The Discoveries of Exoplanets and Further Studies

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I. Abstract

Earth-like exoplanets above all orbit around a star in its habitable zone, and the condition of the star must preserve life, and the Kepler project is aimed at their discoveries. In the past 25 years, there are three major discoveries of exoplanets. The first exoplanet discovered was in 1996, which was afterward awarded with the Nobel Prize. In further studies, scientists derived two earth-like exoplanets from Kepler project's data. From the three planets, scientists made interesting assumptions on requirements for earth-like exoplanets. By studying other earth-like planets in different stages of their life can help scientists understand the Earth, study not only the history but also the future of the earth. These discoveries are also vital for interstellar migration, which may be a solution to overpopulation.

Keywords: Exoplanet, Kepler, habitable, star, discovery

II. Introduction

The discovery of exoplanets are very important, not only in understanding of the universe but also to the future of human species. By studying the conditions required to form an earth-like system that have the potential of life, people's understanding of their place in the universe will be clearer. Other earth-like planets at another stage of their life can give scientists a more thorough understanding of the past, as well as the future, of our own planet. Furthermore, the study of earth-like exoplanets may lead to discoveries of extraterrestrial life, and even migrating to another earth-like planet.

In this paper, the background information of astronomical units and solar-like stars are first stated, then the discoveries of three exoplanets are introduced, and it is finally concluded with future applications and benefits.

III. Context

There are many different types of stars. Solar analogs are stars that have detailed properties similar to the Sun's ((K. Fuhrmann and R. Chini, OUP Academic (2018).)) They have similar structure. The difference in temperature should be within ~500K, and there should be no close companion stars. The solar twins are stars almost the same as our sun. They should have less than ~10K differences in temperature and the metallicity should be within 0.05 dex. They also should be as old, or as young; the difference should be no more than 1 Gyr. And it should not have any companion since the sun is on its own. Similar to biological identical twins of a person, it's almost impossible to have identical stars.

An exoplanet is a planet outside of our solar system. It is either orbiting a star or on its own—a rogue planet. We can calculate the density of an exoplanet by measuring its diameter and mass so that we know from which element it is mainly composed. We rarely find exoplanets by seeing them in the telescope. Now, almost all exoplanets we directly observed are giant gas planets that orbit far from the star.

The Kepler mission is a search for earth-like exoplanets orbiting a solar analog in the habitable zone during 2009 to 2013. For an exoplanet to be earth-like, there are a few conditions it needs to meet. ((A. Strickland, CNN (2020))) The star it's orbiting is preferred to be at least a solar analog, but what is most important is that its orbit should be in the habitable zone. ((EarthSky (2020))) It means that the planet will receive enough energy from the sun so that liquid water—a sign of potential life—will exist on the surface. Also, it needs to have an atmosphere so that there's a relatively constant surface temperature, or it's very difficult for lives to thrive.

In 1995, the first exoplanet orbiting a solar analog was discovered by Michel Mayor and Didier Queloz, who were awarded with the Nobel Prize in 2019. ((M. Mayor and D. Queloz, The Extrasolar Planet Encyclopaedia - 51 Peg b (1995))) Then, in 2020, Kepler-160 is identified as a solar analog and Kepler-160 a, an exoplanet orbiting it, is suspected to be earth-like. ((A. Strickland, CNN (2020))) This is a major breakthrough in searching for

habitable exo-planets. Following the discovery of Kepler-160 a, Nasa scientists discovered another potentially habitable planet: Kepler-1649c. ((P. Brennan, NASA (2020)))

IV. Experiment

Mayor and Queloz were equipped with the relatively new spectrograph ELODIE of the Haute-Provence Observatory, France. ELODIE is a reflector, which is developed by André Baranne from the Marseille Observatory, detects extrasolar planets by the radial velocity method. With the help of it, scientists can measure the velocity of celestial bodies more precisely. The observation of 51 Peg started in 1994, when they found a 4.23 days orbit and a scatter of the orbital solution that had a velocity of 24 m/s. ((P. Brennan, NASA (2020))) These two measurements suggested that there was very likely to be a low-mass companion—a planet. According to their data, it was almost impossible for this scatter to be a brown dwarf—a dead star—for the mass is just too low. Therefore, it was a planet companion rather than a stellar companion.

TABLE 1 Orbital parameters of 51 Peg	
P	4.2293 ± 0.0011 d
T	$2,449,797.773 \pm 0.036$
e	0 (fixed)
K_1	0.059 ± 0.003 km s ⁻¹
$a_1 \sin i$	$(34 \pm 2) 10^5$ m
$f_1(m)$	$(0.91 \pm 0.15) 10^{-10} M_{\odot}$
N	35 measurements
$(O - C)$	13 m s ⁻¹

P , period; T , epoch of the maximum velocity; e , eccentricity; K_1 , half-amplitude of the velocity variation; $a_1 \sin i$, where a_1 is the orbital radius; $f_1(m)$, mass function; N , number of observations; $(O - C)$, r.m.s. residual.

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In 2020, the data for two potential earth-like exoplanets is collected from the Kepler project. Nine years from present, Kepler-160 is discovered together with two planets in its close orbit. ((A. Strickland, CNN (2020)))

They're very unlikely to be earth-like, for they're too big and their orbits are too close.

However, In April, data of two more planets orbiting the same star are collected from the Kepler project, and one of them is Kepler-160 a. It is less than twice as big as the Earth and its orbit is in the habitable zone. Furthermore, the data suggested that it's receiving approximately the same amount of heat from its star compared to the Earth. It's orbital period is 378 days—another similarity to the Earth. If it has an atmosphere, the climate of Kepler-160 a can be extremely earth-like.

Scientists also discovered Kepler-1649c from reanalyzed data. In the previous observations of Kepler, a computer algorithm misidentified it, and scientists reviewed the data and realized that they probably discovered the exoplanet which has most similarities with the Earth humans ever detected. It's 300 hundred lightyears away, only 1.06 times bigger than the earth. ((P. Brennan, NASA (2020))) The amount of straight light it receives from its sun is 75% as much as the Earth is. The star, however, is not a solar analog; instead, it's a red dwarf, of which type is known for solar flare-ups—a phenomenon that makes life challenging to occur on its planets. What is more intriguing is that another same-size rocky planet orbits Kepler-1649 at about the half distance of Kepler-1649c: the two planets' relationship, and the relationship between Earth and Venus are extremely alike.

V. Further studies and application

In the future, with the development of telescope and computer power scientists will be able to study more exoplanets more thoroughly. Data will be collected with better accuracies, which will further help develop accurate models of exoplanets for scientists to study. By then, the focus should be on the environments, the influences that different types of star, for instance white dwarf, may have on the formation of their planets' atmosphere and meteorological activities. With the data of other exoplanets at various stages of their life, scientists will be able to deduce the history and predict the future of our own solar system, and then have a further understanding of our own place in the universe.

The discovery of extraterrestrial life is also a possible outcome of future studies on exoplanets. By analyzing the temperature, atmosphere component and geology, some exoplanets will turn out to be very similar to Earth, or their condition can support life. Then, probes can be sent for a close study, and if we're fortunate enough solid signs of aliens will be discovered. Another possibility is migrating to other planets after discovering earth-like planets by analyzing the same data. Since the population is growing explosively, in the future we will need to find more space to fit these people, and interstellar migration might be the best solution.

VI. Conclusion

The discovery of the three exoplanets contributed tremendously to the study of the universe, as well as the origin of the Earth. By analyzing the data collected from observation, scientists got a deeper understanding of the formation of earth-like exoplanets. The further study in this field can enhance people's understanding of the origin of the Earth, as well as provides scientists with a better picture of the future of human species.

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