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Progress in the Observation of Exoplanets

Tsiferana M. Andrianjafy[1], Hery T. Rakotondramiarana[2,*]

[1]Department of Physics, Faculty of Sciences, University of Antananarivo, Antananarivo, Madagascar
[2]Institute for the Management of Energy (IME), University of Antananarivo, Antananarivo, Madagascar

Abstract It is known that the Universe also contain many other planetary systems which are different from our Solar system in terms of host star, number and natures of orbiting planets. The present paper aims at reviewing works done for observing exoplanets. For that purpose, detection technologies and methods are specified first. Then, different possibilities of exoplanet characterization are presented. Finally, progress of the search for habitable exoplanets is discussed. Though Earth is up to now the perfect planet ever known where life is possible, humanity does not lose hope and continues to invest to build more efficient exoplanet detection instruments.

Keywords Exoplanet, Habitable zones, Detection technologies, Characterizations

1. Introduction

Science of exoplanets is one of the most important and the most advanced recent fields in astronomy [1-3]. Discovery of exoplanets which are extrasolar planets, resulted in a steady increase in number of planetary scientists, who are experts in studying various space objects [4] for discovering one or even more planets similar to the Earth [5]. Many exoplanets have been discovered by astronomers [6-8] although many steps are necessary to confirm the existence of an exoplanet [9] which can be detected by means of telescopes [10]. There are several types of telescopes that are specified according to their observability [2, 11-13]. In particular, space telescopes give rise to new astrophysics [14], but terrestrial telescopes which have wide diameters are also invaluable for the characterization of exoplanets [15].

Instruments within the telescopes are specialized for the characterization of the exoplanets to observe. For example, SPHERE (Spectro-Polarimetric-High contrast Exoplanet Search) [16] inside a telescope in Chile, 4 high-tech instruments being installed in the James Webb Space Telescope [17] large, as capturing lights from certain celestial objects is difficult [11].

Extraction of physical properties of a planet or a system of exoplanets can be more precise whether by combining several observation techniques that follows a certain number of steps [18] or by uniting many observation domains [18, 19]. Due to the surrounding environment of extrasolar planets, that is, surroundings which are close except the chemical composition of their near star, exoplanets have particular movements [5, 20, 21]. A project called ExoMol aims at listing several molecules so that astronomers can characterize the physical and chemical aspects of astronomical objects, especially exoplanets [7]. COROT-7b is the first rocky exoplanet discovered by astronomers, it is very close to its parent star and is in its phase to transform into a gaseous giant [22].

In the present paper, it will be recalled first that there are many star systems in the universe and there exist exoplanets orbiting around various stars. Then, methods used by astronomers for detecting exoplanets will be presented. The next section focuses on available human technologies for observing extrasolar planets. After that, the characterization of these celestial objects will be discussed. The last section will talk about astronomy and the detection of extrasolar life.

2. Systems of Stars

In the universe, there are several systems of stars either in binary systems or in multiple systems [23]. In addition, almost half of the stars in the universe are in binary systems [24]. Similar to Sun and its neighbouring stars, there are also stars with a simple system [25]. There are several varieties or classes of stars according to their names [6, 25-31]. For example, our near star "Sun" is a star belonging to class G [32] which is in its main sequence phase [33]. There are also several types of binary or simple star systems being in the main sequence phase [11, 26].

While stars being the seats of nuclear reactions, hydrogen atoms are fused into helium in the case of Sun. As for white dwarfs, their hydrogen atoms have all been burnt [16] while helium atoms of class B stars are all burnt in their cores [30]. Stellar activities such as the southern movement of stars have

* Corresponding author:
rktmiarana@yahoo.fr (Hery T. Rakotondramiarana)
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effects on the stellar convection zone and its dynamic mechanisms or cycles [34]. Stars have then specific nuclear properties according to their classes or groups [35-38]. Some of them have a long lifetime [28].

The high spectral resolution of stars allowed discovering their physical and chemical properties [39, 40]. Besides, binary systems enabled researchers to more easily derive the masses of stars that form such a system [24]. Special projects and instruments have been implemented and invented for studying stellar oscillations [12, 41] as well as confirming the natures of stars [11, 42]. While light being a source of information in astrophysics [11], the majority of our knowledge of the universe obtained by the experts come from spectral studies of astronomical objects [35]. In particular, astronomers were able to detect exoplanets by characterizing stars [36].

3. Other Exoplanets around Star Varieties

The solar system is not the only system in the galaxy where planets revolve around a star [43]. Our galaxy, which is very large [44], is full of planetary systems [11]. In 1995, Mayor and Queloz [47] were the first to discover an exoplanet which revolves around a star of the main sequence called 51 Pegasi b [5, 46]. Later on, several extrasolar planets have been discovered [42, 45].

Most of the aforementioned planetary systems differ from ours [48] as the planets that compose these systems have their own characteristics [45]. Some of the exoplanets that have been discovered are found in binary star systems [42]. For example, a binary star system of the main sequence M0 and M1 was detected from the ESO-NIT [25], as a planet orbited around one of the stars [25]. Another binary star system of class M in which 5 exoplanets orbit one of the stars that form the planetary system was also discovered [32]. However, exoplanets revolve around varieties of stars but not around stars of the main sequence only [27, 33, 36]. The first confirmed exoplanet system was discovered around a pulsar that surprised scientists [27]. An exoplanet orbited a class K star which is rich in heavy elements [37]. Projects such as AAPS (Anglo - Australian Planet Search) are currently implemented in order to detect exoplanets around class F, G, K and M stars.

There are several types of exoplanets [20]. The majority of exoplanets discovered by researchers are gaseous giants [2], very wide, very hot and none of them is similar to Earth [43]. Planets that have 10 times the mass of Earth may be Jupiterian-like planets [47]. The abovementioned 1995 first discovered exoplanet is Jupiterian-like type [47]. Giant planets often form around stars that are rich in heavy elements [45]. An exoplanet that is 8 times the mass of Jupiter was detected around a star named KO I-13 [49]. Another Jupiterian-like planet was also detected by the QES, orbiting a class K star [37]. Two Jupiterian-like exoplanets were found around a subgiant class star [28]. Hence, a project called BEST was carried out for the search of exoplanets that have masses neither smaller nor larger than Jupiter [48]. Likewise, another project entitled "Rapid Imager to Search for Exoplanet" has been conducted for the observation of Jupiterian-like exoplanets [50].

There are also Mercury-like exoplanets [51]. A system formed by 5 planets that are similar in size to Earth and orbit a class M star has been detected [32]. Moreover, exoplanets that have weak orbits have also been detected [31, 52]. On the other hand, a system formed by 3 planets having similar sizes to Neptune’s was also discovered [53]. In addition, there is also an exoplanet of which size is equivalent to Earth’s, it is called Gliese 581g [24]. Besides, another planet having a radius equal to 1.6 times that of Earth was discovered by the instrument PAVO [55]. The number of exoplanets in the Milky Way is estimated at 100 billion [54].

It is worth noting that brown dwarfs are astronomical objects of lower temperature than stars; they are neither stars nor planets [56].

4. Detection Methods

The first exoplanet discovered by Mayor and Queloz [47] was confirmed by the observation method called the radial velocity method [57, 58]. This method is the first to successfully detect exoplanets [59]. It is based on the "Doppler effect" caused by the light of a star [1]. More precisely, it is based on the observation of the oscillation or wavelength variation of the star’s spectral lines, which is caused by planet(s) orbiting it. The radial velocity method is then a method of indirect observation [11]. It appeared to be an effective method in the detection of exoplanets [3, 60]. This method allowed us to know many exoplanets [61, 62]. It is because of it that scientists have also discovered other planetary systems [23].

Moreover, most of our knowledge of exoplanets comes from the radial velocity method [63]. Despite its advantage in detecting exoplanets [41] and determining the orbital period as well as the eccentricity [52] of a detected planet [34, 45], the mass of a planet detected by means of this method is not accurate [57, 64] because of the poor knowledge of the inclination angle between the orbit of the planet [61, 64] and the observer’s sight line [64, 65]. Any modification of this method may lead to false results during detection [9, 66].

Another method which is also effective [67] and practicable for detecting exoplanets [68] is the "transit method" that enabled scientists to observe many exoplanets [16]. It is based on the observation of the exoplanet-star eclipses seen from an observer [40, 67, 68]. It is used for the first time in 2003 [45].

The orbital inclination of a planet and its relative radius vis-a-vis its parent star can be obtained during transit [50], that is, the passage of the planet in front of the star seen from the observer [68]. This method can reveal the mass, radius, and also the density of a detected planet [37].

The disadvantage of this method is that the light flux of the planet is very weak in comparison to that of its host star [11, 69-71].

By combining data retrieved from the transit method with that of the radial velocity method, the masses and rays in an exoplanetary system are thus obtained [58, 72]. Other physical parameters of the system can also be derived from the combination of these two methods [50, 57]. The radial velocity method provides more information on a planet when compared to that of the transit method [59]. For exoplanets that are in simple or normal star systems, the radial velocity method is simpler to find the masses of the planets in this system, whereas the transit method is more suitable for multiple star systems [71].

Many methods are valid for detecting exoplanets [34]. For example, it measures the transverse component of the displacement of a star due to the gravitational perturbation of the planet orbiting it [27]. The TTV method is also effective in the detection of Exoplanets [73]. Exoplanets can also be detected based on the principles of geometric optics [74].

Direct observation of exoplanets also has an issue related to light flux between the exoplanet and its host star [68]. Stellar activities can cause false detection except for the direct detection method [36]. It is difficult to detect an exoplanet having a particular position such that destructive interference from the host star generates minimal interference [74].

5. Detection Technologies

5.1. Earth Telescopes

One of the most developed areas of astrophysics is the discovery of exoplanets [1]. This discovery is sometimes difficult [11, 43] because the light sent from an exoplanet is very weak when compared to that of its host star [71]. The terrestrial telescopes can still detect them [47]. There are several terrestrial telescopes that can detect exoplanets [75-78]. A small telescope is also able to confirm the nature of a star [33, 79].

As examples, the AAPS project, the Lick and Keck telescope can detect exoplanets around certain star varieties, more precisely F, G, K stars, and stars of class M, which have magnitudes lower than 7.5 [31]. WASP was able to observe an exoplanet candidate in a more or less precise position [77]. A project called YETI is a project to locate small telescopes, with a diameter ranging from 0.2 to 2.6 m, in all four corners of the world for detecting exoplanets around star groups as well as young extrasolar planets during their phases of transit, as much as possible [36]. Moreover, HARPS is a telescope located in Chile and uses the radial velocity method [48]. There is also the Automated Planet Finder Telescope which also uses this method of observation [33].

Terrestrial telescopes play important roles in the characterization of gaseous planets during transit [80]. UKIRT (United Kingdom Infrared Telescope) was able to obtain information about the chemical composition of the atmosphere of an exoplanet [81]. ELT (Extemely Large Telescope), which is a large-diameter telescope and can solve certain detection problems such as Earth's atmosphere [11], it can also characterize the atmosphere and surface of a planet having Earth's size [82].

Today, terrestrial telescopes can detect satellites of Earth-size exoplanets that are in the habitable zone of their host star [83]. In the future world, large terrestrial telescopes will detect extrasolar planets that are in the habitable zone of the main sequence stars [78].

Instruments in terrestrial telescopes are used to highlight the lights sent by exoplanets and to discover new exoplanets [29] as the case of SPHERE equipping the VLT telescope [16]. Another example of such instrument is RISE (Rapid Imager to Search for Exoplanet) which, equipping another telescope located in Liverpool [84], was modelled to obtain more precision on lights released by exoplanets while using the TTV technique, and was designed for the observation of transit planets and Jupiterian-like ones [50]. It was with the help of RISE that astronomers were able to observe an exoplanet called WASP-13 [84].

5.2. Spatial Telescopes

On Earth, it is impossible to detect exoplanets which are smaller than Earth due to the Earth's atmosphere; this envelope is an obstacle for various waves released by planets and other celestial objects, that is to say, ground based telescopes cannot obtain more astronomical object waves [11, 13]. This is the major cause of spotting telescope out of the Earth's atmosphere [11]. Those spatial telescope are effective in the detection [10, 12, 47, 48, 55, 64, 85] and in the characterization of exoplanets [13, 16].

COROT (Convection Rotation and Transits) is the first spatial mission aiming at detecting stellar seismology [12] and exoplanets during their transits with a high precision in photometry [86]. As its name indicates, it uses the transit observation method [58, 85]. It was launched in February 2007 and stopped in 2012 due to electrical failures within it [58, 86]. It was assumed to detect an Earth-size exoplanet [85] and satellite of exoplanets having size smaller than the Earth's [83]. COROT has detected numerous exoplanets [58, 85, 86] and has characterized exoplanets and it is the first telescope which discovered a rocky exoplanet [58]. Its drawback was that it could not detect exoplanets in any binary star sys-tem [58].

COROT is not the only spatial mission for scrutinizing exoplanets [16, 58, 67, 80, 87, 88] and stars [89]. In 2009, the NASA launched the Kepler mission for studying astronomical objects by means of the transit method [48, 58]. Kepler could pick photometric signals up with high resolution [64]. One of the objectives of that mission is to discover exoplanets orbiting in the habitable zone of their respective host stars [55, 90]. Though Kepler stopped its works in May 2013 [58], not only it allowed observing several exoplanets [6, 49, 58], but also enlarged our knowledge about smaller size exoplanets [58, 86], that orbit in binary star system [86] and exoplanetary system [90]. Scientists found that the results obtained with the Kepler telescope are equivalent to those obtained with the radial method [52]. Small exoplanets detected by the Kepler mission have small orbits [52]. Even though it was designed to look for rocky exoplanets that have orbits similar to the Earth's, the first and only detectable exoplanets are those orbiting near to their host star [22]. The Kepler mission could not distinguish or group the rocky exoplanets according to their types, that is, either Earth-like group, Venus-like group or Mercury-like group [91].

Spatial telescopes, such as HST and SST, carry infrared instruments [13, 32, 81]. The Hubble telescope can observe in the ultraviolet and optical wavelength [18], it can provide astronomical data about the atmospheres of some giant gaseous exoplanets [92]. With the infrared instrument equipping SST, atmospheres of some exoplanets were detected [32]. The Splitzer telescope has also presented data on the decrease of the luminosity flux due to the passage of a planet behind its host star while sighting from Earth [81].

TESS had been proposed to be launched in august 2017 by NASA, it should observe bright stars [58]. It would detect Earth-size exoplanets [16] that are situated in habitable zone of some types of stars [58]. Besides, "StarShade" mission, also known as Exo-S, offers the capability to measure the spectra of Earth-size exoplanets [93].

Ground based telescope and spatial telescope harmonically work [86, 93] to make the establishment of the transit objects' nature and their masses easier [86]. A spatial telescope, named JWST, that is a project of NASA, Canada and Europe, is scheduled to be launched in October 2018 [16] for succeeding the Hubble telescope [2]. It can also study or code molecules in the atmosphere of exoplanets [94].

5.3. Instruments and Detections

Observation of exoplanets that orbit other stars than Sun is very blurred because they are too far away and their closest stars are too bright [11]. Thus, data obtained from observations can be limited by these noises [46]. Optical and interferometric technological devices were used to remove obstacles that may drive astronomers to false results during observations [55].

The VLT has an instrument called SPHERE [16, 29] which equips an adaptive optics and coronagraph instruments to highlight the luminosity of exoplanets [16]. Spectrograph is an effective instrument in the study of stellar object [59]. NACO is an instrument with high contrast in the field of spectroscopy [78]. PRIMA can also allow astronomers observing exoplanets that orbit bright stars [41].

Observation of astronomical objects in the infrared wavelength is one of the most efficient methods in the interstellar and interplanetary areas [2, 19]. Researchers can draw some deduction about mineralogy composition of one planet in this domain of wavelength observation [83]. At Calar Alto astronomical observatory can be found. MAGIC which is an example of a device that is equipped with an infrared instrument [42]. Another example of this type of instrument is UKIRT which was able to obtain some information about the atmospheric chemical composition of an exoplanet [81].

Instruments for detecting exoplanets in the near future will be fit out with infrared, coronagraph and adaptive optics devices [46]. JWST which is going to carry four infrared and spectrometric cameras, such as NIRCAM, NIRSPEC, MIRI and FGS [17], can study rocky Earth-like exoplanets [95] and will work in the fields of infrared [16] to detect more molecules in exoplanets [2, 94]. Earth itself is an infrared source and it is also for this reason that telescopes equipped with infrared instruments are often in space [11]. In addition, infrared cameras can detect stars in binary systems [25]. New instruments have been invented to detect new exoplanets [29] and also to resolve observational issues such as the luminosity between exoplanets and their host stars [70]. Another spatial telescope called SPICA and basically equivalent to JWST, is going to be launched in 2018. More precisely, it works in the infrared observation domain and is also equipped with a coronagraph instrument which is generally useful for obtaining astronomical data [97] needed for the study of star corona [88]. The SCI will be able to detect giant gaseous exoplanets with masses lower than Jupiter's; in addition, astronomers can also deduct ages of some planets for understanding their formation and evolution by means of this kind of telescope [96].

The majority of the astronomical data of exoplanets come from a series of observations either with high accuracy in photometry [45, 47, 63] or in spectroscopy [63] using the radial velocity method [45, 63]. Data that are obtained from high contrast instrument and optimized in the case of direct detection of giant gaseous exoplanets, can be limited by spectral noises. Though there are many methods that allow obtaining more visible and more understandable images, several images remain unclear, especially those of faint planets [46].

Reconstruction of an exoplanet image from the obtained spectra is complicated [98]. The Python scientific software was used for data analysis in the radial velocity method [63]. PynPoint is an improved version of Python [69] that researchers use to process the obtained data in order to detect exoplanets in 2-dimensional image [69]. Another algorithm was proposed to automatically organize in group the data obtained from an observation [5]. MCMC was invented to facilitate the Bayesian method [51, 99]. The Bayesian is a basically mathematical study which can facilitate exoplanet detection during the observations of stars using the method of the radial velocity. VISTAR is a software that allows predicting the spectra of the planets in the solar system, exoplanets, and some types of stars [100].

6. Exoplanet Characterizations

6.1. General Characterization

The relationship between X-ray emission by a star's corona, the age of the same star and the change of this relationship are requisite to reveal the following exoplanets' history, that is to say, the age of the orbiting exoplanets [39]. To understand the mechanism of formation and evolution of planets, data from characterization of their host stars are useful [40, 101]. The transit method enables scientists to detect and to study the formation of some exoplanets [5, 18].

Star's interaction can modify the form of exoplanets which are in their way of forming or formation phase: if this force is strong, the corresponding planet will have size similar to comet's; if this interaction is strong and other planets orbit the same star as the planet in its formation phase, then its orbit will vary [20]. Thus, this can affect masses and radius of planets which are in their phases of formations [22]. Strong interaction between planets and its or their host star plays an important role in the movement of each components which constitute the planetary system: it synchronizes the rotation of the corresponding system [20]. Analytical and practical method have been invented to calculate this force between astronomical objects that form a planetary system in order to determine the planets and star velocities as well as positions with time [102]. Planets do not orbit stars instead it is the entire system (planet(s) – star) that orbits one point named "the center of masses" of the following system, in one sense [11].

Orbital distributions of planets in one system is one of the keys to understand the formation and evolution of planets respected [40]. Radial velocity method offers researchers an opportunity to extract orbital parameters of exoplanets [66], for example eccentricity and orbital period [34, 45]. AAPS and the Keplerian Lamb Scales are projects which are able to detect directly particular exoplanets having large eccentricity [103]. Eccentricity of exoplanet has a major role on the rotation and climate of exoplanet [104, 105].

Observation from Super WASP, TLC, data from the ETD and those from Jena telescope allowed scientists confirming that the orbital period of an exoplanet named X0-1b changes [3]. The ratio of heavy elements in a star has no relationship with migration or orbital change of a planet that orbits a star [5], but it is the presence of neighbouring heavier planets that principally causes the exoplanet's eccentricity or orbital change [20]. Ultraviolet evaporation has a major impact on the distribution of the semi-major axes of a giant planet [21]. Several Jupiterian-like planets that have orbits very close to their host stars, have been detected, although they cannot form in those positions [21].

Orbital inclination of one planet and its radius relatively to the host star are obtained by means of photometry observation series during the corresponding planet transit phase [50, 63]. PRIMA is an example of instrument which can determine this inclination [41], contrary to most of exoplanets that have been discovered via radial velocity method in which orbital inclinations are often unknown [61].

Mass and radius of planet play important roles in the planetary internal structure and composition [45, 94]. These parameters can be obtained from stellar properties [101]. In exoplanetary system, they can be obtained by combination of data from radial velocity method and those from the transit method [50, 72]. Exoplanet mass values obtained via spectroscopic observations [65] or via radial velocity might be limited as the angular inclination between planet's orbit and the observer's sight line is unknown [64, 65].

The density of a planet can be deduced from its mass and its radius [72]. Based on the study of density, an estimate of the relationship between the radius and the atmosphere of an exoplanet can be suggested in which planet that has 3/2 of the Earth's radius could be enveloped by gas [71].

6.2. Dynamic Characterization of Exoplanet

Exoplanets also possess atmospheres [13] of which identification is based on the molecular composition of the host star's light waves striking the following planet [35]. Spectral rays sent from astronomical objects hide their atmospheric compositions [20, 35, 81] since the atmosphere characterization of an exoplanet is based on the studies of its host star too [29]. Spectroscopic observations of Jupiterian-like exoplanets have allowed astronomers deriving the thermal structure and molecules in their atmospheres [13]. The atmosphere's chemistry of exoplanet is possible currently for some types of exoplanets [11, 95, 106]. Astronomers can decipher atmospheric compositions of gaseous exoplanets from infrared data [2, 29, 32, 92]. The characterization of the atmospheres of exoplanets is easier in the observation of spectra in the ultraviolet, optical and infra-red domains [71]. The disappearance of atmosphere on some exoplanets are mainly caused by X-ray and ultraviolet radiation that hit them [92, 106].

Several researches were done from three-dimensional simulations for the study of atmospheres of exoplanets [107, 108]. Astronomers assert that the atmosphere of young gaseous planets is composed of dust [29].

Sodium atoms have been detected in the atmosphere of a planet and atoms of hydrogen, carbon as well as oxygen were found in its exosphere [81], whereas clouds of silicon have also been discovered in atmosphere of others [11]. Huge amount of oxygen can stabilize or retain the atmosphere of a planet up to millions of years, if this amount is not enough then the atmosphere will be absorbed by the planet itself or evaporated into space, which is the case of Venus a long time ago [95].

Planets that have masses between 1 to 20 times the Earth's mass might be primordially enveloped by hydrogen layer as they had captured gases from the solar nebula but the following planet may loss it [105, 109]. In geophysics, factors such as volcanic activities might also play important roles in the storage of gases in the atmosphere of a planet

[110].

A method was developed for measuring the temperature of certain Jupiter-like planets via the association of photometric data with the infrared's [19]. Theoretical studies show that the temperature on the surface of an exoplanet increases due to condensation of Greenhouse Gas (GHG) such as carbon dioxides (CO2) in its atmosphere. The temperature at the surface of an exoplanet that has an atmosphere dominated by GHG also depends on the orbital distance of the exoplanet, pressure on its surface and in its atmosphere, stellar spectrum striking the planet's atmosphere and surface, as well as the mass of the exoplanet [6]. In particular, cold planets having an atmosphere dominated by CO2, would have small rate of hydrogen and water vapor in its atmosphere but if the atmosphere is dominated by hydrogen then the amount of oxygen in its atmosphere is small [111].

Strong magnetic field on planet protects it from stellar wind and helps it retain water on its surface for a very long time [112]. The measurement of magnetic field on an exoplanet drives scientists to the knowledge of the interior dynamics of it [113]. Magnetic field detection is currently possible for giant gaseous exoplanets by means of specific instruments, while on rocky exoplanets no data have date obtained. The existence of magnetic fields on rocky planets in our solar system depends on their compositions or their internal structures [114].

The relationship between the mass and the surface of a planet has a major influence on the increase or decrease of its polarization [29]. The spectral analysis of an exoplanet is necessary to characterize its surface. An analytical method was applied by scientists for studying the polarization of Mercurian-like exoplanets [51]. The strength of the atmosphere of an exoplanet has an influence on its surface's polarization [29].

The study of the interior properties of rocky planets enabled experts to reveal some important properties of a planet. Plate tectonics plays roles in the evolution of planets and their habitability conditions similar to Earth's and also organisms which are on it [115, 116]. Two-dimensional and three-dimensional models were applied for the study of plate tectonics in rocky planets, this parameter is independent of the planet size but the presence of water on its surface. It is also due to the plate tectonics that oceanic and terrestrial crusts formed on Earth [117]. While estimating spectral density emitted by Jupiterian-like exoplanets, scientists found some candidates out where volcano activities may be possible, they occur in exomoons of those Jupiterian-like exoplanets and are located 25pc from Earth [38].

6.3. Chemical Composition

Atoms and molecules have been detected in small exoplanets of which size is smaller than our Neptune's [71]. Mineralogical information about planets are obtained from spectral lines in the infrared band [40, 118]. The composition, structure and evolution of planets that orbit a star depend on the star chemical compositions [45]. Some scientists have gathered all the different molecules which exist in our Solar System to determine the chemical components of exoplanet that looks like Earth or simply a twin of Earth [8].

7. Astronomy and Extraterrestrial Life Research

Research for habitable exoplanet(s) is equivalent to the search for planets having the same conditions as Earth and it should orbit around a star similar to Sun [34]. Several projects were proposed to search Earth-like exoplanets [43].

7.1. Habitability

In astrobiology, the expression habitable means suitable for life [26]. The comfortability of life is a general classification of habitable zone defined for life [6]. The standard definition of habitable zone is based on assumption that one habitable planet will have climate dominated by the greenhouse caused by CO2 gas and water molecules [109]. The habitable zone is the zone in a planetary system where liquid water can take form under its formation conditions and temperature is neither too hot nor too cold [43].

Some detected planets are located in the habitable zone of their host stars [6, 10]. Planets situated in the habitable zone of the main M-class sequence stars are good targets for detecting habitable environments [111]. According to stellar conditions, a habitable planet should have a mass ranging from 0.5 to 10 times the Earth's and is at a particular distance where the temperature on its surface and its atmospheric properties are suitable for the formation of liquid water [40].

7.2. Satellites of Exoplanets

A motivation was also proposed to observe exoplanetary satellites or exomoons because they may hold more habitable environment than giant planets [83]. It may be possible that an exomoon could be the same size as the Earth's [83].

7.3. Life is Still Unique

Water is mainly the basis of life [6]. The presence of oxygen in the atmosphere of an exoplanet does not really mean that life on this planet is possible. On Earth, photo-synthesis produces oxygen [95]. Detection of water and oxygen outside the solar system is a priority to discover extrasolarlife because of their roles as being the sources of life [19]. The possibility of extrasolar life on the exoplanet named Gliese 581 was confirmed, by some observations, due to its properties [40, 119]. With JWST, scientists could observe with high precision in the infrared domain molecules that indicate life outside Earth [2].

8. Conclusions

The study of exoplanets is a vast field in the science of celestial objects because its detection and confirmation require several steps even though it is one of the most recent sciences in astronomy and astrophysics. It is due to this topic that numerous theoretical models were developed and many inventions of new high-tech instruments have spread throughout the world as well as in space.

It can then be asserted that the abovementioned subject has only begun because the future observation instruments should bring new discoveries and new data about the characterization of extrasolar planets with their surroundings.

Many projects or space missions aiming at searching for extrasolar habitable planets have been launched either on the surface or outside the atmosphere of Earth. Several clue parameters which indicate the possibility of extrasolar life were found; for example, exoplanets located in the habitable zone of their host stars were discovered but the main factor that indicates life, liquid water existence like on Earth's surface, have not been discovered yet.

According to the mankind sciences' and the technology's in the present day, Earth is the planet that owns the perfect condition for the existence of life on it. Though the search for extraterrestrial life is only at its start phase, experts have already found a lot of encouraging clues. Implementation of the Square Array Kilometre (SKA) project, in which the home country of the present paper authors (Madagascar) actively participates, can contribute in enhancing exoplanet and extraterrestrial life research.

ACRONYMS

AAPS: Anglo-Australian Planet Search
BEST: Berlin Exoplanet Search Telescope
COROT: Convection ROtation and Transit
CO_2: carbon dioxide
ELT: Extemely Large Telescope
ESO-NIT: European Southern Observatory-New Technology Telescope
ETD: Exoplanet Transit Database
Exo-S: Exoplanet Science https://www.hou.usra.edu/meetings/abscicon2015/pdf/7747.pdf
ExoMol: Molecular line lists for exoplanet and other hot atmospheres https://www.exomol.com
FGS: Fine Guidance Sensor https://jwst.nasa.gov
GHG: greenhouse gases
HARPS: High Accuracy Radial Velocity Planet Search
HST: Hubble Space Telescope
JWST: James Webb Space Telescope
MAGIC: https://magic.mpp.mpg.de
MCMC: Markov Chaine Monte Carlo
MIRI: mid-IR instrument
NACO: NAOS-CONICA
NASA: National Aeronautics and Space Administration https://www.nasa.gov
NIRCAM: Near Infrared Camera https://jwst.nasa.gov
NIRSPEC: Near Infrared Spectrograph https://jwst.nasa.gov
PAVO: Precision Astronomical Visible Observatory
PRIMA: Phase-referenced imaging on a micro-arc second astrometry
QES: Qatar Exoplanet Survey
RISE: Rapid Imager to Search for Exoplanet
SCI: SPICA Coronagraph Instrument
SKA: Square Array Kilometre
SPHERE: Spectro-Polarimetric-High Contrast Exoplanet Search
SPICA: Space Infrared Telescope for Cosmology and Astrophysics https://sci.esa.int
SST: Splitzer Space Telescope
TESS: Transit Exoplanet Satellite Survey
TLC: Transit Light Curve
TTV: Transit Timing Variation
UKIRT: United Kingdom Infrared Telescope
VLT: Very Large Telescope
VSTAR: Versatile Software for Transfer of Atmospheric Radiation
WASP: Wide Angle Search for Planet
YETI: Young Exoplanet Transit Initiative

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