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A Comprehensive Literature Study on Technology Pertaining to Interstellar Travel and the Current Human Standing

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Abstract

Humans are always fascinated by looking at the night sky. Numerous worlds are waiting to be explored. In this paper, we have reviewed the work done by researchers that will help us answer the possibility of Interstellar travel. What is our current stance on the journey of Interstellar travel? What are the challenges that we have to counter? What are the limitations of the human body in the course of interstellar travel? Can our Human body withstand the cosmic rays that can smash a whole spaceship within a glimpse of seconds? And even if we have countered the challenges, how will we decide our destination star or planet? Are there any criteria for choosing a habitable planet? Our present technologies can't take the responsibility to make us travel millions of light years. So which technologies can become a favorable candidate for interstellar travel? How can Genetic Engineering become a boon for interstellar travelers? How will we communicate during unbound and unpredictable isolation? Lastly, what is our view on the possibility of Interstellar travel and what are the future scope and possibility of interstellar travel?

Keywords: Interstellar Travel; Space Exploration; Space Challenges; Space Technology.

1. Introduction

Interstellar comprises two words, inter which means between, and stellar, which means Stars. So in simple terms, it means traveling between the stars or moving through the cosmos. It is the journey of humanity in spacecraft destined outwards away from the Earth towards galaxies, star systems, exoplanets, etc. Within 200 years, the Earth would become inhabitable for humans as well as various other species.

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So, if we want to protect our species and take the leap toward becoming a multi-planetary species, we have to look forward to interstellar travel. There have been several theoretical concepts like wormholes, and warp drive that can make interstellar travel possible. But these only lie on equations and paper till now. There are several techniques which if worked upon in the future then interstellar travel will be possible shortly.

Throwing light on the current standing of humanity in terms of advancements about the technology needed that could render interstellar travel possible, we have a long way ahead of us, unless such a discovery is made that could cause a paradigm shift. Consequently, shattering the very foundations on which our physics has been built; the last such being the theory of relativity.

2. Present Scenario and Past Work

The first technical outline of an Interstellar rocket was created in 1911 by Russian scientist Konstantin Tsiolkovsky. His idea was based on decaying radioactive substances quickly to create sufficient reactive power to make trips to distant bodies in our Solar System. After the creation of nuclear weapons, plans for nuclear pulse propulsion emerged for interstellar travel. The prediction of antimatter in 1928 by Paul Dirac and its discovery in 1933 by Carl D. Anderson marked the beginning of studies regarding the dynamics of relativistic rockets. Advances in this field were made between 1973 and 1978 by Daedalus, a project by the British Interplanetary Society. At present, Project Icarus aims to design a nuclear propulsion-based unmanned space probe [69,71,72].

Our current capabilities can be evaluated based on our missions done till now. It showcases our technological capabilities of traveling, mechanisms of spacecraft designed, aims of traveling, chances of survival and what is our maximum reach at present. To the current date, only 2 spacecraft designed by us have reached Interstellar space, Voyager 1 and Voyager 2. The former one has crossed the heliopause, which is the boundary of the maximum influence of the Sun and when Interstellar space begins. Voyager 1 has been traveling in Interstellar space for over a decade now and is undoubtedly the representative of the whole of the Earth and the life on it. Its successor, Voyager 2 followed it and has also left the heliosphere in 2018. Both of the spacecraft are functioning and sending important data back to Earth. Voyager 1 traveled at a speed of 35,000 km/hr continuously for 44 years just to reach the end of the Solar system. The speed might seem a big number, but in reality, is negligible compared to the vastness of the space. With the ongoing speed, it will take the spacecraft another 10^4 years to reach the nearest star system, Alpha Centauri, which of course is a very big time interval considering the duration of humanity's existence from the beginning [1,2,3].

3. Challenges Faced

With a dream like this, there are several obstacles in the way that need to be crossed to make our progress further. In this section, we shall have a look at why it is not easy to travel outside the Earth to such large distances, and traveling thus will have consequences.

3.1. The Technical Aspect

Technological development is a must in the face of Interstellar Travel. With the current status, we have several issues listed below:

1. Propulsion Technology
2. Cosmic Obstacles
3. Communication limitations

3.1.1. Propulsion Technology

The current rocket propulsion technology has been facing a severe issue of travel time duration. If we were to travel with the current Chemical propulsion technology, we would have to travel for many years before we reach our destination, by many more years it means about thousands to millions of years. The conventional methods of space exploration propulsion technologies have a serious issue of power demand. For instance, if were to take a spacecraft weighed one ton with a speed of 0.1c, it would require power of at least 125 TWh. For a better understanding, we must know that the entire energy consumption worldwide in the year 2019 was $1.73*10^5$ TWh. Here, 1 TWh means 10^{12} Watts-hour [4].

3.1.2. Cosmic Obstacles

The Cosmic Environment refers to the outer space environment other than the Earth. It is one of the serious issues faced by the energy technologies used in outer space exploration. The conditions outside are harsh and not so favorable for the spacecraft to travel for a long distance. The interstellar medium consists of charged particles like electrons, ions, and neutral gas, and impact with the ISM can cause high radiation doses. The cosmic rays in intergalactic space have very high energies ranging from 100 MeV to 10 GeV. Cosmic radiation consists of Thermoelectric, Electromagnetic, and nuclear radiation, among which the latter has the most influence. The cosmic dust grains are considered the primary collision hazard for the spacecraft as they create a highly energetic collision with speed near the speed of light [5, 6,7].

3.1.3. Communication limitations

Interstellar travel involves the traveling of spacecraft and humans boarding it to large distances. During such a journey, communication is the most important component of the system. The time-to-time reporting of the journey is a much-needed facility. Interstellar travel comprises the movement to other solar systems, galaxies, star systems, and exoplanets. Connectivity to such a large distance is not possible with the current technology. The unavoidably high signal propagation latency and limited data rates of the communications links contribute to the impossibility of wireless communication over nanocrafts. That is why until the mid-1980s, the space missions were manually operated from the ground [8, 9].

3.2. Human Body Limitations

During interstellar travel, there are several biological and physiological problems arising due to various factors: Reference [10].

1) Altered gravity

2) Radiation Sickness

3) Spacecraft Environment

4) Psychological Challenges

5) Distance and Isolation

3.2.1. Altered Gravity

In the absence of a 1G gravity field, fluid balance in the human body is altered, the heart alters its pumping, and due to no longer bearing weight long bones lose rigidity and muscles become weak. Serious disorders for Interstellar travelers include vision alteration resulting from the effects of reduced gravity on the distribution of fluids in the human body and edema. Since interstellar travel will last for years and years there can be instances where we have to step on asteroids for fuel or for other problems. These asteroids exert gravity which is just a fraction of that exerted by Earth. We have some medications that successfully slow the decay, but we don't yet have a complete solution.

3.2.2. Radiation Sickness

Photonic radiation (X-rays, gamma) is very common on Earth. In space, however, the majority of the radiation is particulate radiation. The Sun produces ions and radiation that are harmful to the human body, and these hazards are more pronounced in space. Galactic Cosmic Radiation (GCR) is everywhere and comes from every direction. It consists of heavy atomic nuclei stripped of electrons and accelerated to near lightspeed by nova and supernova explosions throughout the cosmos. These particles are called HZEs (High Energy Atoms). Fe^{26+} atoms are accelerated by approximately 600–1000 million electron volts (mega EV or MEV) to simulate GCR particles resulting from a supernova explosion. The resulting heat release would cause a steam explosion, destroying the unlucky organism that happened to trap the HZE. On Earth's surface, we are protected from GCR and solar wind by the Earth's thick atmosphere and electrically and magnetically charged "magnetosphere." In the mission to the moon, humans had been protected from the radiations by the tail of the magnetosphere of the earth. Missions to Mars and long-duration habitations of space will require solutions to the effects of space radiation on the human body. Aside from cancer risk, or purely physical damage from solar radiation, radiation similar to that which will be encountered outside Earth's orbit causes damage to bone, cartilage, blood vessels, and the brain. We can build more shielding into our ships and habitats but can we adapt and perhaps even engineer humans to be more resistant to space radiation?

3.2.3. Spacecraft Environment, Distance, and Isolation

Human Beings are social animals. It can be possible to isolate a group of people for a couple of months. But Interstellar Travel demands isolation for months and years. The environment of the spacecraft also affects the interstellarites. Psychological challenges like loneliness, anger anxiety, depression, etc. have to be addressed. The good news is that these three risk categories can be studied - and hopefully solved - a lot closer to Earth. We could study the psychological behaviors of the ISI astronauts and Submarine crew and find out the solution to the above problem. If humans are to eventually go to the stars, we will first have to go out into space, beyond the ISS, beyond the Moon, even beyond Mars. These all require the utmost sacrifices, funding, and convincing the masses about the importance of the mission even after failures. To do that, we not only have to want to go, we have to want to do so in the face of great risks and inevitable losses.

4. Possibilities of Travel

Indeed, launching a mission as of now is not at all possible for us, but sometime soon, the development will start and missions for Interstellar travel will become common. So, for that, we now analyze the main components of traveling in the Interstellar medium.

4.1. Where to travel?

A proper route mapping is required for the working of an Interstellar Mission, among which the first work should be the identification of destinations that would be suitable for us to design the mission. The potential candidates to be chosen for our destination can be nearby star systems according to the distance at which they are located from the Earth.

The nearest star system located to the Earth is Alpha Centauri which is located at 4.3 light years. It is a 3-star system, out of which one is similar to our Sun. The second candidate can be Epsilon Eridani located at 10.8 light years from us. It is slightly smaller in size and colder in temperature than our Sun. It has two asteroid belts and thus could potentially harbor a planetary system. The third candidate that can be chosen for an Interstellar mission can be Tau Ceti located at approximately 11.8 light years. This star system has 5 planets, out of which two are possibly in the habitable zone.

Talking in a general way, everything outside the Solar System is a new world for us waiting to be explored in many ways. So, no matter where we choose to go, everything will be new for us. Still, the selection is an important component to work on so that our adaptability in the new environment might be easy [11].

The destination of our travel can also be decided peculiarly based on the following table:

4.2. How to travel?

Interstellar travel demands a high energy supply which traditional combustion techniques can't promise to supply. Therefore, we have to look forward to some better energy supply methods. Also, since an enormous amount of energy is required for harnessing interstellar travel therefore the energy source must be unlimited. So, we require an energy source that is unlimited as well as enormous. Also, the technology that we are choosing must allow interstellar travelers to reach their destination in the least amount of time possible. The technology can fulfil the earlier needs but if it takes hundreds and thousands of years to reach the destination then the technology will certainly be of no use at all. The following technologies given below come with their respective advantages and disadvantages.

Table 1 : [13,14]

	Advantage	Disadvantage
Wormholes	Fastest mode of interstellar travel	Theoretical, Requires the need for the creation or finding of Negative Mass.
Warp Drive	Enables the transportation of objects nearly at the speed of light with the need for exotic energy sources.	It needs infinite energy to work. (Energy of the Universe is constant. It would be nearly impossible to create infinite energy.)
Laser-induced annihilation of Ultra-Dense Hydrogen	Ultra Dense Hydrogen Is present in enormous amounts and can therefore be thought of as a great energy source.	These high particle energies give radiative temperatures of 12000 K in collisions against a solid surface and will rapidly destroy any spaceship structure moving into the H(0) clouds at relativistic velocity
Propulsion Techniques like Light Sail, Electric Sail etc.	Uses radiation pressure to move the spacecraft. (The Universe is filled with radiation).	It takes a long time to accelerate the spacecraft at a desirable speed.

4.2.1. Wormholes

We want to travel to some distant star located thousands of light years away. Even if we travel at the speed of light, it would take thousands of years to reach the destination. In this dilemma, wormholes act as a shortcut to reach the star. Wormholes are eerie structures connecting two distant points in space and time. The thousands of light years distance gets reduced to just a few kilometers. The concept of wormholes was first predicted by Einstein in his General Theory of Relativity. Although even now many Physicists believe that the concept of wormholes is fictional, the solutions of GTR have predicted certain results (one of which is a black hole) that have a high probability of existing. There is also a possibility that wormholes are just complex projections of a 4D space-time fabric. Wormholes have two openings and a tunnel connecting these entry points. Each of the openings is a spheroid and these spheroids connect two different positions of space and time. The bridge or tunnel might be twisted or straight, depending on the inherent variables. Most of these are mathematical assumptions. The string theory suggests that there had been numerous wormholes created during the Big Bang. The two openings of the wormholes had been connected through strings that can extend to millions of light years across. And since wormholes connect two distant points of space and time, it is possible that we could do time travel. The term

Worm Holes was coined by American physicist 'John Wheeler'. There are many kinds of Worm Holes but we are going to discuss two kinds of Worm Holes namely, Einstein-Rosen Bridge and Exotic Matter Wormholes.

4.2.1.1. Einstein-Rosen Wormholes

The General Theory of Relativity has predicted that massive objects like Neutron Stars and massive Stars curve the space and time fabric. In the case of Black Holes, the curvature is so intense that it actually breaks the space-time and then opens in some other part of the same universe or some other universe (if a multiverse exists). It is thought that on the other side of the black hole, there is a hypothetical place where time flows backward and all the information that is being engulfed by the black hole is spitted out. We call that place a 'White Hole'. There are several problems with these kinds of Worm Holes. First is that these kinds of Black Holes are non-traversable i.e. if anything enters these kinds of wormholes then it would not be able to return through the same path (same wormhole). Thus, it serves as a point of no return. The second problem is that since the entry point is through a black hole, spaghettification, and immense radiation can cause the spacecraft or anything going through it to be destroyed within a glimpse of seconds. One possibility of overcoming the second problem is by choosing large black holes to travel.

4.2.1.2. Exotic Matter Wormholes

Exotic Matter Wormholes are the kind of wormholes that can be theoretically made provided we can find some exotic matter. Exotic Matter has not been found or created as its properties are very different from ordinary matter. Unlike normal mass that is positive, this matter is negative and unlike normal matter, this exotic matter generates repulsive gravity. This repulsive gravity is required because the mouth of a wormhole opens in any part of space-time fabric, the gravity tries to close the mouth as quickly as possible. This may lead to many consequences like the information (spacecraft, humans, or anything that enters) can be lost anywhere in between the tunnel of the wormhole forever and ever. Therefore, the exotic matter is needed so that when it is enforced in the mouth of the wormhole, it keeps the entry and exit points open. But the problem is that we haven't found a way to create exotic matter. Some suggest that exotic matter is a form of dark matter and also the concept of dark energy that theoretically causes the universe to expand is due to the repulsive gravity that is caused by the exotic matter References [15,16,17] .

4.2.2) Warp Drive

Miguel Alcubierre proposed a metric called a warp drive in which expansion and contraction of spacetime does not have a speed limit, thus the laws of general relativity are not broken. Alcubierre's warp creates a peculiar distortion of space such that the region directly in front of the spacecraft experiences the most contraction of space, while the region behind the spacecraft experiences the most expansion of space. This region of distortion is called a warp bubble, and it travels in the form of a wave. Any object inside this wave would be able to travel along with the bubble. Warp drives create the bubble by curving spacetime around that bubble to reduce distances. When the field is active, the field's boost results in a much higher apparent speed, as measured by an earthbound observer. For any object inside the bubble, it stays in an inertial frame of reference. Thus, as the region moves, the ship is carried along with it, rather than moving within the bubble. So there is no relativistic mass increase or time dilation effects. Moreover, the Energy density for the metric is negative, which will add an effective negative mass to the spacecraft's overall mass budget. As the amount of negative mass increases, the specific mass of the spacecraft approaches zero, and the transit time becomes exceedingly small, approaching zero [18,19,20].

4.2.3.Laser-Induced Annihilation of Ultra-Dense Hydrogen

Interstellar Travel demands enormous energy. So, one theoretical way to produce energy is by laser-induced annihilation1 in ultra-dense hydrogen H(0). Laser-induced nuclear processes in ultra-dense hydrogen H(0) give ejection of bunches of mesons similar to known baryon annihilation processes. The intense energy from the laser can trigger nuclear reactions within the ultra-dense hydrogen nuclei. These reactions may involve the rearrangement of quarks within the nuclei, leading to the creation of new particles. As a result of these nuclear reactions, some of the produced particles could be mesons3. H(0) has a very small inter-atomic distance in the most commonly observed spin level s=2 which is stable at low pressure in the laboratory. It is the densest form of condensed matter that exists in the universe. H(0) is a superfluid and super-conductive. It is so at and above room temperature. Clear transition temperatures to a normal (i.e. a non-superfluid) state exist at a few hundred K above room temperature [21,22].

4.2.3.1. The Idea behind:

Heat generation from nuclear processes above break-even was also reported already in 2015 with the same type of relatively weak laser this was the first report on sustained fusion efficiency above breakeven and also the first fusion process reported using deuterium as fuel. The MeV meson and muon signal is so large that it can be measured directly by a fast oscilloscope connected to a metal collector, thus giving accurate sub-ns-range timing intensity distributions. These fast particles have been observed at distances up to 2 m in a vacuum giving good time resolution. The particle velocity corresponds to 10e500 MeV. By using two and three collectors in a line, it is found that these particles have mass. Magnetic deflection studies confirm that many of the initially formed particles (high-energy mesons) are indeed neutral, thus neutral kaons. The generation of muons from the meson decay is confirmed by accurate[1] measurement of the decay time for the muons. In separate studies, it is confirmed that the charged and neutral kaons and the charged pions formed by the laser-induced processes in H(0) decay with their well-known decay lifetimes. Only negative muons can be used for muon-catalyzed fusion which is the only sustainable nuclear fusion method as it can use deuterium as fuel. Thus, muon-catalyzed fusion does not require the risky handling of radioactive tritium fuel as all other fusion methods under development do. This means efficient nuclear energy production is possible with ordinary hydrogen as fuel and radio-active tritium does

[1] Annihilation is the process by which enormous energy is produced when a particle and its corresponding anti-particle collide. [2] Ultra-dense hydrogen is the Hydrogen characterized by electrons captured within the nuclear region, resulting in a highly dense and exotic state of matter. [3] Mesons are particles composed of one quark and one antiquark, and they can be generated in various nuclear processes, including those involving the rearrangement of quarks within nucleons.

not be used as nuclear fuel [23].

4.2.3.2. The annihilation reaction

The annihilation-reaction step for proton-antiproton is given by:

$$p + \bar{p} \rightarrow 2K^{\pm}\,(96\text{MeV}) + 2\pi^{\pm}\,(69\text{MeV}) + 2\pi^{\pm}\,(0\text{MeV}) \quad (1)$$

$$2 * 938 - 2*(494 + 96) - 2 * (140+69) - 2 * (140) = 1876-1878= -2\text{MeV} \quad (2)$$

The Mesons -decay is given by:

$$K^{\pm} \rightarrow \mu^{\pm}\,(130.5\text{ MeV}) + v_{\mu}\,(235.5\text{ MeV})\text{ branching }64\% \quad (3)$$

$$\pi^{\pm} \rightarrow \mu^{\pm}\,(4.12\text{ MeV}) + v_{\mu}\,(29.79\text{ MeV})\ 100\% \quad (4)$$

And leptons decay and annihilate as:

$$\mu^{\pm} \rightarrow e^{\pm}\,(\text{approx. }35\text{ MeV}) + v_e + v_{\mu}\text{, thus }106\text{-}35\text{ MeV} = 71\text{ MeV to the neutrinos} \quad (5)$$

$$e^{+} + e^{-} \rightarrow 2_{\gamma}\,(0.51\text{ MeV})\ 100\% \quad (6)$$

In the above equations, p is a proton, $\bar{p}$ is an anti-proton, π is pion, K is Kaon, μ is muon, v is neutrino, e^+ is positron and e^- is an electron.

The total energy from the two proton masses is 1876.6 MeV. The stable particles that are lost are neutrinos from the Kaon, pion, and muon decays. Their energies are 2× 235.5 MeV for the kaon decays 4× 29.79 MeV for the pion decays and 6×70 MeV for the muon decays which sums up to 1010MeV or 54% of the energy is lost. Thus 867 MeV is the useable energy for each proton pair which corresponds to 46% of the initial mass. Other small losses can occur by radiation from secondary processes. This keeps us with 850 MeV per proton pair as annihilation output. 1 g of hydrogen is approximately 1 mol hydrogen and contains 6.022×10^{23} H atoms. This corresponds to 3.011×10^{23} hydrogen pairs which can give an annihilation energy of 4×10^{13} J = 1.14×10^{7} kWh = 11.4×10^{3} TWh per gram hydrogen or 11.4 TWh per kg hydrogen [62,65,66].

4.2.3.3. The annihilation reactor

In our present first-generation annihilation reactor under construction, each laser shot generates around 10^{13} particles (kaons, pions, muons) with kinetic energy of 0-e100 MeV per particle, and with particle mass in the range 100-500 MeV. This indicates the annihilation of around 10^{13} hydrogen atoms or around 10 pmol annihilated per laser pulse giving the order. With 10 pulses per second from a normal Q-switched laser, this gives 500 J per second or 0.5 kW. As seen from the power output in the kW range, this is inherently a small-scale energy generation method but it can probably be scaled up quite easily to the MW level by using several lasers with higher pulse rates and by designing better reactors that can generate larger amounts of H(0).

4.2.3.4. Ultra dense Hydrogen H(0)

Ultra-dense hydrogen H(0) is condensed atomic hydrogen with a density of up to 100-5000 kg per cubic centimeter. It consists of extremely small (pm-sized) ultra-dense clusters or molecules. It is formed spontaneously from the so-called Rydberg matter of hydrogen H(l), it is the most stable material known. It is stable for long times, days to months at or above room temperature even in the laboratory. It is rapidly formed by catalytic processes using especially carbon surfaces and metal oxide-based catalysts. Both ultra-dense protium p(0) and ultra-dense deuterium D(0) or d(0) are closely related to the lowest forms of ordinary Rydberg Matter (RM) of the type H(1). H(0) is superfluid at room temperature. D(0) is a type-II super-conductor even at elevated temperatures. Only hydrogen isotope atoms are expected to give an ultra-dense material form since the inner atomic electrons prevent this formation for all other atoms. Doubly excited atomic states eg. He** gives excellent agreement with the so-called Diffuse Interstellar Bands (DIBs)observed in space. H(0) has a density ten thousand times higher than the center of the Sun. H(0) exists wherever there is Hydrogen. The H(0) clusters have dimensions down to a few PMs as measured by time-of-flight, mass spectrometry, and rotational spectroscopy. This means that they will not absorb or scatter electromagnetic radiation with a wavelength longer than a few PMs, and thus, H(0) clusters will be invisible (dark) in any spectral range with a wavelength longer than typical gamma rays. Due to the strong interatomic bonding in H(0) with energy of the order of 1-2 keV, absorptions in the visible or UV ranges are unlikely. The bond energy in H(0) of at least 500 eV corresponds to a temperature of 5 Mega Kelvin. Thus, in any dense region in space where the temperature is lower than approximately 1 MK, ultradense hydrogen H(0) will be the dominant form of hydrogen. This means that this form of hydrogen will dominate even inside many stars. The formation of Hydrogen is spontaneous from higher hydrogen Rydberg Matter. H(3)->H(2)->H(1)->H(0) [24,64,67].

4.2.3.5.Nuclear Processes in H(0)

The initial particles observed in the laboratory studies, are both charged and neutral kaons each with a mass close to 0.5 mass units (490-500 MeV) and charged pions. These mesons are identified from their characteristic decay times. From two nucleons, one pair of kaons and two pairs of pions are ejected. The kaons each have kinetic energy close to 100 MeV. The kaons decay into pions and muons (kaons are unstable), and the decay processes are quite complex. The particles ejected by the nuclear processes are similar to those found in nucleon-antinucleon annihilation, so the processes observed are not ordinary nuclear fusion but a form of particle annihilation, similar to neutron + antineutron annihilation. The final product particles after decay are electrons and positrons, each with a mass of only 511 keV. These leptons may also annihilate to some degree, giving annihilation of gamma photons. Some meson decay channels also end up as gamma photons. The total energy released by these nuclear processes is roughly a factor of a hundred higher than that released by ordinary fusion.

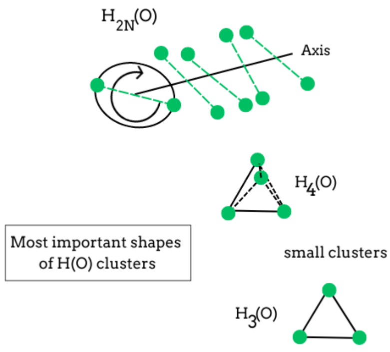

Figure 1: (Source: Nuclear Processes in Dark Interstellar Matter of H(0) Decrease the Hope of Migrating to Exoplanets)

H2N(0)-> Theoretical shape for H(0) in superfluid

H3(0) and H4(0) → Shape where nuclear processes take place primarily.[63][68]

4.2.3.6. A conflict

H(0) is the most stable form of matter. It is one of the proposed forms of dark matter. Although there are several proposals of dark matter eg. WIMPs (Weakly Interacting Massive Particles), and MACHOs (Massive Compact Halo Objects). However, H(0) is still the most stable form of dark matter. The abundance of atomic hydrogen in space is well-established through various observational methods. ERE spectra mentioned as signatures of H(0) of course are not atomic but rotational spectra of two or more hydrogen atoms in the H(0) clusters

4.2.3.7. Limitations

We have seen earlier that the space is made up of ultra dense Hydrogen H(0). We also know some of the properties of H(0). H(0) can show nuclear reactions. It can emit kaons and pions having a kinetic energy of more than 100MeV, after induction by fast particles example spaceship. These high particle energies give radiative temperatures of 12,000 K in collisions against a solid surface and will rapidly destroy any spaceship structure moving into the H(0) clouds at relativistic velocity. H(0) can be shown to have been observed in space from the so-called extended red emissions (ERE) [21].

4.2.4. Propulsion Techniques

The use of the current chemical propulsion techniques already proposes the shortcomings of a mission designed for Interstellar travel. The requirement for a large power source for a long duration of time is a must and the work on development of such source or technique is a must. There are already some proposed propulsion techniques using which, if developed, we might be able to travel in the Interstellar medium between star systems one day in the future [25,29].

4.2.4.1. Solar Propulsion

The use of solar energy has been emphasized in recent times for several projects both, on the Earth and outside the Earth. Solar energy provides us with an almost infinite source of energy without worrying about the amount. This proposed technique which involves the use of solar energy is good but has characteristic acceleration limitations due to which its applicability in the missions is likely not. Interstellar travel requires traveling outside the solar system. The Sun's energy will continue fading away as the distance increases so the use of Solar-driven Electric thrusters also proposes problems of power shortage. Reliability on other star systems can't be our only option for energy as harnessing energies of different types of stars is not an easy task.

4.2.4.2. Nuclear Propulsion

The use of nuclear propulsion is a long-talked technique but only in books. It comprises 3 different types of nuclear techniques, namely:

4.2.4.2.1. Nuclear-Electric

This technique involves using Nuclear Fission with power driven electric thruster. It proposes multiple challenges like a limitation of Energy produced effectively, complex mechanisms, and security risks. The construction of a combined mechanism involving an electric thruster with power driven from Nuclear fission will pose significant challenges. Even if developed, with the use of electric thruster, there will be a limitation of velocity that the spacecraft is capable of traveling which in turn will increase the duration of the Interstellar mission. This technique is currently in a formulated version and not functional as of now.

4.2.4.2.2. Nuclear-Thermal

The use of nuclear-driven thermal propulsion is in the functional verification stage but has some major issues due to which its use in Interstellar missions is likely not. It involves high radiation emissions by the nuclear reactor. Harnessing such radiation will cause harmful effects, both for the spacecraft as well as the humans traveling on it. The engine assembly has a heavy weight in this system and is a major issue.

4.2.4.2.3. Nuclear Fusion

Nuclear Fusion-driven thermal propulsion is one of the considerable techniques that might be used in the future for Interstellar travel. The only limitation in using this method is the lack of technological knowledge. We do not have the appropriate methods to create a piece of machinery that uses controlled nuclear fusion as its power source.

4.2.4.3. Antimatter Propulsion

This propulsion technique is completely hypothetical because of the lack of knowledge as well as materials. When a particle of matter and antimatter combine, they destroy one another creating pure energy. Harnessing this form of pure energy is currently far beyond our capabilities. The lack of availability of Antimatter as well as its knowledge is what makes this technique not considerable as of now.

4.2.4.4. Battery Technologies

Space exploration depends on battery chemistry technologies, particularly when solar and other energy sources are scarce and imperfect. The advantages of Li-based battery systems, which include Li-SO2 or Li-SOCl2 with liquid cathodes or Li-CFx, include higher specific energy, higher voltage, a wider operating temperature range, and longer usage times. These battery systems have dominated battery technologies in recent space missions. Li-SO2 is the most used battery system in the aerospace industry. Li-ion batteries have been extensively used in all recent space missions as they can be used in a wide range of temperatures. The Mars Odyssey and Mars Reconnaissance Orbiter missions involve the use of Nickel-Hydrogen battery technology. Launched by ESA in 2001, PROBA is the first mission in Earth orbit to use Li-ion batteries as its primary power source. It has been in operation for 20 years [30,34].

5. Proposed Concepts

5.1. Missions

There are some missions proposed for Interstellar travel. One of them is the mission Starshot having a top speed of 0.2c. It is a light sail interstellar probe being designed to travel to the Alpha Centauri star system. Another mission is the Pragmatic Interstellar Probe designed to travel outside the heliosphere to a Very Local Interstellar Medium. The hypothetical vehicle would leave the Sun's gravity field with an asymptotic escape speed twice that of Voyager 1 by using a super heavy-lift launch vehicle (SHLLV), with one or two extra stages and a Jupiter gravity assist. It would carry scientific instruments weighing 90 kg, itself being Voyager-sized of weight 860 kg. The objective of the mission would be to explore the local interstellar medium just outside the Solar System. Thorough engineering and trade-off analyses have demonstrated that it is possible to design, build, and launch such a mission by the early 2030s [35,43].

5.2. Genetic Engineering-creating Homo Stellaris

This is a hypothetical future human subspecies adapted for interstellar travel and life beyond Earth. Humans might have denser bones to withstand low gravity, different respiratory systems for alien atmospheres, or even enhanced lifespans for long journeys. Desirable traits would first need to be studied to determine what genes produce the desired effects (and in all likelihood, it would require manipulating hundreds of genes just to produce resistance to low gravity, for example) and then the appropriate human cells would need to be edited. mRNA provides an interesting possibility for temporary or short-lasting treatments aside from simply vaccine production. There is considerable interest in “torpor” – lowering human metabolic activity – to enable humans to subsist on fewer resources, as well as for vital medical benefits during surgery or wound stabilization. A popular method of inducing torpor in science fiction and public media is cryogenic hibernation – essentially lowering metabolic activity by lowering body temperature. Many arctic species avoid cellular damage via "antifreeze" proteins which lower the freezing point of blood or simply prevent the formation of ice crystals. These proteins would be an ideal target for an mRNA treatment that produces protective compounds temporarily. The advanced features of the homo Stellaris: Foremost among any considerations should be a tolerance for low-gravity or 0-gravity environments. The human body adapted through evolution to the gravity field of Earth, which we define as 1G.

1. Thick long bones of the legs, no longer have to support the body. Wide flat feet with short toes are not necessary for one is no longer attempting to balance and walk in gravity. Therefore, it would make more sense to have four arm-like appendages instead of two.

2. Thickening of the epidermis (the outer layer of skin) could serve multiple functions such as improving tolerance to low pressure, reducing injury caused by environmental obstructions, and increasing resistance to radiation. At the same time, changes to blood-forming organs could enhance the repair mechanisms responsible for the body's natural functions which isolate and rewrite the DNA damage from radiation damage and environmental toxins.

3. Some other desirable features of the human body:-

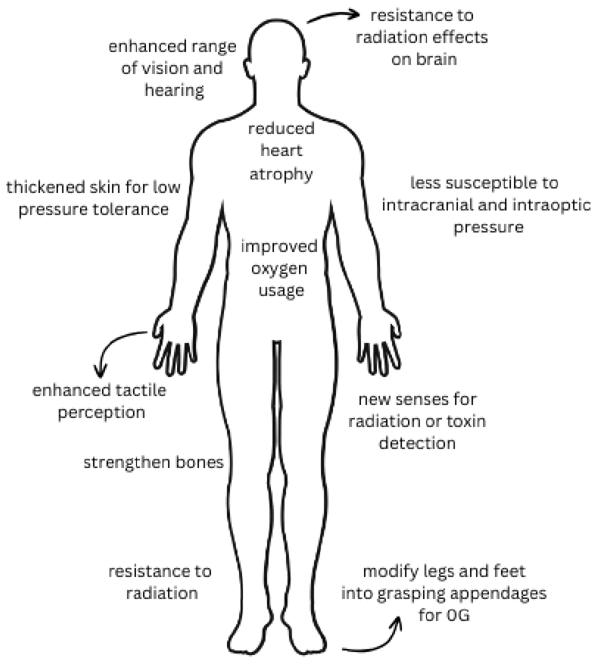

Figure 2: (Source: Future interstellar rockets may use laser-induced annihilation reactions for relativistic drive)

5.2.1. Methods-Hacking the Genome

5.2.1.1. Epigenetics

In recent years, however, it is been found that chemicals and substances in cells outside of the nucleus can enter the nucleus and change which gene codes are transcribed and translated into proteins. Epigenetics refers to changes in gene activity that don't involve altering the DNA sequence itself. This “epigenetic” mechanism allows modification in the interpretation of that gene code from outside of the gene code. Moreover, we have learned that epigenetic changes can be inherited, particularly in combination with DNA that is not part of the chromosomes in a cell nucleus. Mitochondria, the energy production part of a cell, also has DNA, which is inherited strictly from the female parent. Thus, Epigenetics refers to changes in gene activity that don't involve altering the DNA sequence itself.

5.2.1.2. Optogenetics

Optogenetics is a tech in biology that combines light and genes to control cells, especially nerve cells. It works like this:

- Scientists introduce genes for light-sensitive proteins into specific cells.
- When shone with a certain light, these proteins activate or deactivate the cells.

Optogenetics utilizes the ability to insert algae-derived genes that are sensitive to specific wavelengths of light. The resulting proteins are known as “opsins" and can add light-activated sensory abilities to organisms. Two of the most well-studied opsins are channelrhodopsin and halorhodopsin. Optogenetics promises the ability to create new receptors via novel proteins that can be activated optically, chemically, or mechanically. This might lead to the creation of new senses, or the expansion of existing senses, for instance extending the breadth of wavelengths of light detectable by human vision far into the infrared or ultraviolet spectrums, or other regions of the electromagnetic spectrum. Another would be additional chemical senses, such as the ability to detect toxins in food, water, or air. Moreover, these traits could be linked to further genetic engineering to develop tolerance to these substances.

5.2.1.3. Brain-Computer Interfaces

Brain-computer interfaces (BCIs) will allow the human brain to remotely operate computerized instruments and machines. Initial forms of these interfaces have taken the form of simple games, which can replicate simple left-right or up-down controls by sensing changes in fundamental rhythms of the brain. More sophisticated interfaces have been developed for the control of robotic limbs and prosthetics. Brain-computer interfaces (BCIs) empower extraterrestrial exploration by allowing control of habitats and machinery from a safe distance. This direct brain-machine connection facilitates operation in hostile environments and could be vital for long-term interstellar travel, enabling humans to adapt and thrive in any encountered environment. Homo Stellaris can function in any environment encountered in the course of interstellar exploration. It may even be necessary for long-duration hibernation, with human brains connected to virtual environments while a body is held in stasis for the decades-long journey to another world. If there is to be any hope of adapting humans to space, we will have to take charge of evolution and control it. Only then will we truly become Homo Stellaris: The people of the stars [21] .

5.3.Communication using twisted photons

Photons move not just through a medium in interstellar communications, but also across the textures of spacetime, requiring consideration of general relativity. For Interstellar Travel, data transfer between two points must be transmitted efficiently, effectively, and at masses. Multiple degrees of Freedom, including the wavelength, polarization, and time bins, have been utilized to convey information in optical communications.

- Wavelength(λ) =c/$\boldsymbol{\nu}$. It refers to the frequency of the light. Different wavelengths of light can be used to carry information. An example is an optical fiber.
- Polarization. Manipulating the polarization of light additional information can be decoded. This doubles the data-carrying capacity of the optical fiber.
- Time-bins. It is a technique used in quantum information science to encode a qubit of information on a photon. Quantum information science uses qubits as a basic resource similar to bits in classical computing.

However, since these entanglements may be altered during propagation under the impact of media, their transmission must be investigated to compensate for these modifications.

5.3.1. Twisted photons carrying orbital angular momentum (OAM) are competent candidates for future interstellar communications

They possess unique properties due to their spiral phase front, allowing for the encoding of information in the spatial mode of light. Additionally, entanglement—a quantum phenomenon where the states of two or more particles are correlated in such a way that the state of one particle instantaneously influences the state of the other(s)—can be created between twisted photons. Orbital angular momentum (OAM) of light may assume well-defined values of $l\hbar$ where $l = 0, \pm 1; \pm 2; \ldots$, that span an infinite-dimensional Hilbert space. Because information may be encoded in a high-dimensional space, light with OAM is a potential source for future quantum communications. But the OAM entanglements suffer from adverse effects from the environment (eg Atmosphere). Outer space, fortunately, has no such adverse effects. However gravitational fluctuations do cause the degradation of spatial entanglement.

5.3.2. Gravitational fluctuations and the degradation of spatial entanglement

Gravitational fluctuations may come from a variety of sources. Classically, they can be a remnant of primordial gravitational waves generated during the early stage of the universe, a remnant of the Big Bang as the cosmic microwave background, or the sum of the gravitational waves randomly produced by a vast variety of sources in the universe. Also, gravitational fluctuations can arise due to the quantum gravity Gravitational waves can induce oscillations in the spacetime metric, potentially affecting the coherence and entanglement of photon states References [44,45,46] .

5.4. Metastructures

Metastructures are developed from metamaterials, which are artificial electromagnetic media, that provide optical properties that can be reproducibly shaped on length scales below the wavelength of light. Expandable metal plates with hexagonal corrugation are fabricated using silicon rubber by the 3D printing process.

A mechanism of controlling the hexagonal corrugation for optimal tensile behavior, which has been envisioned for the artificial metastructures in multifunctional applications such as bio-wings in bio-mimic robots or light sails in space travel has been discussed. Different from the bulk structures that can be considered as symmetric since the overall size is much larger than that of the local structures, these plate-like structures may suffer from the asymmetry of the corrugation in the out-of-plane direction. As a consequence, out-of-plane transverse deflection can develop in corrugated meta plates subjected to in-plane tension. However, the wrinkling of films is mainly caused by instability, which is different from the corrugation asymmetry-induced out-of-plane deflection. The corrugation asymmetry in the transverse direction leads to the out-of-plane deflection in tension. It has been concluded that due to the geometric asymmetry resulting from the hexagonal corrugation, the metaplates experienced transverse displacement.

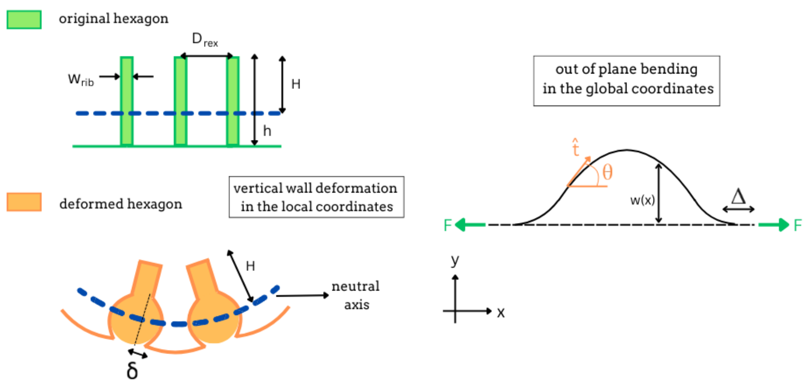

Figure 3: (Source: Oumuamua's Rotation with the Mechanical Torque Produced by Interstellar Medium.)

6. A Case Study: Oumuamua, an Interstellar encounter

The first known interstellar object to pass through our solar system is called Oumuamua. It was discovered in October 2017 by astronomer Robert Weryk during a Pan-STARRS survey in Hawaii. The analysis of this mysterious object is necessary for our understanding of Interstellar travel. Now why is this mysterious, we shall find out [49,50].

6.1. Origin

The origin of Oumuamua resides outside our Solar System, which already makes it a mysterious case. The study of its trajectory showed it came from the direction of the Lyra constellation. The journey of this interstellar visitor is at least some thousand years old. When it began, the celestial objects' position concerning us differed. It is therefore very difficult to showcase its exact origin as it could have been traveling for billions of years.

6.2. What was it?

Many scientists across the world have proposed theories and hypotheses regarding the Interstellar Vagabond. It was the first of its kind known to us and is therefore expected to be a topic of debate for mankind. A hypothesis stated that it might be a symbol of Extraterrestrial Intelligent Life and is an alien spacecraft. It gave two conditions, either the spacecraft is controlled by the alien life, not necessarily directly but through advanced types of equipment and computers, or is uncontrolled. The easier one to believe is that it's unguided. According to a study, it was found that Oumuamua had a rotation period of approximately 7 h with tambling rotations. It suggested that the object is not under control, or completely under control. Due to its drifting trajectory, the possibility of it being under control is weakened. Another hypothesis stated that it might now be controlled by an alien civilization but could potentially be a message by them. It is like a sign to show that they exist, not telling where but somewhere they do. It was designed in such a way so that civilizations in another star system if they exist, realize that they are not alone. It had a light-sail-like design, about which we shall talk later, and was assumed to be accelerated by directed energy. Limitations by the rocket equation can be overcome by this type of acceleration [51,56].

Oumuamua's excess acceleration and mysterious shape were explained using Hydrogen ice by Seligman and Laughlin. The understanding of their model showed that the object was around 100 million years old. Postulating a speed of 30 km/s, it was produced in Giant Molecular Cloud at a distance of around 5 kpc. Füglistaler & Pfenniger proposed that objects of H_2 formed via a phase transition must be larger than 5 km in size to make the journey from GMC to our Solar System. Due to its changing brightness, it was also classified as a comet at one point but was stated as controversial as it showed the absence of comet activity while passing near the Sun. It was thereby proposed to be a comet made of Nitrogen ice explained by the missing dust tail and signs of outgassing, but had a speed too high for it to be a comet or an asteroid [57,58].

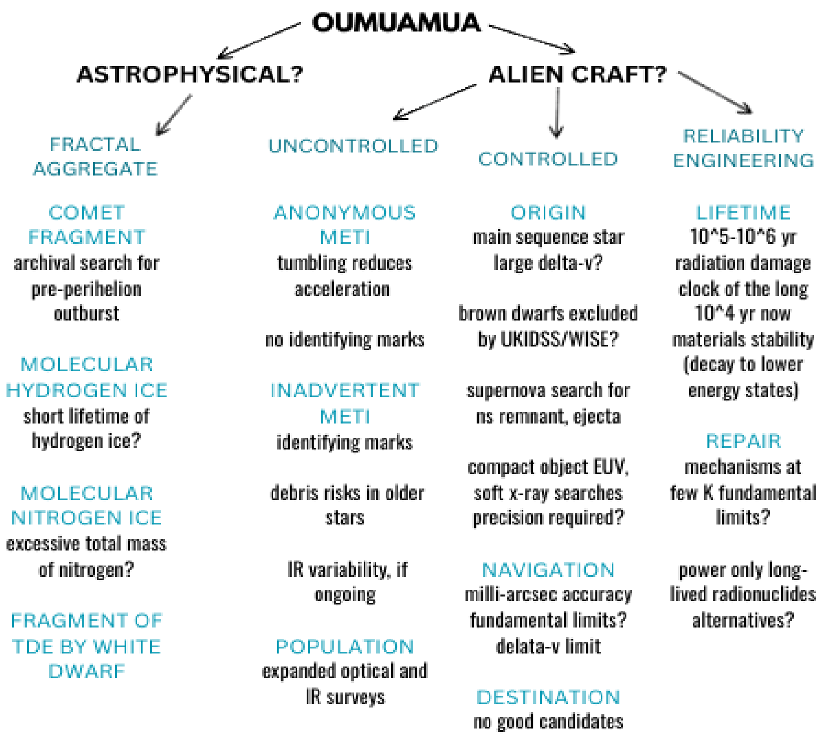

Figure 4: (Source: Research programmes arising from ‘Oumuamua considered as an alien craft.)

6.3. What to Infer?

The task of designing for a spacecraft having a large lifespan like Oumuamua presents formidable reliability engineering challenges. Its lifetime is around 4000 times longer than our longest working spacecraft Voyager 1 and 2, launched in the year 1977. The interstellar object 1I/2017 U1 (Oumuamua) was observed to have an unprecedented trajectory and unique spectral properties, which resulted in a controversy regarding its origin. It has been assumed as a spacecraft, particularly a thin light sail sent on a mission to our Solar System.[55][59][60]

6.3.1, Why has Oumuamua been regarded as a spacecraft?

It has been found that Oumuamua has a nongravitational acceleration. This could be due to the Sun's radiation pressure as it has been assumed as a light sail with a thin oblate shape (length $\sim 10^2$ m, and surface density ≈ 1 kgm^{-2}). Also, Oumuamua’s density is similar to that of refractory asteroids ($2–3\times10^3$ kgm^{-3}), so we can compare its effective thickness ($\sim 3–5\times 10^{-4}$ m) to that of an eggshell, which is two times magnitude smaller than that of the International Space Station. Oumuamua has a high albedo, similar to that of asteroids.

6.3.2. Dynamics of a light sail

Dynamics have been discussed to test the probability of an ISO being a light sail, with the example of Oumuamua. Firstly, magnetic and gas drag by the ISM cause drifts in the trajectory of freely floating light sails. Hydrogen atoms in the turbulent ISM exert a drag force (normal to the surface of the light sail) which results in a sideways acceleration of the tumbling light sail. Also, due to the imperfect alignment of the surface normal vector with the heliocentric position vector, radiation pressure causes a sideways acceleration, which would result in a considerable non-radial deviation from Kepler motion. [This can be said in the case of Oumuamua because its orbital path has a perihelion distance of 0.26 au (by observation) and departs from a parabolic Keplerian trajectory with a component of nongravitational acceleration predominantly in the radial direction away from the Sun]

The tumbling motion of the extremely thin light sail implies a light curve with an immense amplitude. [Oumuamua has a high cadence light curve with an irregular brightness variation over an amplitude range (2.5–3). This has been used to deduce its tumbling motion.] In the ISM, over a travel distance of 1 parsec, the drift of freely rotating light sails can reach ∼100 au. This drift increases with the travel distance as $\sim L^3$. Secondly, if the net flux of incident solar light on the light sail is not parallel or antiparallel to its orbital trajectories, the solar radiation would cause a sideways pressure. Consequently, due to the tumbling motion, a sideways radiation force would act on the light sail and cause significant sideways displacement. According to experimental observations, the data of Oumuamua significantly deviates from the expected values for a light sail.

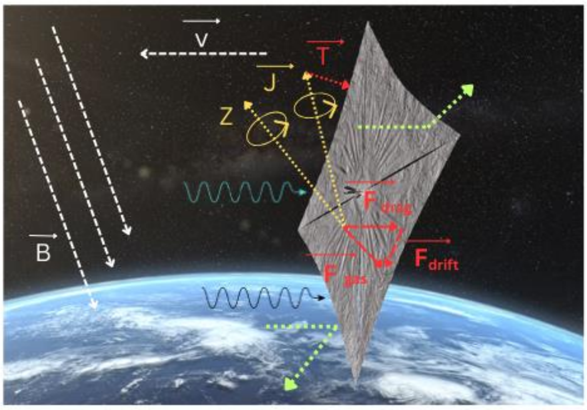

Figure 5: (Source: Observable tests for the light-sail scenario of interstellar objects)

Thirdly, the amplitude of the light curve can also be used to analyze the axis ratio of ISOs. The analysis of ‘Oumuamua’s observed light curve suggests that it is most likely to have an oblate shape (axis ratio of 7 : 7: 1), while the probability for such a light curve for a light sail is approximately 1.5%.

6.3.3. Results

Keeping in mind these three observations, it is unlikely that Oumuamua could be a light sail. The dynamics of an intruding light sail would lead to observational features such as non-negligible sideways radiation force and normal displacement from the Kepler orbit, a light curve with an extremely high amplitude, and irregular invisibility in the sky. These parameters can be used to judge the possibility of any such ISO to be a light sail [61].

7. Conclusion

It can therefore be concluded that Interstellar travel still lies in a domain where numerous technological advancements and innovations are required. It lies well beyond our current technological and biological capabilities. Till now various concepts and propulsion techniques have been discussed and proposed but all these technologies have limitations. Some of them have a scarcity of resources available like antimatter and some of them have disadvantages like the limitation of maximum velocity achievable leading to time constraints. Depending on technologies that have not been developed till now make it difficult to work. Only the theoretical justification requires time and money to be worked upon. If we do think, we as in our generation, don't need to work on making our species Intergalactic. We just have to move towards Interplanetary species, developing our nearby planets, and potentially moving to nearby star systems to a well-defined boundary. The future work would be done by our future planetary species which we have developed, the subsidiary ones. This is how the development shall occur, like a spider's web, spreading in all directions step-wise. We should know that things we see today were also once a dream and thought to be impossible to exist. The upcoming technologies make it feasible for us to now seriously discuss, plan, and execute programs that could render interstellar travel and deep space exploration possible. We can go beyond our existing low-speed chemical and ion propulsion techniques and adopt more future-oriented technologies. The case with Interstellar travel is such that we feel it is not achievable. Science-fiction books and movies have already set the bar high and increased our hopes for a life in which space is accessible to every one of us. One day, it will be inevitable to launch missions of Interstellar Travel because the Earth cannot sustain life forever. We will have to move beyond our planet to make our species interplanetary and plan for the future work that is to be done by the subsidiary colonisations of Earthlings. So, we can see that there is not likely an option of not traveling, we have to continue our development directed towards it so that when the time comes, we are ready for the giant leap. The effectiveness of travel is defined by multiple fields of science and technology. Keeping in record of the growth and work in the respective fields would help us tally our plan ahead and act upon the same accordingly. Therefore, it can be concluded interstellar travel is not possible with current technologies but in the coming future, it needs to be turned into reality for transforming the homo-sapiens into homo-stellaris [69,70].

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