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Evolutionary Panspermia: Planets Micro-Life and Beyond

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Abstract

Panspermia is a concept that proposes the genesis of life on our planet and can either be interstellar or interplanetary. The proposed mechanisms of panspermia include lithopanspermia, accidental panspermia, directed panspermia and radiopanspermia. Life has three major requirements to thrive: liquid water, the appropriate chemical elements and an energy source. The space environment has high ultraviolet radiation, but the ability of some extremophiles like tardigrades and microbes to survive in the vacuum of space and ISS is not negligible. This overview studied some parameters on the Martian planet and compared them with the Earth. The parameters of the Mars planet compared to the Earth include; the presence of organosedimentary structures, water channels from runoffs and the presence of biosignature. The analysis of the biosignature methane from this overview showed that Mars methane has varied over time. The presence of methane on the red planet cannot be underestimated because on Earth over 90% is generated by biological activities. The Mars curiosity probe as of 2014 to 2017 has detected variations in plumes less than 1 ppb but there have been spikes of 21 ppb and above. In comparison to Earth, there is an increase in Earth methane level and as of June 2020 stands at 1872.2 ppb. This overview also studied the Europa moon and Exoplanets. From this study, Mars, Europa and Exoplanets like Kepler-452b, Kepler-1649c, TRAPPIST-1d, TOI-700d have potentials for extraterrestrial life. Currently, with the help of molecular biology, the search for extraterrestrial life in our solar system and beyond has taken a new dimension. With the new ability to isolate, sequence and identify microbes aboard the ISS using MiniPCR and MinION, the search for extraterrestrial life has become more fascinating. To understand panspermia better, it is essential for more scientific studies, because its findings will deliver new insights into the primeval solar system and the origin of life on our planet.

Keywords: Panspermia, Earth, Mars, Exoplanets, Methane, MinION and MiniPCR

Introduction

According to Thompson (2018), Panspermia, broadly defined proposes that living organisms or genetic material can travel between planets in our solar system, and even between our solar system and nearby stars. Panspermia is an old concept, dating back as far as the concept of taxonomy when French historian Benoît de Maillet proposed that life on Earth was the result of germs "seeded" from space (Josh, 2011). Panspermia hypotheses propose that microscopic life-forms that can survive the effects of space (such as extremophiles) can become trapped in debris ejected into space after collisions between planets and small solar system bodies that harbour life (Chotiner, 2019; Ruvkun, 2019).

Extremophiles like tardigrades and microbes (bacteria and fungus) can survive for extended periods in the vacuum of space. An experiment on the International Space Station (ISS) found that a number of microbes survived just fine in space for nearly two years and it's almost guaranteed that some species can survive for longer periods (Thompson, 2018). According to Hoyle and Wickramasinghe (1981); Wickramasing *et al.* (2010) and Grossman (2010), Panspermia studies concentrate not only on how life began, but on the methods that may cause its distribution in the universe. Some organisms may travel dormant for an extended period of time before colliding randomly with other planets or intermingling with protoplanetary disks. Under certain ideal impact circumstances (e.g. into a body of water) and ideal conditions on a new planet's surface, it is possible that the surviving organisms could become viable and begin to colonize their new environment. At least, a research study reports that specific species of Bacillus bacteria discovered in Morocco can survive extreme temperatures up to 420 °C (788 °F), making the argument for Panspermia even stronger (Schulze-Makuch, 2018). Contrarily, Pseudo-panspermia argues that the pre-biotic organic building-blocks of life originated in space, became incorporated in the solar nebula from which planets condensed, and were further and continuously distributed to planetary surfaces where life then emerged (abiogenesis) (Klyce, 2001).

Proposed Mechanisms of Panspermia

According to khan (2014) and Dent *et al.* (2014), Panspermia can be said to be either interstellar (between star systems) or interplanetary (between planets in the same star system). Space vehicles may also be a viable transport mechanism for interplanetary cross-pollination in the solar system or even beyond. However, space agencies have implemented planetary protection procedures to reduce the risk of planetary contamination (Thompson, 2018). The proposed mechanisms are:

Lithopanspermia

Lithopanspermia postulates the transport of microorganisms between planets as hitchhikers within rocks ejected into space by impacts (Fajardo-Cavazos *et a*l., 2009). The transport of rocks from Mars-to-Earth is no longer in dispute because to date, more than 30 meteorites have been found on Earth that unequivocally originated on Mars and represents direct samples of Martian lithic environments (Nyquist *et al*., 2001; Meyer, 2007). According to Fajardo-Cavazos *et al.* (2009), the interplanetary transfer process has been divided into three separate stages: (i) impact-mediated ejection (launch) of rocks from the surface of the “donor planet” (ii) space transit and (iii) atmospheric entry and deposition on the “recipient planet”. Each phase of interplanetary transfer is rife with its particular hazards to the survival of life.

Accidental Panspermia

Accidental panspermia is a theory typified as the "Gold Garbage Theory". In 1960, Thomas Gold, a leading professor of astronomy suggested the hypothesis of "Cosmic Garbage". He proposed that life on Earth might have originated accidentally from a pile of waste products dumped on Earth long ago by extraterrestrial beings (Gold, 1960). According to Freitas (2008), Gold opined that extraterrestrial visitors carelessly allowed some of their native microbiota to escape.

Directed Panspermia

Directed panspermia was proposed by Crick and Orgel (1973). Directed panspermia envisages the deliberate transport of microorganisms in space, sent to Earth to start a life here or vice versa. The aim is to seed new planetary systems with life by introducing varying species of microorganisms on lifeless planets. Actively directed panspermia has been proposed to secure and expand life in space (Mautner, 1997). The probability of directed panspermia to secure and expand life in space is becoming acceptable because of developments in solar sails, precise astrometry, extrasolar planets, extremophiles and microbial genetic engineering (Gros, 2016; Barba, 2018).

Radiopanspermia

Radiopanspermia mechanism refers to single exposed microorganisms which are small enough to be accelerated to high velocities by solar radiation pressure, then exit the solar system and traverse interstellar space (Arrhenius, 1908). Provided that some enormous number of microorganisms were ejected from a solar system, it is conceivable that a small fraction may intersect a hospitable planet in a new star system, after $\sim 10^6$ years in interstellar space (Secker *et al*., 1996). For radiopanspermia to effectively seed life on the new planet, some small fraction of the microbes must survive the space harsh conditions and radiation damage. However, even though microbes subjected to full solar radiation are inactivated, the data gathered by the orbital experiments ERA, BIOPAN, EXOSTACK and EXPOSE determined that isolated spores, including those of *Bacillus subtilis* were killed if exposed to the full space environment for merely a few seconds, but if shielded against solar UV, the spores were capable of surviving in space for up to six years while embedded in clay or meteorite powder (artificial meteorites) (Horneck, 2010; Horneck *et al*., 2001).

The Martian Evidence

Over the years, there are a lot of proposals if the Mars support life, currently, evidence is reviewed which supports the hypothesis that prokaryotes and eukaryotes may have colonized Mars. The evidences studied below proves that the red planet may once have blossomed like our planet millions of years ago.

The Organosedimentary Evidence

Fig 1

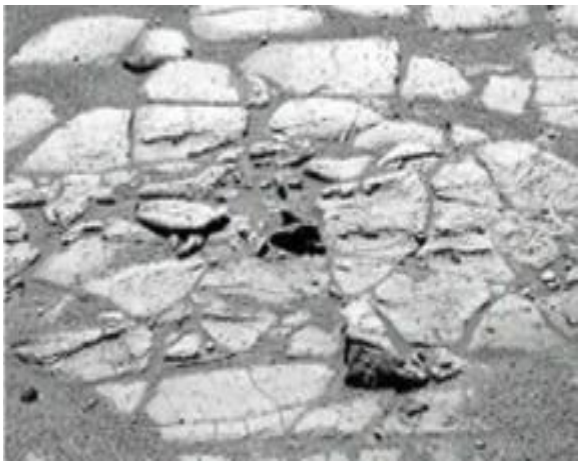

Fig 2

Fig 1 is a tabular domed structure of living Australian stromatolites that could explain the origin of disjointed structures observed on the Martian Surface Fig 2 (Image source: Rizzo and Cantasano, 2009).

Stromatolites prove the evidence of life millions of years ago, the presence of organosedimentary structures on Mars proves that life may have existed on the red planet. In a research carried out by Rizzo and Cantasano (2009), the study used the Microscopic Imager (MI) of NASA Rover Exploration Mission (REM) 'Opportunity' and aimed to explain the origin of laminated sediments lying at Meridiani Planum of Mars and of the strange spherules, known as blueberries. The study proved that such laminated sediments and the spherules they contain are organosedimentary structures, probably produced by microorganisms under extreme conditions. Furthermore, from the structural and textural data the study acquired, they opined that there could be the existence of life on Mars, which could be similar to that of terrestrial stromatolites.

Channels on the Floor of Lyot Crater, Similar to Terrestrial Arctic Region

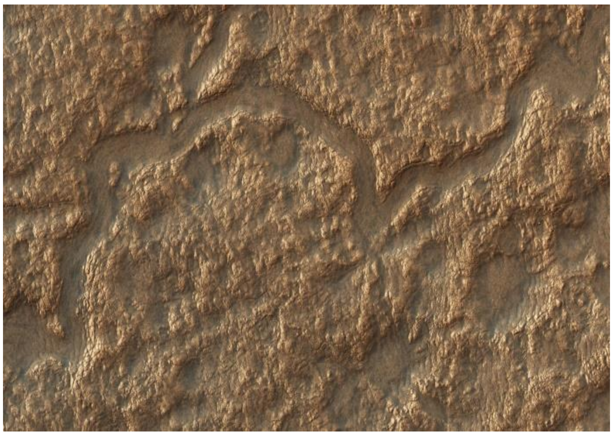

Fig 3

Fig 4

Fig 3 shows the Channels on the floor of Lyot Craters in northern lowlands of Mars by NASA's Mars Reconnaissance Orbiter (MRO). Fig 4 shows the runoff from melting permafrost in Alaska flowing towards the sea (Image source: Greicius, 2017 and Weisberger, 2018).

Over the years, scientists have been trying to study images from the red planet. The study of a network of channels in the Mars Lyot Crater located in the northern lowlands of Mars using images from NASA's Mars Reconnaissance Orbiter has proved the possibility of Martian life millions of years ago. According to NASA scientist Greicius (2017), on the Crater's floor, there is a network of channels connecting a series of irregularly shaped pits; these resemble terrestrial beaded streams, which are common in the arctic regions of the earth and develop from uneven permafrost thawing. These landforms suggest liquid water flow in the past or may result from the process of sublimation and which might have potentially preserved evidence of past habitability.

Presence of Biosignature

The presence of the biosignature methane on Mars in comparison to Earth methane proves that life may have originated on the red planet. Currently, there is an increase in Earth methane level and as of June 2020 stands at 1872.2 ppb (NOAA, 2020). The Mars methane mystery has varied over time. The curiosity mission has detected different level of methane over time on Mars. The probe as of 2014 to 2017 has detected variations in plumes less than 1 ppb but there have been spikes of 21 and 45 ppb recorded at different locations on Mars respectively (Kaufman, 2019). The 45 ppb recorded was gotten using a ground-based telescope by NASA scientists and has since been non-replicable. The presence of methane on Mars can be proof of microbial activities; some microorganism respires CH_4 instead of CO_2. On Earth, more than 90% of methane is produced via biology, so its presence on Mars cannot be underestimated.

Table 1: **Curiosity TLS-SAM Methane Enrichment Measurements at Gale Crater (4.5ºS, 137.4ºE) over a 38 Month Period (Source: Webster *et al.*, 2018)**

Martian sol after landing on 6 August 2012	Earth date	Ls (degrees)	Global pressure multiplier	CH_4 (ppb)	Error ± 1 SEM (ppb)
573.08	17 March 2014	103.48	0.970	0.419	0.089
684.06	9 July 2014	158.61	0.877	0.653	0.121
965.99	25 April 2015	331.57	1.003	0.609	0.088

1086.06	26 August 2015	32.81	1.050	0.241	0.053
1169.02	19 November 2015	70.57	1.062	0.235	0.076
1322.00	24 April 2016	142.46	0.881	0.502	0.097
1451.06	4 September 2016	216.58	1.007	0.500	0.078
1527.06	21 November 2016	265.78	1.076	0.357	0.104
1579.00	13 January 2017	298.76	1.036	0.246	0.069
1709.00	27 May 2017	10.84	1.020	0.319	0.098

SEM- standard error of the mean; Ls- solar longitude; The global pressure multiplier is derived from in situ REMS pressure measurements. Earth dates refer to the time when the gas ingest was started. The decimal portion of the sol is used so that sol 573.08 represents local time 01:57.

Table 2: Comparative Earth Data on Methane from 2014 to 2017 (Source: NOAA, 2020)

Earth month (average)	Average CH_4 (ppb)	Average uncertainty
March 2014	1818.1	1.2
July 2014	1815.6	1.1
April 2015	1833.2	1.0
August 2015	1829.1	1.0
November 2015	1844.7	1.0
April 2016	1843.7	0.7
September 2016	1844.2	1.3
November 2016	1851.4	1.2
January 2017	1849.8	1.0
May 2017	1847.1	0.9

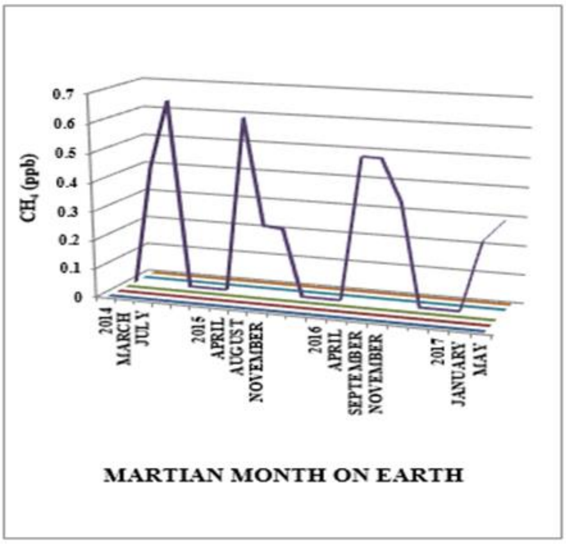

Fig 5: Methane levels on Mars

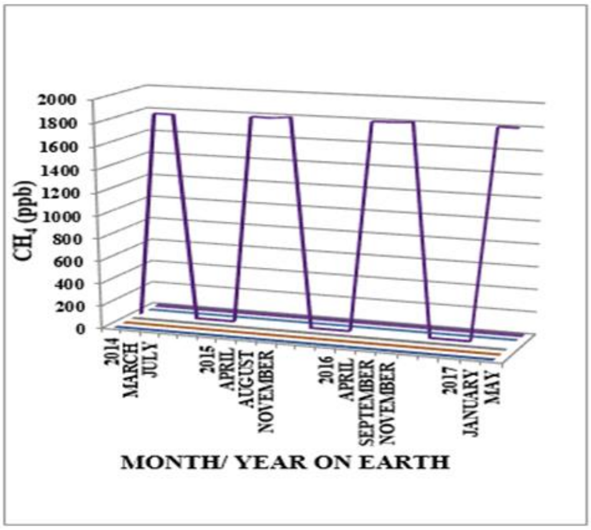

Fig 6: Methane levels on Earth

Figures 5 and 6 compare the varying levels of methane on Mars and Earth planets. The minute detection by the NASA Curiosity Rover is compared with the abundance of methane on Earth by NOAA global monitoring laboratory.

A variety of microbes remain viable after long term exposure to the radiation intense environment of space and simulations studies have shown that prokaryotes, fungi and lichens survive in simulated Martian environments. These findings support the hypothesis that life may have been repeatedly transferred from Earth to Mars or vice versa. Detection of carbonates and polycyclic aromatic hydrocarbons in Martian meteorite ALH84001 which has been dated to 4 billion years suggesting biological activity, also support the hypothesis that Mars may have been a living planet (Rhawn *et al.*, 2019). Nevertheless, these evidence remain circumstantial and required more scientific proof.

The Europa Evidence

In our solar system, even though there are other natural satellites like Enceladus (Saturn), Ganymede (Jupiter) and triton (Neptune) with water-ice, Europa (Jupiter) will be our major focus because it's the most potentially habitable.

Fig 7
Jupiter's moon Europa (source: NASA, 2019)

Europa is the smallest of the four Galilean moons orbiting Jupiter and also the sixth-largest moon in the solar system. Europa is primarily made of silicate rock and has a water-ice crust and probably an iron-nickel core (Chang, 2015). It has a tenuous atmosphere, composed primarily of oxygen (NASA, 2019). According to Tritt (2002), Europa has a smooth surface and scientific evidence have led to the hypothesis that a water ocean exists beneath the surface, which could conceivably harbour extraterrestrial life.

Life has three major requirements to thrive: liquid water, the appropriate chemical elements and an energy source. Scientists believe that Europa has abundant water and the right chemical elements, but an energy source on Europa has been difficult to confirm (NASA, 2019). On Earth, extremophiles have been found thriving near deep-sea vents, subterranean volcanoes and other extreme environments. The ability of organisms to adapt in these extreme environments give scientists the clue that life may be able to survive beneath Europa's ice shell. Currently, the European Space Agency (ESA) and National Aeronautics and Space Administration (NASA) are planning two Europa missions in 2022 and 2025 respectively, and these missions will give us a better clue of what life is like in Europa (Amos, 2012; Borenstein, 2014).

The Exoplanets and Its Habitability

According to Briggs (2020), Exoplanets are planets that orbit a star other than our sun and astronomers have confirmed more than 4,000 Exoplanets orbiting distant stars, with at least 1,000 more awaiting confirmation. The first scientific detection of an Exoplanet began in 1988. Afterwards, the first confirmed detection came in 1992, with the discovery of several terrestrial-mass planets orbiting the pulsar PSR B1257+12 (Wolszczan and Frail, 992). The first confirmation of an Exoplanet orbiting a main-sequence star was made in 1995 when a giant planet was found in a four-day orbit around the nearby star 51 Pegasi. One of the goals of the NASA Exoplanet missions is to find unmistakable signs of life in other planets. NASA in a quest to discover other planets have launched the Kepler mission, K2 mission and the forthcoming James Webb Space Telescope scheduled to launch in 2021 which could provide more scientific evidence on the most probable habitable worlds (Coughlin, 2018; NASA, 2020b).

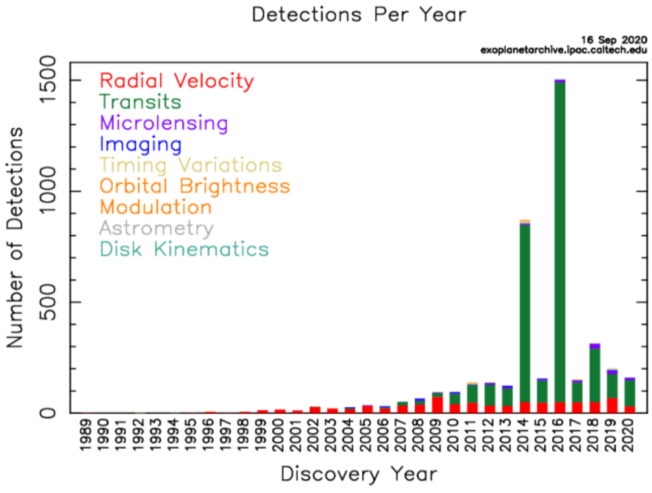

Fig 8

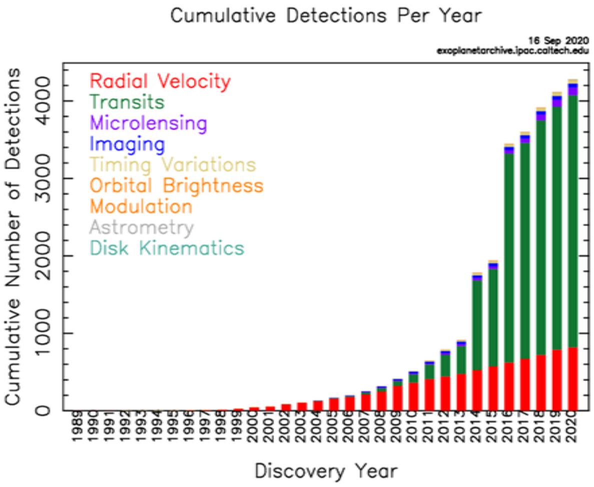

Fig 9

Figures 8 and 9 show the discovery of Exoplanets per year and their cumulative detections per year as of September 2020 (source: NASA Exoplanet Archive)

NASA Kepler mission uses data from NASA's Kepler space telescope and has discovered Earth-size Exoplanets orbiting in its star's habitable zone, the area around a star where a rocky planet could support liquid water. These Exoplanets with the possibility of extraterrestrial life include Kepler-452b, Kepler-1649c, TRAPPIST-1d and TOI-700d (NASA, 2020a). In consistence with these findings, there is a possibility that life exists somewhere in the universe, only waiting to be discovered.

The Role of Molecular Biology and Genetic Engineering in Life Finding in Other Planets (MinION and MiniPCR Project)

NASA and ESA in its quest to understand life in our solar system has sponsored orbital experiments like the ERA, BIOPAN, EXOSTACK and EXPOSE. Recently, due to the help of molecular biology in understanding units of life, NASA has set up molecular biology missions in the ISS which are majorly Gene in space-1 and Gene in space-3 missions. Thus, the question of the genesis of life is fundamental, a biochemical question to determine molecular building blocks for life and a source of environmental energy. The Genes in space missions was developed to be able to prepare, sequence DNA and identify unknown organisms from space. Being able to identify microbes in real time aboard the ISS without having to send the microbes back to Earth for identification is revolutionary for the world of astrobiology and space exploration.

Genes in Space-1 marked the first time the PCR was used in space to amplify DNA with the miniPCR thermal cycler, followed shortly after by Biomolecule Sequencer, which used the MinION device to sequence DNA (Johnson, 2019). NASA astronaut Kate Rubins sequenced the first DNA aboard the ISS in 2016 which was part of the Biomolecule Sequencer investigation (Rainey, 2017). The investigation at microgravity sequenced Earth samples i.e. samples of mouse, virus and bacteria DNA sent to the space station to test a commercially available DNA sequencing device called MinION, developed by Oxford Nanopore Technologies. This breakthrough, necessitated the success of Genes in Space-3 in 2019, which completed the first-ever space sample to sequence process entirely aboard the international space station.

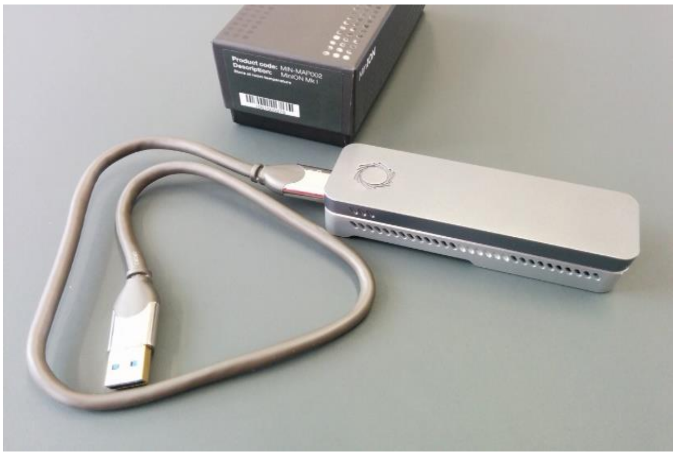

Fig 10

Fig 10 shows portable MinION DNA sequencer from Oxford Nanopore. (Image source: Hazelwood-Smith *et al*., 2016)

The Genes in space missions generally adopted spaceflight technology, MiniPCR and MinION, allowing for unknown biological samples to be prepared, sequenced and then identified in space. The ability to identify microbes in space could aid in diagnosing and treating astronaut ailments in real-time, as well as assist in identifying DNA-based life on other planets (Johnson, 2019). The ability to identify microbes in space using DNA based experiments will help in future planetary missions, especially in studying the possibility and availability of life in other planets.

Fig 11

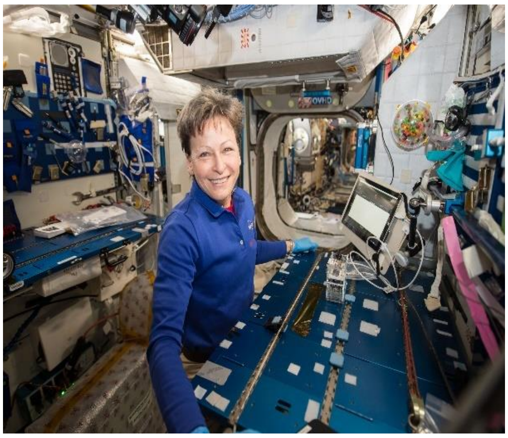

Fig 12

Fig 11 shows the first Gene in space-1 sequencing by NASA astronaut Kate Rubins using MinION, while Fig 12 shows NASA astronaut Peggy Whitson performing first Genes in Space-3 investigation aboard the ISS. (Image source: Rainey, 2017 and Johnson, 2019)

Current Research on Panspermia and the Role of NASRDA, Nigeria

Currently, world space agencies like NASA, ESA, United Arab Emirates Space Agency (UAESA) and China National Space Administration (CNSA) are on space race on who to find extraterrestrial life in our universe, but their current focus is on the Mars**.** In 2020 alone, NASA launched its Mars “Perseverance” mission, China launched its Mars “Tianwen-1” mission and the United Arab Emirates launched its Mars “Hope” mission. The curiosity to explore Mars is based on the hypothesis and unproved evidence that it once supported life. There has been a lot of theories on life in the outer space but with 21st-century technologies, these speculations and theories are about to be over.

National Space Research and Development Agency, Nigeria (NASRDA) as a leading space agency in Africa can affiliate with NASA LARS program (Laboratory Analysis of Returned Samples), China and United Arab Emirates space agencies as they are willing to accept proposals and partnerships from other nations. The goal of this affiliation is to ensure that the Nigerian space sector is not lagging in the scientific world and technical knowhow. These affiliations will help NASRDA, Nigeria in active involvement in analysis of returned samples from these developed countries. Space exploration and launching of rockets to space are expensive, it requires a lot of scientific input. NASRDA, Nigeria through proper affiliations needs to be up to date in all astrobiology and scientific missions to find life in our solar system. There is increased commercialization of the space industry with the private sectors getting more involved globally, it’s a wakeup call to African space industries to get more involved.

Conclusion

The search for extraterrestrial life in our universe is vital because these findings could deliver new insights into the primeval solar system and the origin of life on our planet. Even though there are a lot of interesting new results and observations been obtained from space missions, a lot more is required to establish these facts. The universe is vast and there has been a lot of conspiracy theories about human existence on Earth. The answer to all these theories relies mainly on human scientists to develops technologies that can explore deeper our universe, thereby bringing answers.

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