

We live here in the Milkyway



Are There Habitable Worlds Out There?

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The Quest for Exoplanets

The search for earth-like planets outside the solar system has been a long standing one. However, the present technology falls short in providing the required equipment to make such detection possible. The coming quarter century may prove to be crucial for further discoveries.



Our solar system relative to the Milky Way galaxy. The pink/orange area represents where the majority of exoplanets have been found with current telescopes. (Source: Wikimedia Commons)

HUMANS have always been fascinated by the prospect of coming across another Earth in the infinite expanse of space or encountering alien life forms. It is highly probable that we are not alone in the universe. The search for earth-like planets outside the solar system has been a long standing one.

The panorama of stars in the vast skies holds planetary systems, and among them are many that are Earth-like or near Earth-like in existence. Scientists call them exoplanets or extra-solar planets. Exoplanets by definition are planets beyond our solar system and so far in the past two decades thousands of them have been discovered.

The journey has just begun and we are still in the nascent stages. Our solar system is but a speck on the gigantic canvas, and our knowledge may be limited by our perception. It is difficult to say what lies out there as humankind is on a quest like never before, aided by rapid technological growth, to explore the universe.

Take a look at where we stand now, as the discoveries unfold, many doubts are clarified even as many more questions arise.

The Goldilocks Principle

The huge stellar systems hold planets that are locked to their parent star. The stars themselves are either huge or dwarfs, cold or hot. Depending on their proximity to the star and the type of the star, the planets are envisaged to contain water in liquid form. This is considered a criterion for life to exist. Also depending on the age of the

planet, the surface can be rocky, dusty, and have atmospheres.

The Goldilocks principle is comparable to the popular fairy tale character: you will recall the little girl Goldilocks, who wanders in to the house of the three bears. Here she finds a bed, food and warmth just right for her, eliminating the other two extremes.

Similar to this, a habitable world may exist if optimal temperatures are experienced on the exoplanets; just as Earth has optimal temperature – neither too hot like Venus nor too cold like Mars. This is required to hold water in its liquid state, without either freezing it or evaporating it.

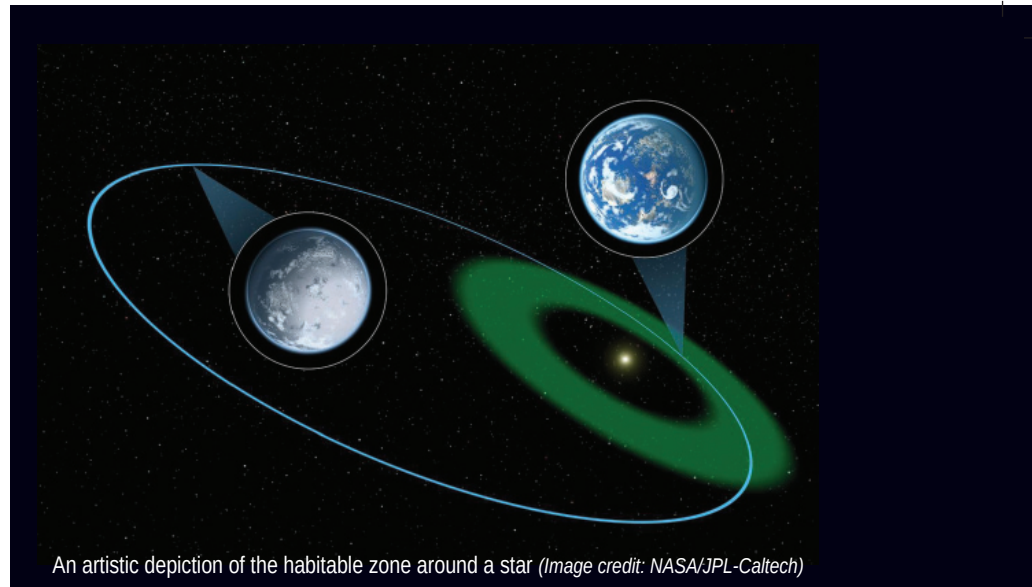
For water to exist in this state, many factors have to come together: the temperature of the star, the distance of the planet from the star, presence of atmosphere on the surface for water to sustain its liquid nature. The Goldilocks principle binds all this together and based

on these factors and studies, scientists enlist exoplanets in habitable regions.

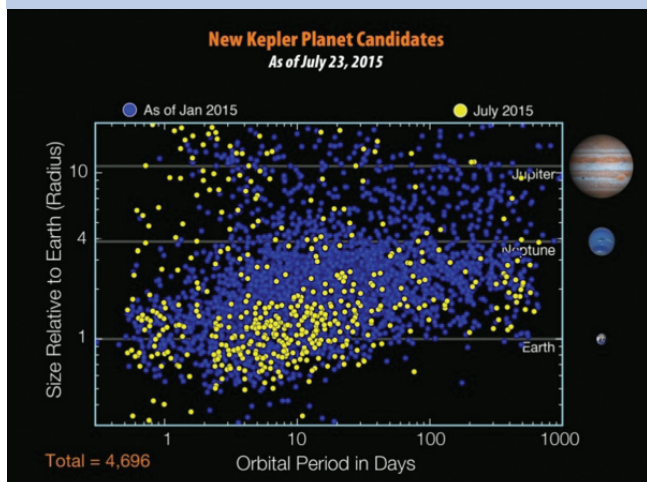
It all Began in 1992...

Though the existence of planetary systems beyond our solar system was speculated long back, detecting their presence from ground-based telescopes was a big challenge fraught with errors and shortcomings. With improved technology, it was in 1992, two astronomers Alex Wolszczan and Dale Frail using the Arecibo Observatory in Puerto Rico, discovered two exoplanets orbiting a pulsar (PSR B1257+12) located in the constellation Virgo, about 2,300 light-years away from Earth. Again in 1995, another exoplanet was found around 51 Pegasi.

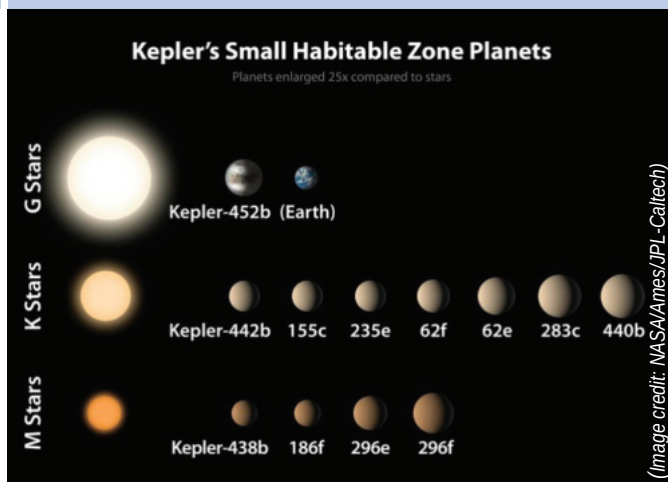
Since then, the last two decades have seen the identification of nearly 5,000 planet candidates with more than 3,000 being verified. Advancement in space technology and the numerous space missions that are taking place has only strengthened the search and astronomers are excited as the list of discoveries grows bigger.



New Kepler Planet candidates as of 2015 (Image source: Wikimedia Commons)



Some of the exoplanets found by Kepler which are comparable to Earth



When the Kepler mission was launched in 2009, more than 2,300 of the exoplanets were confirmed. (The Kepler telescope is a probe stationed in space and monitoring 1,50,000 stars continually.) After this, the K2 probe, equipped with further modifications, took over. Even as we read this, K2 is continuously monitoring stars and beaming back data about them.

An Exciting Discovery

In 2015, Michael Gillon and his team of Astrophysicists discovered an ultra-cool dwarf star, just 39 light-years away from Earth, by scrutinizing the intermittent light signals. Soon the presence of three exoplanets was discovered by the team from the La Silla's observatory in Chile using the 60-cm TRAPPIST (TRAnsiting Planets and Planetesimal Small Telescope), in 2016.

Artist's depiction of the transit of exoplanet



A View From the Exoplanet

Imagine yourself to be on one of the TRAPPIST 1 planets. Then how would the horizon appear?

The most amazing visual is of the sky. The panorama captures the obvious presence of the other six planets, with the closest appearing nearly twice the size as our full moon.

"You wouldn't see them like we see Venus or Mars, like dots of light. You would see them really as we see the Moon. ... You would see the structures on these worlds," explains Gillon.

The lighting received by these planets can appear quite faint to the normal vision. Since the star is an ultra-cool one, most of its radiations are in the infra-red region. Explaining this further, Triaud, a co-discoverer, interprets that daytime skies on the planets would never be brighter than Earth's sunset time, giving a suffused light all around.

The "planet years" are quite short and roughly average to less than two earth weeks. This is primarily due to the tight tidal lock of the system with the parent star. Along with the star-planet pull, the interplanetary tug is also significant making it difficult to calculate a steady orbital period.

Another consequence of tidal locking is the eternal days (or night on the other side) on the planet. So one would experience short years and eternal days (night) on the planet.



This team continued observing the star, named TRAPPIST 1, this time with the help of the Spitzer Space telescope. Using this infrared space telescope, the scientists were able to closely observe the star and its planet system. Using the transit method of observation, in February 2017 the team yet again announced, with more clarity, the presence of more planets

around the star. Now the total had gone up to 7.

This discovery garnered a lot of interest due to not only the proximity of the star but also due to the dense planet systems around it; all with a high probability of holding liquid water, and in extension, the probability of existing life forms.

TRAPPIST 1 is 500 million years old,

is an ultra-cool dwarf star which is nearly 2,000 times cooler than our sun; in size it is slightly larger than Jupiter. The seven planets are bound to it in tight tidal lock orbits. This makes them show only one surface at all times (like our Moon). The planets are comparable in size to Earth – around three quarters to a maximum of 1.5 times the Earth's size.

How Do They Find an Exoplanet?

One wonders how exoplanets are discovered. Detecting a planet in the vast sky is a highly difficult task. Even with a powerful telescope, a star would appear like a small bright spot. Planets are much smaller in size than stars and appear as dark spots. They are often close to the star and so almost invisible in the dark background.

In order to overcome this difficulty astronomers observe the stars instead. So when a planet traverses across the star under observation, it causes minute variations in the light signals received from the stars. These signals are detected, analysed and then concluded.

Some common methods employed are:

Radial velocity method: Most of the initial exoplanets were discovered using this method, which was considered quite reliable up until Kepler was launched. Here the slight wobble of the star (due to gravitational tug of the orbiting planet) when a planet crosses it, is detected by using Doppler Spectroscopy. These periodic changes are detected and the spectrum analysed.

A major drawback of this method is detecting the mass of the planet, which is a criterion to differentiate between a smaller star and a planet. Another shortcoming is the plane of observation compared to the orbital plane. While there are no errors with an edge-on plane (the wobble is detected as a shift towards or away from the observer and recorded as a spectrum of blue to red), for face-on plane no spectral changes are obtained in the perpendicular plane and in many instances, the observer is unaware of the presence of a planet.

Transit method: Here, when the planet transits between the earth and the star, a minute radiation dimming is observed. This is recorded for periodicity and is called a "transit". In this method the rate of the dimming is a direct measure of the ratio of the size of the star and planet. With photometric recordings, the size of the planet can be determined. Kepler space telescope was designed on the transit method of detection and is responsible for detecting more than 2000 exoplanets recorded so far.

A combination of the two methods gives most accurate results.

Microlensing: This method is chiefly used to detect planets orbiting stars that are thousands of light years away – at the centre of the galaxy and is based on Einstein's General Theory of Relativity. When a star crosses the path between another star and the observer on Earth, the gravity of the intermediate star will slightly bend the received light from the source star, leading to a "lensing effect" creating an "Einstein ring".

In 2006, a planet orbiting a star which was 22000 light years away was detected by this method.

Image credit: NASA/JPL-Caltech

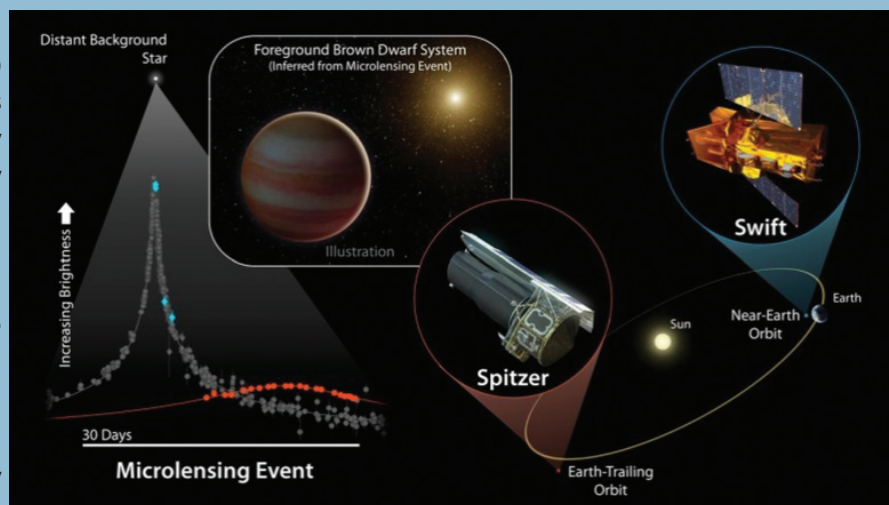
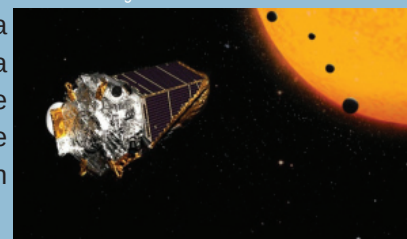
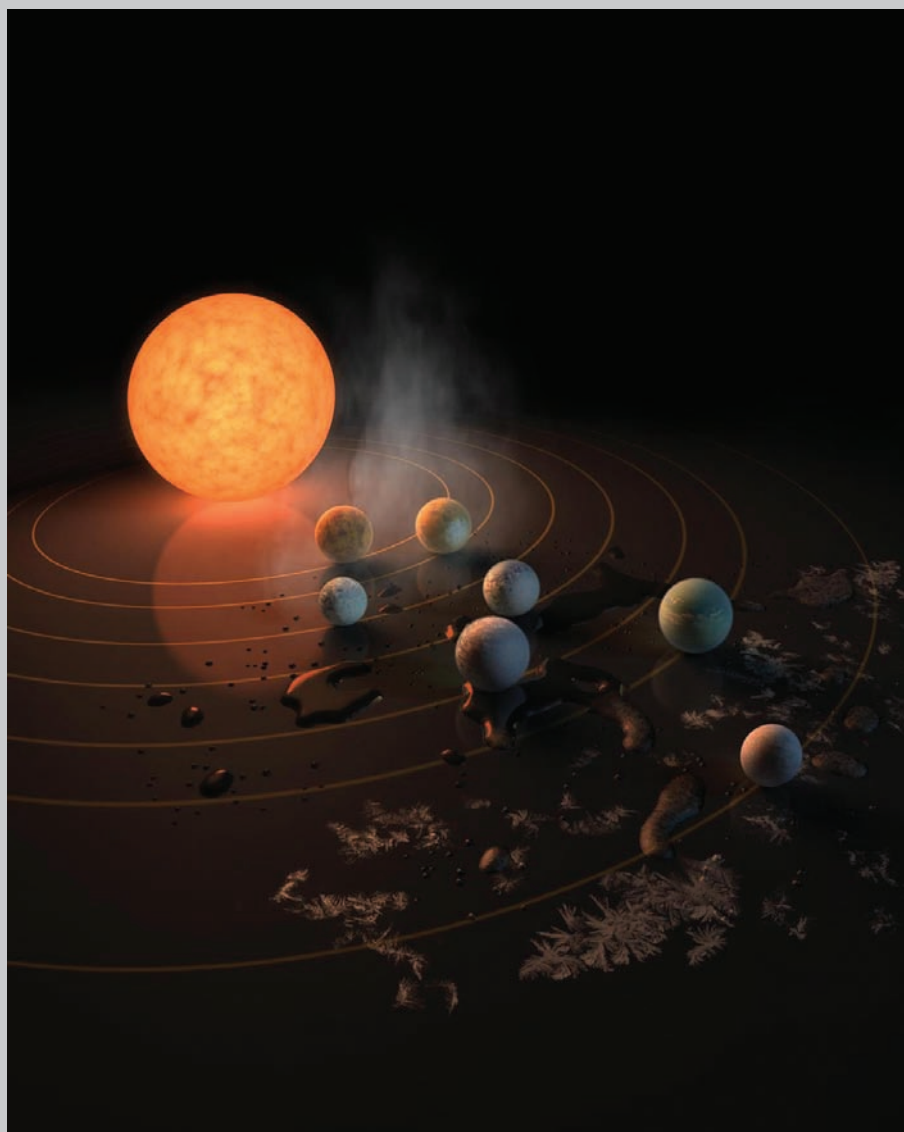
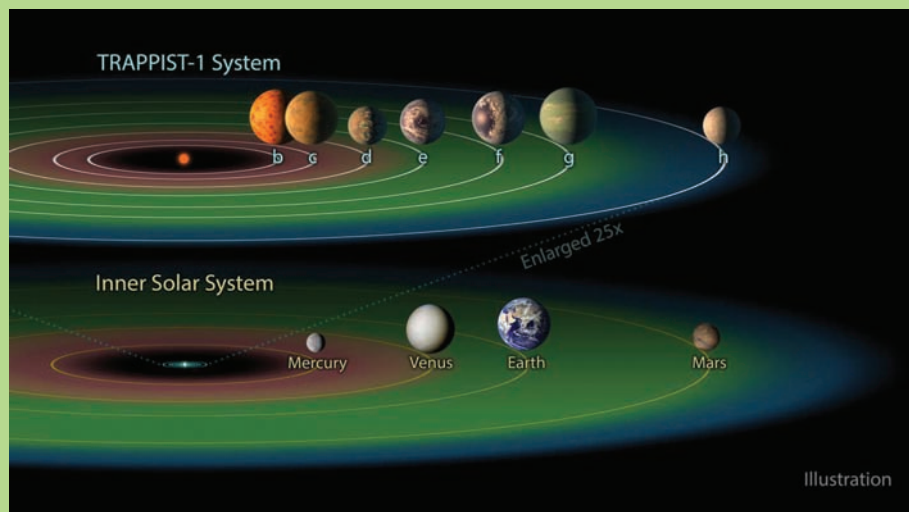


Image credit: NASA/JPL-Caltech



An artist's impression of the TRAPPIST 1 system in tidal lock orbits
Image credit: NASA/JPL-Caltech

An illustration to indicate the planetary system (enlarged) in comparison to our solar system
Image credit: NASA/JPL-Caltech



“The planets are in close proximity to the star and hence receive many times more radiation than we receive on earth,” says Michael Gillon. “The tight gravitational locking leads to heating up of the core of the planets leading to volcanic activities, more so with the inner two planets,” he added.

Are They Habitable Planets?

Earth has company to boast about, just a hop, skip and jump away, guess scientists. Despite tidal locking and proximity to the star, the TRAPPIST 1 system is found to be very much in the habitable zone, thanks to the cool star. Though the planets show only one side and can experience complete day zone and night zone, it is possible that the temperature is transmitted from the day side to the night side. “The temperature gradient need not be catastrophic,” clarifies the team of scientists.

In model studies conducted it was found that planets e, f and g of this system had a high probability of having liquid water, with all seven planets speculated to contain the life sustaining chemical. Gillon further explained that the topography, amount of water, presence of rocky matter, atmosphere, etc. may be different from the Earth’s composition.

The TRAPPIST 1 Family

This dwarf star consists of 7 exoplanets in tidal lock with its parent star. Named 1b, 1c, 1d, 1e, 1f, 1g and 1h.

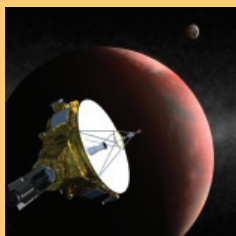
- Planet b and c are almost Earth-sized. Being the innermost in the system their orbital days are short – 1.5 and 2.4 Earth days. Their mass too is close to that of earth.
- Planet d is smaller in size and its mass is less than half that of the Earth with orbital periods of just over four days.
- Planets e, f and g are again near Earth-sized and mass of half of Earth to 1.5 times. Their orbital periods are 6-12 days.
- Planet h, the farthest has approximate figures as it is still to be studied in detail. With a size of 75% that of Earth, its mass is yet unknown and the orbital periods are approximated to 20 days.

All the planets are close to their parent star – less than 0.07 AU (1 AU = distance

Mammoth Distances, but Astronomically Close

TRAPPIST-1, touted as the closest star to house the highest number of habitable planets, is just 39 light years away from us, or in more perceptible terms, at a distance of 370 trillion km. This means that if one were to travel at the speed of light- c - of 3,00,000 m/s, it would take a mere 39 years to reach this dwarf star in its current location. Though this is astronomically close, it is unimaginable to make a probe to travel at this phenomenal speed.

The best of our present space probes, the New Horizons and Juno, are travelling at high speeds, but nowhere close to c . Here is a look at their journey times if they were to travel towards TRAPPIST 1:



New Horizons – at 14.3km/s or around 51,480 km/h, it would take 8,17,000 years to reach TRAPPIST-1.

Juno – hit a top speed of 2, 65,000



km/h when it took Jupiter's gravity assist. If it travelled constantly at this speed, it would say hello to our neighbour in 1,59,000 years.

Voyager 1 – on an interstellar mission, this probe designed to reach another nearby star AC +79 3888 has exited our solar system in 2012. Travelling at a speed of 23,875 km/h, in 40,000 years it will reach within 1.6 light-years of the star.



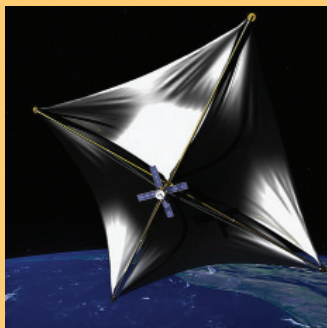
The Best Bet

Sending probes to exoplanets will involve immense travel time and may not be currently viable. To overcome this, Stephen Hawking, the brilliant theoretical Physicist, proposed a theory.

His *Breakthrough Starshot* initiative theorises an interstellar space mission by using tiny, laser-propelled probes called nanocrafts. These probes are capable of travelling at amazing speeds – nearly 20% of the speed of light, which is around 216 million km/h.

With the current trends of miniaturization in electronics, chips weighing less than 1 gram are achievable. These stamp-sized “StarChips” can accommodate computers, cameras, communication laser systems and nuclear battery. The StarChip aided by a Lightsail is what makes a nanocraft.

Many such StarChips would be beamed by a 100-gigawatt laser beamer array from the ground propelling them at top speeds, with accelerations escalating to greater than 60000 times the Earth's gravity, in two minutes. At these speeds, reaching TRAPPIST 1 would take a mere 200 years!



Other Potential Habitable Worlds

Kepler 186f (nickname “Earth’s cousin”)

Distance 490 ly, dwarf star

Size and mass close to earth

Orbit 130 days, radius 52 million km

Kepler-22b

Distance 600ly, star comparable to our Sun

Size around 2.5 time’s earth

Distinguishing feature possible greenhouse effect with surface temperature around 22 deg C

Kepler-452b (a strong

contender) Distance 1400ly, many features comparable to solar system

The habitable zone is found to be existing for more than 6 billion years

Gliese 667Cc *Distance 22 ly, star is 30% of sun*

Size a super earth is part of a triple star system

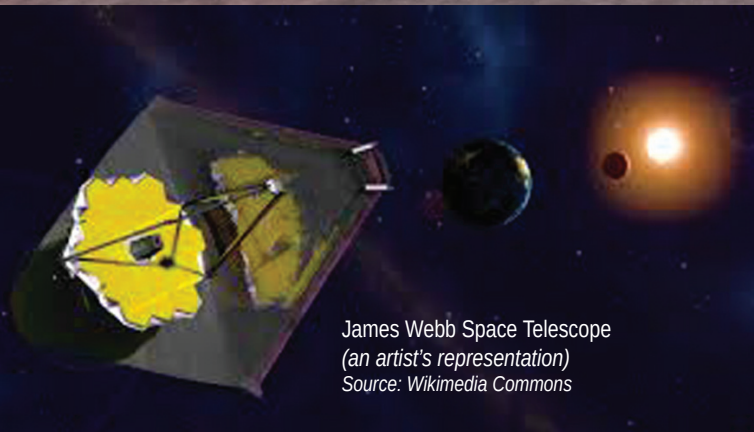
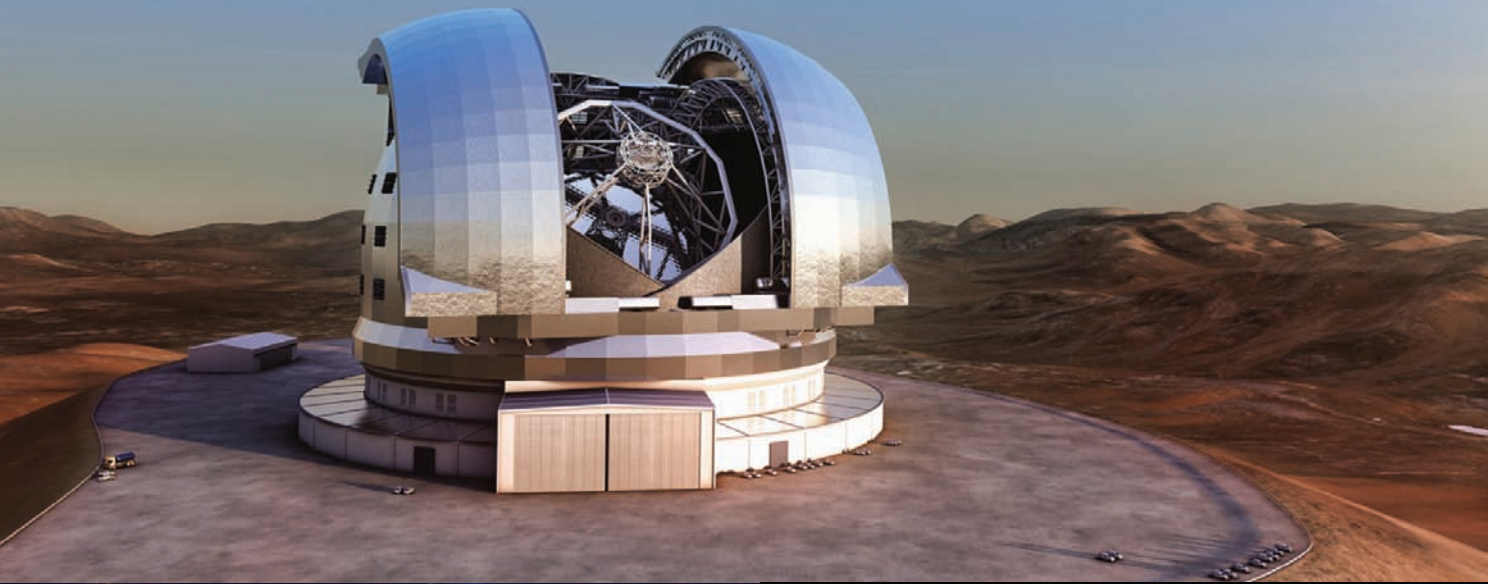
HD 40307g *Distance 42 ly many features are comparable*
Again a super earth to be studied closely due to proximity

HD 85512b

Distance 35 ly

This super earth is one of the 50 planets discovered by HARPS instrument.

European Extra Large Telescope (a representation)
Source: Wikimedia Commons



James Webb Space Telescope
(an artist's representation)
Source: Wikimedia Commons



Hubble Space telescope
Source: Wikimedia-Commons

Habitable world may exist if optimal temperatures are experienced on the exoplanets; just as Earth has optimal temperature – neither too hot like Venus nor too cold like Mars.

between Earth and Sun). This indicates they are all closer to their sun than Mercury is to the Sun in our Solar system. Of these, three of them are most likely to have liquid water on them.

In the Offing...

On the threshold of such a major discovery, further studies on these planetary systems are underway at a rigorous pace. By using the Hubble Space telescope, the atmospheres of these planets are being observed and recorded.

The coming years will see the launch of better and powerful telescopes to further glance into the galaxy. Armed with better technology and cameras, NASA's James Webb Space Telescope is expected to be launched in 2018. In addition, ground-

based systems such as the European Extremely Large Telescope and the Giant Magellan Telescopes slated for use by 2020 will further validate the discovery and give us a closer look at the planets.

Detecting oxygen or methane on the surfaces of the planets will open a new chapter in the discovery, as these are the principal gases produced by life forms. Finding them would be compelling evidence supporting the existence of extra-terrestrial life.

In response to media queries, Prof. Amaury H M J Triaud from the team envisions, "I think that we've made a crucial step toward finding [out] if there is life out there. Here, if life managed to thrive, and releases gases similar to that that we have on Earth, then we will know."

However, the present technology falls short in providing the required equipment to make such detection possible. A lot depends on the upcoming projects and others that are on the anvil and soon to be operational.

The coming quarter century may prove to be crucial for further discoveries. Who can say, we may soon encounter alien life forms out there! To borrow a tagline from the popular X-Files series, "The truth is out there!"

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