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How to Find Exoplanets

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In this time period, we are at the peak of Space exploration. This much work in the space field never been done in past decades. All this work came to life due to advancement in technology, Human resources, a good funding and most important our curiosity.

When Apollo 11(the spaceflight) landed two people on moon, Neil Armstrong and Buzz Aldrin on lunar surface on 20 July, 1969, It was the moment that change the people aspects towards space and made them curious. They wanted to know what could be ahead of lunar (moon) and this leads us to do more space mission.

In the past decade different space missions took place which amazed humankind.

All this curiosity now lead our scientists to find exoplanets and this paper is on this word 'EXOPLANET'.

So first we should know what is exoplanet - According to dictionary exoplanet is 'a planet which orbit a star outside the solar system.' These exoplanets orbits a star in another solar system. These are very far from our solar system. There is so much research being done on it.

So, why we all suddenly started to taking interest in exoplanets besides other space missions because of extraterrestrial life in which humankind always take interest and to find a new planet which can support human life. As we know our future generations will face a lot of problems on Earth like global warming, lake of land, Undrinkable water, unbreathable air, population that Earth cannot handle and lot more. And now we have technology so we should try our best to find solution to this and the best solution is to find new home as famous scientist -Stephen Hawking said "This planet will support life only for 100 years". So we should think of our future and fund these kind of missions or programme.

In this aspect the American space agency Nasa started its programme named "Exoplanet Exploration" , which gave us many amazing results.

So, this paper will focus on the different types of methods to find exoplanets in detail and will open reader's mind towards space exploration. I hope it help all readers to create more and more interest in space Exploration. So let's get started.

NASA's Exoplanet Exploration Program is leading humankind on a voyage of ambition, promising insight into three of our most timeless questions: Where did we come from? Are we alone? Where to find new home?

The primary goal of this program is to discover and characterize planetary systems and Earth-like planets around nearby stars.

So how Scientists discover these exoplanets in such short time with all these details like- their radius, mass, distance etc.

Most of the exoplanets are found by these methods which we are going to study in detail:-

1) Transit Photometry

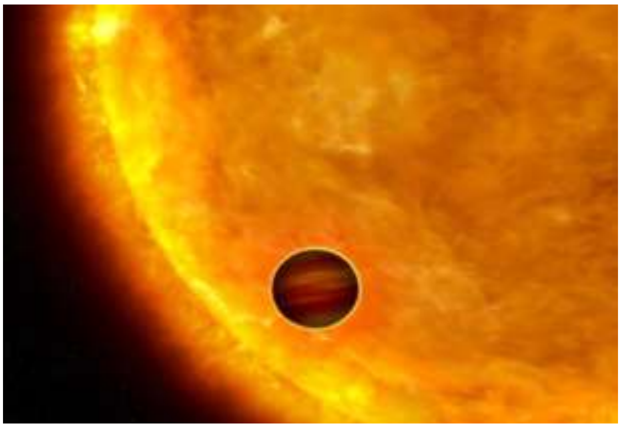
This method detects planets by measuring the minute dimming of a star as an orbiting planet passes between it and the Earth. The passage of a planet between a star and the Earth is called "Transit". If such a dimming is detected at regular intervals and lasts a fixed length of time, then it is very probable that a planet is orbiting the star and passing in front of it once every orbital period.

A small planet transiting a large star will create only a slight dimming, while a large planet transiting a small star will have more effect. So we can say that the dimming of a star during transit reflects the size ratio between the star and planet.

The size of host star can be known with its spectrum and photometry. Photometry is the science concerned with measuring human visual response to light, therefore it gives astronomers a good estimate of orbiting planets size, but not its mass.

This make us to use spectroscopic method which is dispersion of an object's light into its component colors.By performing analysis of an object's light astronomers can infer the physical properties of that object like temperature, luminosity, mass and composition.

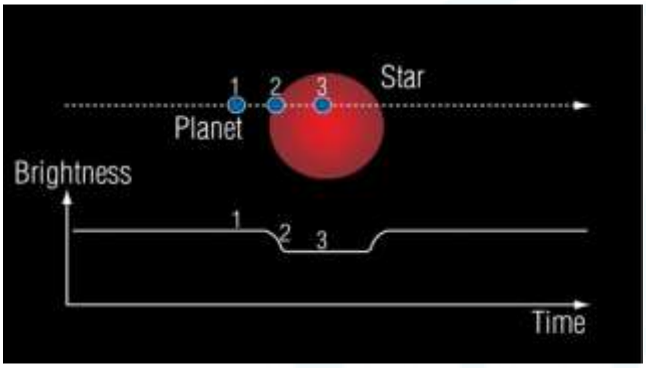
So, using both methods, combining mass and size, scientists can calculate the planet's density, an important step towards assessing its composition.



A planetary Transit

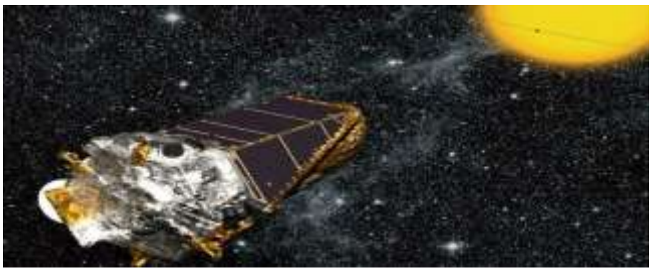
Advantages of this Method

Transit photometry is currently the most effective and sensitive method for detecting extrasolar planets, particularly from an onservatory (a room housing a telescope) in space.



Anatomy of a Planetary Transit

The best example of this is Kepler mission, launched in March of 2009, uses photometry to search for extrasolar planets from space. The spacecraft's sensitivity is such that it has already detected thousands of planetary candidates, including several that are Earth-sized and orbiting in their star's habitable zone. Kepler operates by pointing its photometer continuously on single star-field of around 145,000 different stars. The chances of any one of these stars undergoing a transit is very small, but because of huge number of these stars being tracked thousands of tansits nonetheless take place. Due to kepler's sensitivity, hundreds of the planets detected by end of 2012 are of Earth- like diameter, and dozins are in the habitable zone.



Kepler in Space

Disadvantages of this Method:-

The main difficulty with this method is that in order for photometric effect to be measured, a transit must occur. This means that the distant planet must pass directly between it's star and the Earth. In order for a transit to occur the orbital plane must be almost exactly "edge-on" to the observer.

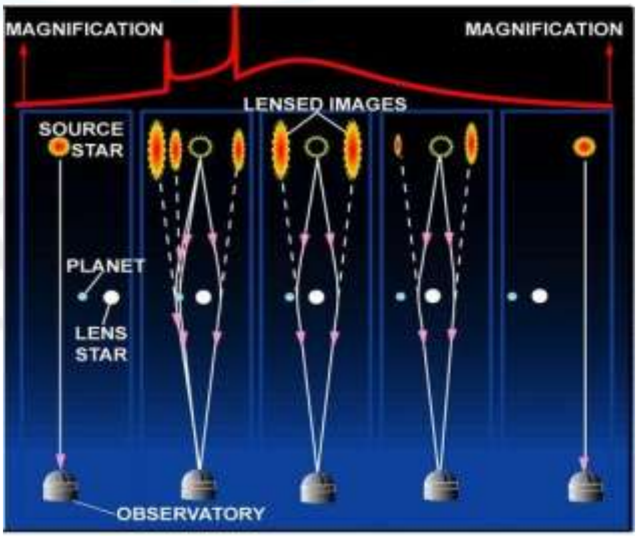
Another problem is that a planet's transit lasts only a tiny fraction of its total orbital period. A planet might take months or years to complete its orbit, but the transit would probably lasts only hours or days. As a result, even when astronomers observe a star with a transiting planet, they are extremely unlikely to observe a transit in progress. Astronomers need to observe not one, but repeated transits occurring at regular intervals.

Finally, experience with transit photometry has shown that the method tends to produce "false positives" --instances when a binary star is mistaken for a planet orbiting a star.

2) Microlensing

Microlensing is the only method for discovering planets at great distances from Earth. We can compare this method to transit photometry as transit photometry can detect planets at a distance of hundreds of light years whereas microlensing can find planets orbiting stars near the centre of the galaxy, thousands of light years away.

Microlensing is an astronomical effect predicted by Einstein's General Theory of Relativity. According to Einstein, when the light emanating from a star passes very close to another star on its way to an observer on Earth, the gravity of the intermediary star will slightly bend the light rays from the source star, causing the two star to appear farther apart than they normally would.



Planet Detection Through Microlensing:{process from left to right: the lensing star(white) moves in front of the source star (yellow) and create a microlensing event. }

If the source star is positioned not just close to the intermediary star when seen from Earth, but precisely behind it, this effect is multiplied. Light rays from the star pass on all sides of the intermediary star creating a ring which is known as 'Einstein's Ring'. Even the most powerful Earth-bound telescope cannot resolve the separate images of source and lensing star between them, seeing instead a single giant disk of light, known as "Einstein's

Disk", where a star had previously been. The resulting effect is sudden increase in the brightness of the lensing star, by as much as 1,000 times which lasts for a few weeks or months before the source star moves out of the alignment with the lensing star.

Above is the normal pattern of a microlensing event but if a planet is positioned close enough to lensing star so that it crosses one of the two light streams from the source star, the planet's own gravity bends the light stream and temporarily produces a third image of the source star. When measured from Earth, this effect appears as a temporary spike of brightness which are great sign of presence of a planet for planet hunters.

The perfect characteristics of the microlensing light curve, its intensity and length, tell researcher a great deal about planet like mass, its orbit, and its period.

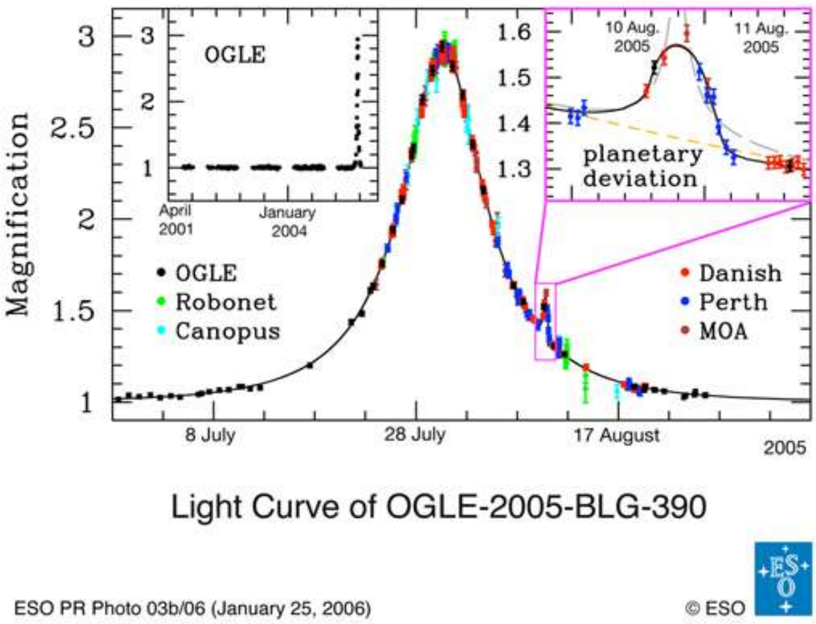
Advantages

Microlensing is capable of finding the furthest and the smallest planets of any currently method for detection exoplanets. For example in January of 2006 scientists announced the discovery through microlensing os a planet of only five Earth masses, orbiting a star near the center of our galaxy, 22000 light years away! It was lowest and furthest planet from Earth that time.

Like transit photometry, microlensing searches are massive, targeting tens of thousands of planets simultaneously. A microlensing event takes place anywhere within the observed starfield, it will be detected.

Microlensing surley has an important role to play. By detecting low mass planets at large distances from their star it brings scientists closer to finding Earth mass planet. Searching at great distances, it increases the number of potential planets that can be surveyed from Earth.

The best example is- OGLE-2005-BLG-390



The Microlensing Curve of Planet Ogle-2005-Blg-390(July 31,2005)

THE "WARSAW "TELESCOPE USED BY OGLE
(1.3 meter and located at Las Campanas, Chile)

Disadvantages:-

Unlike planets detected by other methods, planets detected by microlensing will never be observed again. This is because microlensing event are unique, rare and do not repeat themselves. For example- OGLE-2005-BLG-390Lb is rockey world orbiting a small cool ster near the center of galaxy. After several years the background star has moved away, astronomers can sometimes observe the lensing star again and learn more about it. We will probably never know about it since it will never be observed again.

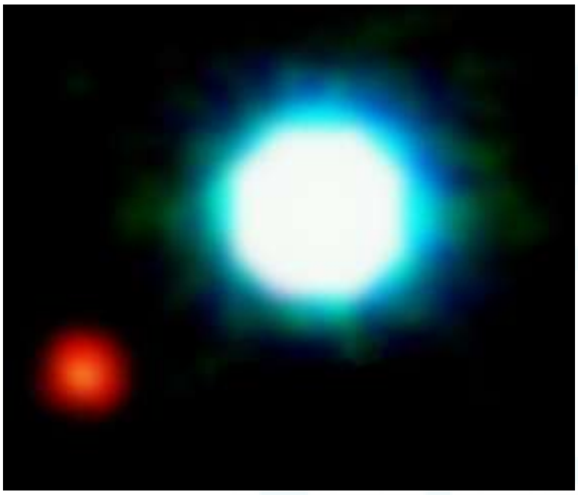
Another problem is that distance of the detected planet from Earth is known only through rough approximation. This could mean errors of thousand of light years!

Microlensing is dependent on rare and random events. This makes the discovery of planets by this methods both difficult and unpredictable. OGLE-2005-BLG-390Lb was the third planet ever detected by microlensing so, this is the biggest drawback of this method.

3) Direct-Imaging

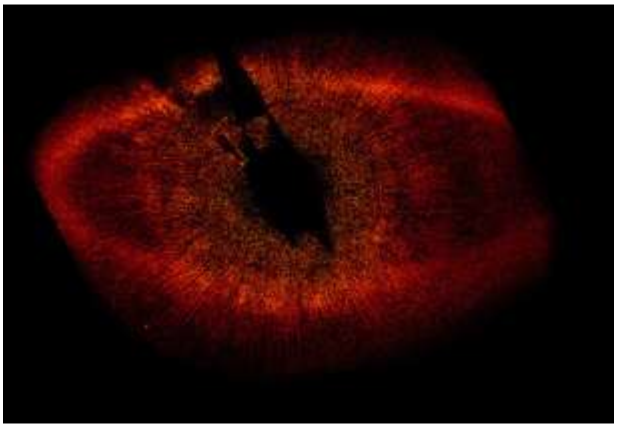
Direct imaging of exoplanet is very very difficult, and in most cases impossible. Being small and dim planets are easily lost in the glare of the giant stars they orbit. There are some special circumstances in which a planet can directly observed with existing telescope technology.

In July 2004 astronomers used European Southern Observatory's Very large Telescope Array to imaged a planetary mass object, several times the mass of Jupiter, in close proximity to a brown dwarf (a star of relatively small size and low luminosity) designated 2M1207 at a distance of 200 light years from Earth. After more observations confirmed that the object was indeed in orbit around 2M1207, and many consider the images to be the first directly imaged exoplanet.



First Image of an Exoplanet
(object around brown dwarf 2M1207)

Also in November of 2008 astronomers using the Hubble Space Telescope announced that it had imaged a planet orbiting the star Formalhault. The discovery was made possible because of Fomalhault is surrounded by thick gas and dust. The sharp inner edge of the disk suggested to astronomers that a planet had cleared out debris (loose natural material consisting especially of broken pieces of rock) from its path and pointed out where its orbit would be. These clues were enough for astronomers to locate the planet in Hubble images of the disk.



Hubble Telescope image of Planet Fomalhault b orbiting star Fomal hault.

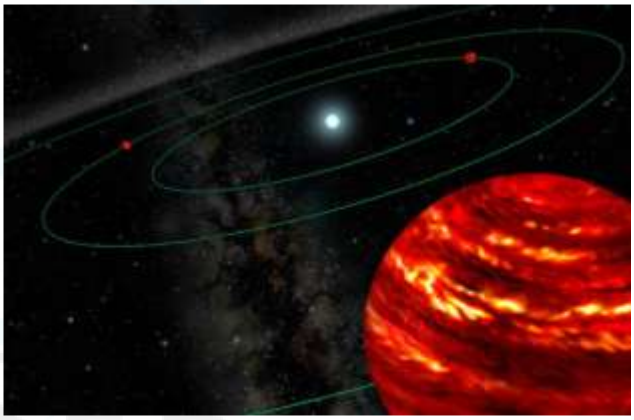
On the same another group of astronomers announced the imaging of 3 planets orbiting the star HR 8799. Unlike Formalhault b, which was imaged in visible light, these planets were detected in the infrared range of spactrum. This is because HR 8799 is a young star and the plantes around it still retain some of the heat of their formation, which registers in the infrared range.

Despite the difficulties, scientists have managed to produce images of exoplantes, however, such imaging is possioble only in rare and unusual situations.

Advantages

For humans "seeing is believing" and that applies extrasolar planets as well. On rare occasions when direct imaging is feasible, it can provide scientists with valuable informations about the planet. For example in case of Fomalhault b, the planet's interaction with the protoplanetary disk (a rotating disk of dense gas and dust surrounded a young newly formed star) and the fact that it is visible in the infrared provided strong limits of its mass and this led scientists to know that it is surrounded by a massive ring system.

For many reasons, direct imaging works best for planets that orbit at a great distance from their star, and for planetary systems that are positioned face on when observed from Earth.



Three planets around HR 8799 (concept image by Artist Lynette cook)

Disadvantages

With current observational technology direct imaging is possible on very rare occasions. Because of strict limitations direct imaging is not good choice for large-scale surveys searching for new exoplanets. This method's importance today is as much psychological as it is scientific.

4) Astrometry

It is the science of precision measurement of star's locations in the sky. When planet hunters use astrometry, they look for a minute but regular wobble (an unsteady movement from side to side) in a star's position. If a periodic shift is detected, it is almost certain that the star is being orbited by a companion planet.

Astrometry is the oldest method used to detect exoplanets. In 1943 astronomer Kaj Strand, working at Sproul Observatory at Swarthmore College announced the presence of a planet orbiting the star 61 Cygni.This announcement was followed after two decades by two other contentious claims. In 1960 Sproul astronomer Sarah Lippincott published a paper claiming that the star Lalande 21185 was orbited by a planet of roughly ten Jupiter masses, and in 1963 Peter Van de Kamp, announced the discovery of a planet orbiting Barnard's Star.

The Keck telescope in Hawaii, the largest in the world, are currently being fitted for astrometrical measurements of the accuracy of 20 micro arcseconds (A unit of angle; one millionth(10^6) of an arcsecond), when directed at single stars. This is equivalent to the diameter of a golf ball at the distance of the Moon.

The future of astrometry lies in space because atmospheric interference limits the accuracy of ground based measurements. NASA's Space Interferometry Mission (SIM) has been delayed multiple times. Once in orbit around the Sun, SIM will be able to make angle measurements of a single as accurate as 1 micro arcsecond. Which we can imagine as the width of human hair at a distance of 500 miles.

SIM PLANETQUEST (artist's conception of SIM. Mission was cancelled in 2010.)

Advantages
Astrometry is one of the most sensitive methods for detection of extrasolar planets. Unlike transit photometry, astrometry does not depend on the distant planet being in near perfect alignment with the line of site from the Earth, and therefore be applied to a far greater number of stars. Astrometry provides an accurate estimate of a planet's mass, and not just a minimum figure.

Astrometry provide excellent help to the spectroscopic method, currently dominant among planet hunters. Whereas spectroscopy works best when planet's orbital plane is "Face on", or perpendicular to an observer's line of site. This is because astrometric observations cannot detect a star's displacement towards or away from the Earth, as it does not produce any change in the star's position in the sky. Astrometry can only detect star's wobble that moves it to different location. So, planet's orbital plane must be "Face on" position when seen from the Earth to get larger component of its movement that can be measured.

A planet with a long orbit causes a greater displacement of its star location during its orbit than a planet that is in close proximity to its star. So, astrometry will be helpful in detecting stars of long periods, orbiting far away. Whereas spectroscopy is best at detection planets with short periods, orbiting very close to their stars. This means that astrometry can actually detect small planets orbiting far from their star and it is a very big advantage for scientists looking for Earth like planets.

Disadvantages
It is really hard to discover exoplanet through astrometry. It requires a degree of precision that is hard to achieve even with the largest and most advanced telescopes. Although astrometry is the oldest method of searching for exoplanets, and after so many claims of discovery that have been made over past 60 years, no exoplanet have as yet been found by this method. Some good missions like SIM also got canceled due to some reasons.

Astrometry is highly sensitive in nature to the distance of a celestial object from Earth. But even accuracy in measurement can have its drawbacks. The new astrometric measurements could be so sensitive that they might be affected by starspots (the darker regions on the face of a star that appear to move as the star rotates).

In order to detect planets, it is important to observe the repeated periodic displacements of its parent star.This mean star needs to be observed for longer than a single orbital period. A star must be observed continuously for years or even decades before the presence or absence of a planet can be proved. Such longtime projects are very hard to sustain due to scientific funding, publishing pressures, and also length of scientific careers.

NOW let's get to the method that actually worked:

5) Radial Velocity
The radial velocity method also known as Doppler (shift in the spectrum of the planet) spectroscopy, is the most effective method for locating exoplanets with existing technology. The majority of Exoplanets discovered so far were detected by this method.

This method works on the fact that a star does not remain completely stationary when it is orbited by a planet. It moves, ever so slightly,in a small circle or ellipse, responding to the gravitational tug (a hard or sudden pull) of its smaller companion. These slight movements affect star's normal light spectrum when seen from a distance. If the star is moving towards the observer, then its spectrum would appear slightly shifted toward blue; if it is moving away it will be shifted towards the red.

Astronomers use highly sensitive spectrographs for searching periodic shifts toward red, blue, and back again. If the shifts are regular, repeating themselves at fixed intervals of days, months or even years, it means that the star is moving slightly back and forth (towards the Earth and then away from it in a regular cycle). This is almost certainly caused by a body orbiting the star and if it is of low mass it is a planet.

6) Meter Telescope Dome (In La Silla, Chile)

This method is so successful because of development of extremely sensitive spectrographs in recent years, which can detect even very slight movements of a star. For example- The spectrographs used by Geoff Marcy's team of planet hunter can detect a star moving as slow as 3 meter per second and this U.S. Berkeley based team is responsible for the discovery of over half of the exoplanets known to date.

Advantages

Radial velocity was the first successful method for detection of exoplanets, and is responsible for identifying hundreds of worlds. It is the most effective method.

Disadvantages

The main drawback of this method is that it cannot accurately determine the mass of a distant planet, but only provide an estimate of its minimum mass. This is a big problem because mass is a leading criterion for distinguishing between planets and small stars.

This problem occur because radial velocity method can only detect the movement of a star towards or away from the Earth.This problem can be overcome if the distant planetary system appears "edge on" when observed from the Earth, in this case the entire movement of the star will be towards or away from the Earth, and can be detected with a sensitive spectrograph. The mass of the planet calculated from this movement will be fully accurate.

However, the orbital plane of the planet is "face on" when observed from the Earth, the entire wobble of the star will be perpendicular to an observer's line of vision.

But in so many cases a planet's orbital plane is neither "edge on" nor "face on" when observed from the Earth. It is tilted at some angle to the line of sight, which is unknown. In these case a spectrograph would not detect the full movement of the star, but only that component of its wobble that moves it towards the Earth or away from it. We can say that mass of suspected planet is directly proportional to the star's actual wobble.

Another drawback of this method is it is most likely to find the type of planets that are the least likely to be hosts to life. Scientists used give "hot Jupiter" name to these type of planets detected by spectroscopy. These are giant planets composed of gas, similar to Jupiter, but orbiting a very short distant from their star. These are most easily detected by spectroscopy. Cooler planets orbiting far away from their home star produce less wobble are much harder to detect with spectroscopy.

So, these are the main methods which are currently being used by our scientists and planet hunters and in future many more methods will also develop.

Now, let's talk about "Why we should fund and do more research in Exoplanet exploration?"

In their life cycles than Earth Exoplanets are often at different stages. The solar systems they make up have different characteristics than our own. This diversity has taught us how our solar system could have looked. Some stars host larger planets, some have their planets distributed differently, and other have planets with more elliptical orbit. This diversity also teaches us about solar system formation. For example, solar systems with Jupiter-sized exoplanets near host stars confirmed the theory that planets move during formation.

And, also exoplanets lead us towards answering what many consider the ultimate question: are we alone in universe? We don't yet have the technology to search exoplanetary life, but that doesn't mean that life isn't out there. As we start to find Earth like habitable planets, one day we even be able to answer this question.

And there is very great saying in the movie "Interstellar" that "Humankind was born on Earth, not meant to die here". And we will only be able to continue this research with full force when we have full funding from the authorities.

Another, idea that can focused is involving common people, school and college students in this research for these space agencies of different countries should come together and provide all required knowledge to all. If we will not have human resource to continue this research then how it will succeed so we have to create a valuable and knowledgeable human resource to continue this research for generations.

There is so much to explore, we have to come together to make a giant effort.

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