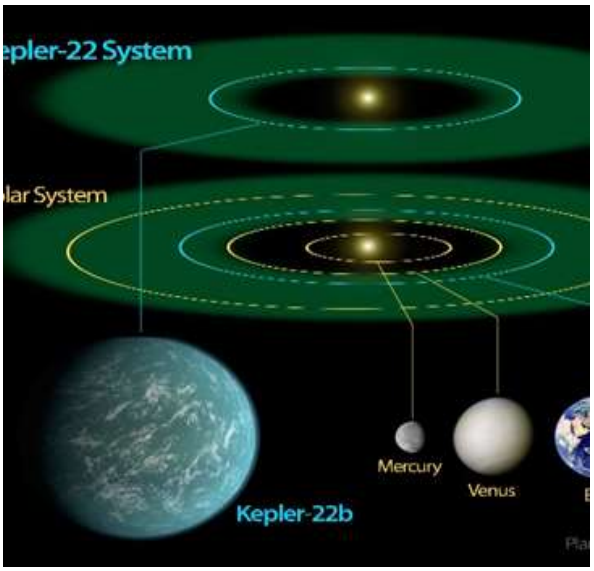

Fig. 1: Kepler 22b

It is an exoplanet located in a star system in the northern part of cygnus constellation discovered in December 2011. Kepler 22b which is twice the size of earth, that orbits a sun like star which has the same mass and radius of the sun. It orbits slightly closer to its parent star than the earth orbits the sun. It has a surface temperature of 22°C and it takes 290 days to complete a revolution around its start. Kepler 22b is at 638 light years away from earth. It has a volatile rich composition with a rocky, liquid, or gaseous outer shell. Liquid water could exist on the surface of this exoplanet [6]. The scientists have dubbed Kepler 22b as an ocean like planet. Evidence suggests that the exoplanet has a moderate temperature. In the absence of an atmosphere, its equilibrium temperature is 262K (-11°C) compared to earth's 255K (-18°C). Such conditions on exoplanets might be appropriate for life. By research it is found that for planets that are away from host star, their tidal forces drop off very sharply. So, Kepler 22b probably is not tidally locked, which is an important property for life to prevail on these exoplanets. It is inside the habitable zone of its host star and one of the best exoplanet candidates for habitability [6].

B. TOI 700d

Fig. 2: TOI 700d

It is a potentially rocky exoplanet orbiting a red dwarf star named TOI 700 in the dorado constellation. TOI 700d was discovered in early January 2020 and is 101.4 light years away from earth. It is also one of the first earth sized exoplanet discovered by the TESS. It is estimated that, this exoplanet receives 86% of the energy that the earth receives from sun. The solar wind, pressure and intensity of the interplanetary magnetic field are potentially like earth, so the planet might have an atmosphere. TOI 700d has a radius around 1.19R and mass of 1.72M. It takes about 37.426 days to complete an orbit around its host star. It has the same mass and radius as that of earth. The low radiation speed indicates low stellar activity. Recent research has shown TOI 700d to be tidally locked as its eccentricity is zero [1].

C. Gliese 667Cc

Fig. 3: Gliese 667Cc

It is an exoplanet orbiting with in the habitable zone of the host star Gliese 667. It was discovered on 21 November 2011 by HAPPS group using doppler method. Gliese 667Cc is 36.2 light years away from earth in the constellation of Scorpius. It is often referred to as super earth with mass and radius greater than the earth. Also, it is heavier than the earth with mass of about 3.7 times the earth's mass. The equilibrium temperature is estimated to be 277.4K [2]. The exoplanet orbits a red dwarf (M type star). The host star radiates only 1.4% of the sun's luminosity. Since the red dwarf emits little ultraviolet light, Gliese 667Cc receives minimum amount of radiation. The host star has a system of two planets and Gliese 667Cc is the second confirmed planet orbiting along the middle of the habitable zone. The orbit of this exoplanet has a semi major axis making its year 28.155 earth days long. Based on the host star luminosity Gliese 667Cc receives 90% of the light that the earth receives. According to the temperature calculations, Gliese 667Cc may absorb slightly more electromagnetic radiation than earth which would make it a little warmer, hence it is closer to the hot inner edge of the habitable zone. [10] It is the fourth most earth like exoplanet. This planet is tidally locked with one side of its hemisphere facing towards the host star, while the opposite side is in complete darkness. Between these two areas there would be a habitable area called the terminator line. This place is suitable for liquid water to exist. In 2013, Gliese 667Cc was found to be subjected to tidal heating that is 300 times more than that of earth because of this, the chances of habitability may be lower [2] [10].

D. HD 85512B

It is an exoplanet orbiting a k type main sequence star. It is approximately 36 light years away in constellation vela. As its mass is 3.6 times the mass of earth, it is a rocky earth size exoplanet. HD 85512B is the smallest exoplanet discovered outside the inner edge of the habitable zone. It has a surface gravity of 1.4g and an estimated temperature of 298K (25°C) with radius about 1.3R.

Fig. 4: HD 85512B

The host star magnitude or how bright it appears from earth's perspective is 7.43 which makes HD 85512b too dim to be seen with the naked eye. Its orbital period is 54 days, and it is tidally locked. If the albedo of the planet is increased due to the cloud cover, water could be present in liquid form which increases its chances for habitability. However, recent studies have shown HD 85512b is a desert planet due to the increased stellar flux. It has been one of the most habitable and stable exoplanets until 2011 [9].

Properties	Kepler 22b	TOI 700d	Gliese 667Cc	HD 85512B
Orbital Period	290 Days	37 Days	28 Days	54 Days
Distance from Earth Light Years	587.1	101.4	22.18	36.2
Radius	15,290 Km	7581.5 Km	9811.3 Km	8282.3 Km
Mass	36 Earth masses	1.72 M	3.709±0.682M	3.1783 Earth Masses
Surface Temperature	295 K	268.8 K	277.4 K	298 K
Luminosity (L)	0.79±0.04	0.0233±0.011	0.0137	0.126±0.008

Surface Gravity	2.4×earth gravity	4.81g	1.6 to 2.2×Earth's gravity	1.4g
Distance from host star	126.038 Million Km	23.7248 Million Km	18.5 Million Km	39 Million Km
Tidal locking	Not Tidally locked	Tidally locked	Tidally locked	Tidally locked

Table 2: Tally chart of the properties of the four exoplanets

V. Observations and Results

After studying the detail properties, characteristics and factors that contribute for habitability we can say that Kepler 22b is the best candidate in exoplanets to host life in future. Though its distance from earth is much more when compared to the distance of other exoplanets, other properties are very favorable for settling life on it in the future. To cover the distance from earth we can have space settlements built that can travel in space, colonizing it and reach towards Kepler 22b for further colonization.

VI. Advantages of Setteling Life on Exoplanets

A. Survival of Human Civilization

One main advantage of settling life on exoplanets is the long-term survival of human civilization. By locating and developing places other than earth, humans can survive any natural or man-made disaster on it. If a habitable exoplanet is found and developed, then humans can be saved from extinction [8]. Michael Griffin NASA administrator stated that "I know that humans will colonize the solar system and one day will go beyond it." There are many factors today that point towards extinction of the humans from earth, like limited duration of solar system, earth getting hit by asteroid, nuclear wars etc. So, to keep the exoplanets ready as an alternative for the human settlement, in case of any disaster is the main advantage [7].

B. Technological progress

As we say necessity is the mother of invention. The need to settle life in a new place other than earth has led us to explore and research mars, asteroids, moon, and exoplanets. With each passing decade, many advancements have been made in space exploration which led to the discovery of many exoplanets which show signs of habitability [5]. As the need to find an alternative to earth to survive for the humans is increasing day by day, many technological advancements are made. Hence, the idea of settling life on exoplanets will enhance the advance technologies that will help the human species and for their survival [7].

C. Usability of vast resources on exoplanets

The available resources on earth are getting exhausted and there is a need to find other sources of energy. Abundant resources are available on exoplanets. If these exoplanets are developed and made habitable, we will have a place abundant with enough resources which will help in further colonization of exoplanets and space [3]. Fuel stations can be built on the exoplanets which will make space travel easy and better. All exoplanets offer endless supply of resources providing limitless potential to grow. Harnessing these resources can help in more economical development and settling life on exoplanets [8].

Fig. 5: Cultivating plants

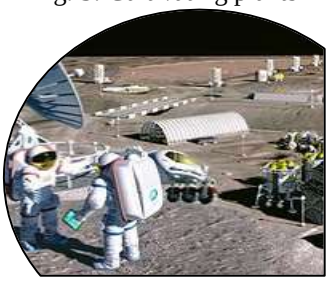

Fig. 6: Mining Resources

VII. Conclusions

Though the discovery of exoplanets has posed many challenges to our traditional planetary science, but it also has opened doors for us to go beyond our solar system and discover many new technologies. The scope of our study in this paper was to find the best candidate among the four exoplanets. After our detailed study on the factors and properties that contribute to habitability of these four exoplanets, we can conclude that Kepler 22b is the best one to host life in future. Settling life on exoplanets also has many advantages that are also discussed in this paper. With advancement in technologies day by day, we will surely reach the exoplanets and develop them to settle life and utilize them for economic and human species development.

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