A Perspective of Practical Interstellar Exploration: Using Field Propulsion and Hyper-Space Navigation Theory

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Abstract. The main proposal of this effort is to develop an interstellar navigation theory eliminating the problem of the twin or time paradox due to Special Relativity. Additionally, the promising field propulsion concepts are introduced in order to achieve above-mentioned interstellar navigation mode. The practical interstellar exploration combines both a propulsion theory with a navigation theory. Here, the navigation theory is defined as a theoretical method of interstellar travel such as traveling through a wormhole. The article describes the fundamental theory and method of use in interstellar exploration.

INTRODUCTION

As is well known in astronomy, sixty-three stellar systems and other eight hundred fourteen stellar systems exist respectively within the range of 18 and 50 light years from our Solar system. For instance, the star Sirius, which is the seventh nearest star is 8.7 light years from Earth, while the Pleiades star cluster is 410 light years from us. According to Einstein's Special Relativity, sending a starship to a stellar system at a distance longer than several hundred light years would ask for an extremely long time even if the starship would travel at the speed of light. For instance, assuming that the starship is traveling to the Pleiades star cluster at a speed of 0.99999c, it will arrive at the Pleiades 1.8 years later and, in the case of immediatly starting of the return travel, it would be back to Earth 3.6 years after leaving for the Pleiades. But this would be just for the clocks of the astronauts onboard the starship for that mission. For people on Earth, the whole time period would be 820 years, with paradoxical consequences as to the feasibility of a mission such as this.

The first solution of the above-stated problem is to obtain a breakthrough in propulsion science. A possible breakthrough could rely upon the notion of using field propulsion theory such as a Space Drive Propulsion scheme. However, no propulsion theory currently exceeds the speed of light. Accordingly, the field propulsion alone is not enough to establish the reality of interstellar exploration, thereby requiring a navigation theory as a secondary solution.

Concerning interstellar navigation, the method using a wormhole is well known; relying on space warps, such as for instance Wheeler-Planck Wormholes, Kerr metric, Schwartzschild metric, Morris-Thorne Field-Supported Wormhole based on the solutions of equations of General Relativity (Forward, 1989). However, since the size of wormhole is smaller than the atom, i.e.,~10^{-35}m and moreover the size is predicted to fluctuate theoretically due to instabilities, space flight through the wormhole is difficult technically and it is unknown where to go and how to return. Additionally, since the solution of wormhole includes a singularity, this navigation method theoretically includes fundamental problems.
The search for a consistent quantum theory of gravity and the quest for a unification of gravity with other forces (strong,

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weak, and electromagnetic interactions) have both led to a renewed interest in theories with extra spatial dimensions. Theories that have been formulated with extra dimensions include Kaluza-Klein theory, supergravity theory, superstring theory, and M theory, D-brane theory related superstring. For instance, superstring theory is formulated in 10 or 26 dimensions (6 or 22 extra spatial dimensions). These extra spatial dimensions must be hidden, and are assumed to be unseen because they are compact and small, presumably with typical dimensions of the order of the Planck length(~10^{-35}m). The navigation method of utilizing extra dimensions (even if they are compactified) has also a theoretical problem as well as using a wormhole.

There exists another interstellar navigation theory. Froning shows the rapid starship transit to a distant star (i.e. Instantaneous Travel) using the method of "jumping" over so-called time and space (Froning, 1983). In addition to this invaluable concept, Hyper-Space navigation theory using a space-time featuring an imaginary time offers great promise to develop practical interstellar exploration. This navigation theory is based on Special Relativity (not on General Relativity), that allows interstellar travel to the farthest star systems to be realized; and removes the present theoretical limitations to interstellar travel that arises from the extremely long time needed (the time paradox) according to Special Relativity (Minami, 1993, 2003). The practical interstellar exploration combines propulsion theory with navigation theory. The objective of this paper is the development of a more reliable means for the interstellar travel by using field propulsion principle and theoretical navigation method.

FIRST SOLUTION: FIELD PROPULSION SYSTEM

The first solution is related to the field propulsion system. In order to breakthrough the theoretical limitations of conventional rocket propulsion system using momentum thrust, an advanced propulsion system combined with the powerful energy system which achieves the hyperbolic trajectory or direct trajectory is indispensable. In the first place, the super-high speed and high acceleration of starship are required.

Outline of Field Propulsion Concepts

All existing methods of propulsion systems, i.e. chemical propulsion, electric propulsion (Ion thruster, MPD thruster, Hall thruster, ARC jet thruster), laser propulsion, nuclear propulsion are based on expulsion of a mass to induce a reaction thrust. The "momentum thrust" is based on momentum conservation law. However, in momentum thrust propulsion the maximum speed is limited by the product of the ejected gas effective exhaust velocity and the natural logarithm of the mass ratio; so the speed of present rockets is too slow as compared with the speed of planets and for interstellar travel.

Alternatively, the concept of "Field Propulsion" has been advanced as resulting from pressure thrust, without mass expulsion. The envisaged solar sails and light sails are propelled just by receiving light pressure, but pressure thrust in Field Propulsion refers to a reaction with space-time itself (i.e. the vacuum) to generate a propulsive force. The propulsive force as a pressure thrust arises from the interaction of space-time around the starship and the starship itself, the latter being propelled against the space-time structure. The field propulsion principle consists in the exploitation of the action of the medium field induced by such interaction and is thus based on some concepts in modern physics in order to bring about the best and most feasible propulsive performance.

The most remarkable results attainable through Field Propulsion are as follows: 1) high acceleration such as several tens of g's can be obtained, 2) theoretical final velocity close to the speed of light, and 3) no action depending upon inertial force. As to item 3), this comes from the thrust as a body force. Since the body force they produce acts uniformly on every atom inside the starship, accelerations of any magnitude can be produced with no strain on the crew, i.e., it is equivalent to free-fall. The field propulsion system appears to violate the

conservation law of momentum because the reaction mass is not readily apparent. The most promising interpretation is to consider that space itself as vacuum is a kind of reaction mass.
Now, a field propulsion system must satisfy the following criteria (Millis and Williamson, ed. 1999):
1) conservation of momentum, 2) conservation of energy, 3) ability to induce a unidirectional acceleration of the starship, 4) controllability of direction and thrust, 5) sustainability during starship motion, and 6) effective capability of propelling the starship.

Generic Propulsion Principle of Field Propulsion

As shown in Fig.1, the propulsion principle of field propulsion system is not momentum thrust but pressure thrust induced by a potential gradient or pressure gradient arising from the space time field (or vacuum field) between the bow and the stern of our starship. Since the pressure of the vacuum field in the rear vicinity of starship is high, the starship is pushed from the vacuum field. Pressure of the vacuum field in the front vicinity of the starship is low, so the starship is pulled from the vacuum field. In the front vicinity of starship, the pressure of the vacuum field is not necessarily low but the ordinary vacuum field, that is, just only a high pressure of vacuum field in the rear vicinity of the starship. Here, the starship is propelled by this distribution of the pressure of the vacuum field. Vice versa, it is the same principle that the pressure of the vacuum field in the front vicinity of starship is just only low and the pressure of the vacuum field in the rear vicinity of starship is ordinary. In any case, the pressure gradient of the vacuum field (potential gradient) is formed over the entire range of the starship, so that the starship is propelled by pushing from the pressure gradient of the vacuum field.

Here, we must pay attention to the following. The starship cannot move unless the starship is independent of the pressure gradient of the vacuum field. No interaction is present between the pressure gradient of the vacuum field and the starship. Starship does not move as long as the propulsion engine generates the pressure gradient or potential gradient in the surrounding area of starship, due to the interaction between the starship's pressure gradient of the vacuum field and the starship. This is because an action of the propulsion engine on space is in equilibrium with a reaction from space. It is consequently necessary to shut off the equilibrium state in order to actually move the starship. As a continuum, the space has a finite strain rate, i.e. speed of light. When the propulsion engine stops generating the pressure gradient of vacuum field, it takes a finite interval of time for the generated pressure gradient of the vacuum field to return to ordinary vacuum field continuum pressure. In the meantime, the starship is independent of the pressure gradient of the vacuum field. It is therefore possible for the starship to proceed ahead receiving the action from the vacuum field. Since the propulsion engine must necessarily be shut off for propulsion, the starship can get continuous thrust by repeating the alternate ON/OFF change in the engine operation at a high frequency.
Concerning the propulsion principle of field propulsion system, the distribution of a typical field as shown in Fig.1 is fundamental; accordingly, several kinds of propulsion systems have been proposed. Any propulsion system is selected, whether the constituents of pressure gradient or the potential gradient generated by the propulsion engine are dependent upon curvature, metric, zero-point radiation pressure or entropy (Minami, 2003).

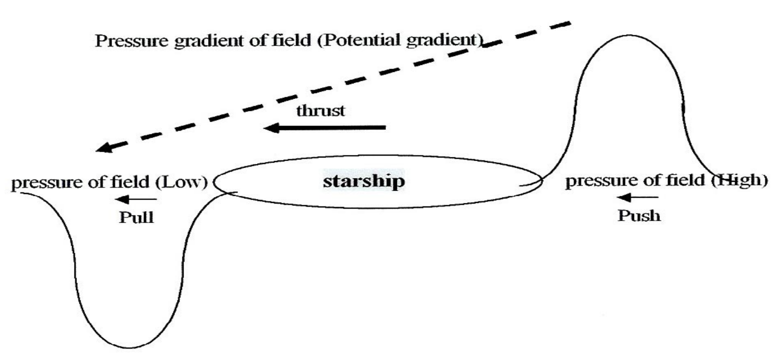


FIGURE 1. Fundamental Propulsion Principle of Field Propulsion.

Candidate and Outline of Field Propulsion System

The following is an outline of the main field propulsion systems proposed up to the present time, i.e. 1) Space Drive Propulsion System (Minami, 1994, 1997, 1998), 2) Superstring-Based Field Propulsion (Minami, 2004), 3) ZPF (Zero Point Field) Propulsion System (Froning and Barrett, 1998), 4) Alcubierre's Warp Drive Propulsion System (Alcubierre, 1994). In this section, item 1) and 2) are described below in the main.

Space Drive Propulsion System

The propulsion principle of space drive propulsion system is summarized as follows. Assuming that space vacuum is an infinite continuum, the propulsion principle utilizes the nature of the field derived from the geometrical structure of space, by applying continuum mechanics and General Relativity to space. In the beginning, the acceleration generated by the curvature of space induced from a strong magnetic field is based on the external and internal Schwarzschild solution. However, superior acceleration based on the de Sitter solution is obtained at present, which does not require a strong magnetic field. These solutions are described in references (Minami, 1997, 1998).

Space drive propulsion system moves by pushing a field (space) or being pushed from a field (space) around the starship. The expression "moves by pushing the field (space) or being pushed by a field (space)" indicates that the starship produces a curved space region and moves forward by being subjected to the thrust from the acceleration field of curved space. The propulsion mechanism is also a kind of pressure thrust. This means that space can be considered as a kind of a transparent elastic field. That is, space as a vacuum performs the motions of a membrane undergoing deformation such as expansion, contraction, elongation, torsion and bending. The latest expanding universe theory supports this assumption. Space can be regarded as an elastic body that resembles a rubber-like membrane. If space curves, then an inward normal stress is generated. This normal stress, i.e. surface force serves as a sort of pressure field. A large number of curved thin layers form the unidirectional surface force, i.e. the acceleration field as shown in Fig.2. Accordingly, the curvature produces the acceleration field. Space drive propulsion system uses the acceleration field as a pressure thrust. In addition, the phase, i.e. the arrangement between engine and body of the starship is important in order to get a unidirectional thrust. A pulse-like operation induced by switching the engine on and off is required. Thrust is generated when the curved space returns to flat space. It is therefore possible for the starship to proceed ahead receiving the action from the acceleration field of space, that is, the starship moves by being pushed from space that continues on to infinity. Cosmic space as an infinite continuum may be deformed very slightly by being kicked. However, this kicking is absorbed by the deformation of space itself continued infinitely. The acceleration is given by

$$\alpha = \frac{2\pi G\lambda}{3c^2}\phi_0{}^4 = 1.6\times 10^{-27}\,\lambda\phi_0{}^4 \quad . \tag{1}$$

Eq.(1) indicates that the vacuum expectation value ϕ_0 of the vacuum scalar field produces a constant acceleration field. As a result, we find that acceleration becomes constant, that is, we can get rid of the tidal force inside of the starship. Figure 3 shows the potential field, i.e. the excited space around the starship. The engine as a small-sized generator produces the excited space in the surrounding area of the starship. Hence, the starship is propelled with acceleration α being subjected to the thrust from the excited space field.

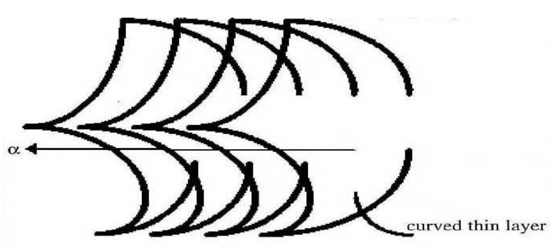


FIGURE 2. Acceleration Field induced by Curvature.

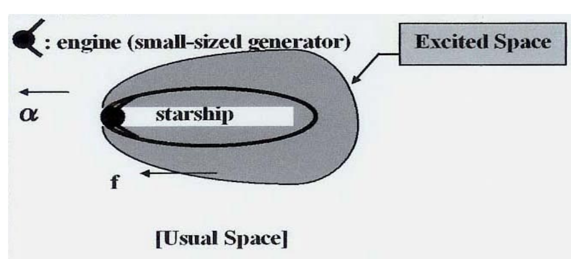


FIGURE 3. Potential Field around the Starship.

A new field-propulsion concept, based on new frontier physics, is presented in this section. The starting conjecture is that superstrings might – as a whole – behave like polymer chains of some elastic bodies (e.g. similar to rubber). It is well known that, for such type of elasticity, the related force is given by the product of temperature and entropy gradient. The entropy can be calculated from the number of microstates of the polymer chains at a given temperature. From superstring theory, the Schwarzschild radius of string increases with the string coupling constant; therefore, strings might be black holes. The relation between superstring and black holes offers a concrete method for calculating the black hole's number of quantum states and yields the same result as the Bekenstein-Hawking entropy. The second key-point consists in applying the 5-dimensional Reissner-Nordström black hole solution to a configuration of strings and solitons. By using the quantum counting method, one can calculate the entropy of a D-brane in terms of the number of states (Callan Jr and Maldacena, 1996, Horowitz and Strominger, 1996). The third basic assumption is that space-time has entropy through D-branes. This suggests that the substructure of space-time is also composed of some kinds of physical microstates and offers the properties of entropy. Recently there has been remarkable progress in the understanding of some string solitons called "D-branes". Superstring theory contains "D-brane" solitons that are extended membranes of various possible spatial dimensions. Since the D-brane is a deformable and dynamical object, and couples with gravity, it should be a source to generate the curvature of space-time (Polchinski, 1998, Johnson, 2003).

In general, elasticity has two kinds of nature, that is, energy elasticity (crystalline elasticity) like a spring and entropy elasticity (rubber elasticity) like a stretching rubber membrane. Energy elasticity is due to the deformation of interatomic distance or displacement between molecules. It corresponds to the decrease of internal energy. Entropy elasticity (rubber elasticity) is due to thermal motion of the polymer chains. It corresponds to an increase of entropy. Elasticity of rubber is very different from that of crystallic solids. The elastic constant of rubber increases with temperature. The space as vacuum is considered to preserve the properties of entropy elasticity from the viewpoint of the latest cosmology and theory of elementary particles. Figure 4 shows the propulsion principle utilizing the entropy gradient. It is explained how a pulsed engine, capable to excite space and induce entropy gradient, might move a spaceship. The field of elastic force, that is, the acceleration field is generated around the spaceship. In the on-state of engine operation (denoted ● in Fig.4), the large entropy state is generated in the front vicinity of spaceship. In the rear vicinity of spaceship apart from the engine, the entropy is small as usual natural space. Accordingly, there exists an entropy gradient in the range of excited space. In this state, the elastic force is generated in the direction of increasing entropy (from small entropy to large entropy), and this state corresponds to the small entropy of stretched rubber. Although the excited space as entropy gradient contracts toward the engine, the excited space cannot contract. This state is maintained till the engine is off, due to the equilibrium state. In the state of the engine off mode, the spaceship is dragged as the excited space (i.e., entropy gradient field) contracts thereby propelling the spaceship forward. This state corresponds to the stretched rubber (i.e., small entropy) contracting to the initial state (i.e., large entropy) of the rubber. The spaceship is propelled receiving the elastic force "F" from the field created by the entropy gradient. As mentioned above, since the engine must necessarily be shut off for propulsion, the spaceship can get continuous thrust by repeating the alternate ON/OFF change in the engine operation at high frequency.

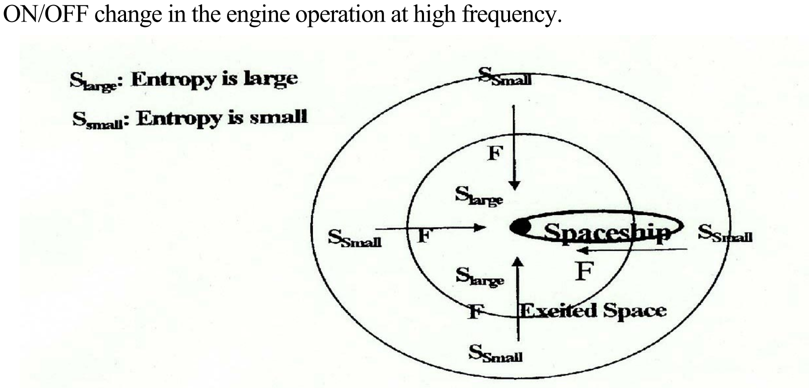
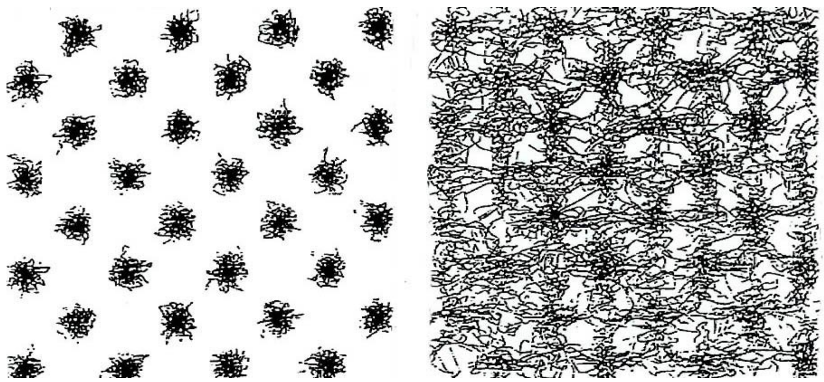


FIGURE 4. Propulsion Principle Induced by Entropy Gradient.

Supposing that the string or D-brane is the constituent of space-time is suggestive of the existence of possible quantum states for the space-time. This indicates that the entropy of space-time can be defined as an assembling of strings. Strings as the constituents of space-time correspond to the polymer chains in the elastic body. Since the statistical entropy is the logarithm of the number of states (i.e., degeneracy of system), it is necessary to consider what kinds of physical state exist.

Figure 5 shows that the open strings cling to the field of space. Figure 5 (a) shows the state of present cosmic space in ultra-low temperature, and figure 5 (b) shows the state of the early universe in ultra-high temperature. The excitation of space implies that the ordered phase of open strings clung to space in Fig.5 (a) is transferred to the disordered phase of open strings clung to space in Fig.5 (b) by some trigger. It corresponds to that the number of twined open strings is transferred from ordered phase (small entropy) to disordered phase (large entropy). This picture indicates that these states can be interpreted as entropy. Accordingly, it suggests the possibility of a new propulsion theory induced by entropy gradient.



(a) Ordered Phase (Small entropy). **(b)** Disordered Phase (Large entropy).

FIGURE 5. Fine-Structure of Space.

Although the superstring theory is a very promising theory for quantum gravity, there exists other strong candidate for quantum gravity, i.e., Loop Quantum Gravity theory. The theoretical framework of loop quantum gravity has evolved through numerous twists and re-foundation, involving mathematical tools such as Penrose's spinor. The physical geometrical quantities such as space-time volume, space-time area and curvature, are quantized in a non-trivial, computable, fashion (Ashtekar, 2001, Smolin, 2003). The field propulsion principle based on loop quantum gravity may also offer great promise.

SECOND SOLUTION: HYPER-SPACE NAVIGATION THEORY

The secondary solution is related to the interstellar navigation theory. Assuming hyperspace as being characterized by imaginary time, it is shown that the problem of the twin or time paradox for interstellar travel as is set forth by Special Relativity are removed.

Properties of Flat Space

In general, the property of space is characterized by a metric tensor that defines the distance between two points. Here space is divided into two types. Actual physical space that we live in is a Minkowski space, and the world is limited by Special Relativity. It is defined as "Real-Space". Here as a hypothesis, an invariant distance for the time component of Minkowski metric reversal is demanded. This is not a mere time reversal. It is defined as "Hyper-Space". The invariance is identical with the symmetries. Symmetries in nature play many important roles in physics. From this hypothesis, the following arises (see Minami, 1993, APPENDIX A in Minami, 2003): the properties of the imaginary time (x^0=ict; i^2=-1) are required as a necessary result in Hyper-Space. Here, "i" denotes the imaginary unit and "c" denotes the speed of light. The time "t" in Real-Space is changed to imaginary time "it" in Hyper-Space. However, the components of space coordinates(x,y,z) are the same real numbers as the Real-Space. From the above, it is seen that the real time (x^0=ct) in Real-Space corresponds to the imaginary time (x^0=ict) in Hyper-Space. That is, the following is obtained:

Real-Space: t (real number), x,y,z(real number) ; Hyper-Space: it (imaginary number; i^2=-1), x,y,z(real number).

The imaginary time direction is at right angles to real time. This arises from the symmetry principle on the time component of Minkowski metric reversal.

Lorentz Transformation of Hyper-Space

Next, the Lorentz transformation of Hyper-Space corresponding to that of Real-Space is found.

Since the components of space coordinates(x,y,z) do not change between Real-Space and Hyper-Space, the velocity in Hyper-Space can be obtained by changing t → it:

$$V = dx/dt \rightarrow dx/d(it) = dx/idt = V/i = -iV \quad . \qquad (2)$$

The velocity becomes the imaginary velocity in Hyper-Space. Substituting " t→it, V→-iV " into the Lorentz transformation equations of Minkowski space formally gives:

< Hyper-Space Lorentz transformation >

$$x' = (x - Vt)/[1+(V/c)^2]^{1/2} , \quad t' = (t + Vx/c^2)/[1+(V/c)^2]^{1/2}$$

$$\Delta t' = \Delta t[1+(V/c)^2]^{1/2} , \qquad \Delta L' = \Delta L[1+(V/c)^2]^{1/2} \quad . \qquad (3)$$

This result agrees with the results of detailed calculation. As a reference, the Lorentz transformation equations of Minkowski space, i.e. of Special Relativity, are shown below:

< Real-Space Lorentz transformation: Special Relativity >

$$x' = (x - Vt)/[1-(V/c)^2]^{1/2} , \quad t' = (t - Vx/c^2)/[1-(V/c)^2]^{1/2}$$

$$\Delta t' = \Delta t[1-(V/c)^2]^{1/2} , \qquad \Delta L' = \Delta L[1-(V/c)^2]^{1/2} \quad . \qquad (4)$$

The main difference is that the Lorentz-Fitz Gerald contraction factor $[1-(V/c)^2]^{1/2}$ is changed to $[1+(V/c)^2]^{1/2}$.

Now consider navigation with the help of both Lorentz transformations, especially the Lorentz contraction of time.

Figure 6 shows a transition of starship from Real-Space to Hyper-Space. In Fig. 6, region I stands for Real-Space (Minkowski space). Consider two inertial coordinate systems, S and S'. S' moves relatively to S at the constant velocity of starship (V_S) along the x-axis. S' stands for the coordinate system of the starship and S stands for the rest coordinate system (V_S=0) on the earth. Δt_{ERS} is the time of an observer on the earth, i.e. earth time, and $\Delta t'_{RS}$ is the time shown by a clock in the starship, i.e. starship time. Region II stands for Hyper-Space(Euclidean space). S' moves relatively to S at the constant velocity of starship (V_S) along the x-axis. S' stands for the coordinate system of the starship in Hyper-Space and S stands for the rest coordinate system (V_S=0) in Hyper-Space. Δt_{EHS} is the time of an observer on the earth in Hyper-Space, i.e. the equivalent earth time, and $\Delta t'_{HS}$ is the time shown by a clock in the starship in Hyper-Space, i.e. the starship time. Now, the suffix."HS" denotes Hyper-Space and the suffix."RS" denotes Real-Space. Figure 6 also shows a linear mapping f:RS(Real-Space)→HS(Hyper-Space), that is, from a flat Minkowski space-time manifold to a flat imaginary space-time manifold. It is assumed that space is an infinite continuum. There exists a 1-1 map f:RS→HS, $x^i \mapsto f(x^i)$ and a 1-1 inverse map f^{-1}:HS→RS, $f(x^i) \mapsto x^i$. The mapping is a bijection. These transformations will be local and smooth.

Now suppose that a starship accelerates in Real-Space and achieves a quasi-light velocity (V_S~c) and plunges into Hyper-Space by some new technical methods. In Real-Space, from Eq.(4),

$$\Delta t'_{RS} = \Delta t_{ERS}[1- (V_S/c)^2]^{1/2} \quad . \qquad (5)$$

Eq.(5) is the so-called Lorentz contraction of time derived from Special Relativity. In Hyper-Space, the starship keeps the same velocity as the quasi-light velocity (V_S~c) just before plunging into Hyper-Space, i.e. $V_{S(HS)}=V_{S(RS)}$.

Therefore, from Eq.(3),

$$\Delta t'_{HS} = \Delta t_{EHS}[1+(V_S/c)^2]^{1/2} \quad . \qquad (6)$$

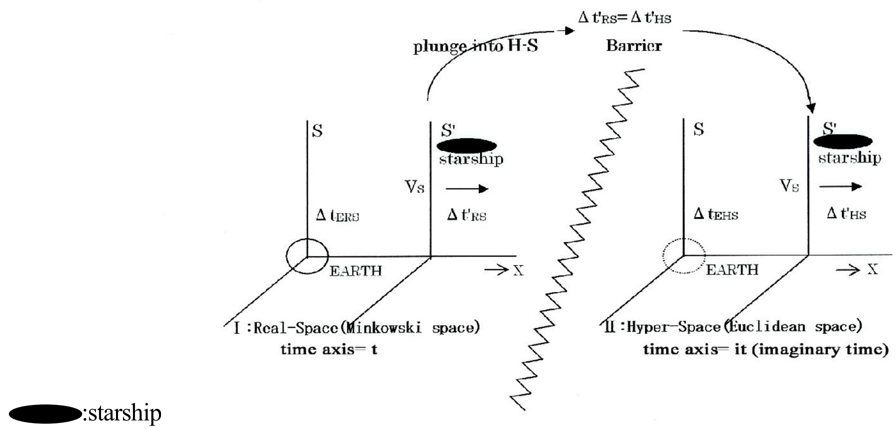


FIGURE 6. Transition from Real-Space to Hyper-Space.

From Fig. 6, after plunging into Hyper-Space, the starship keeps the quasi-light velocity and takes the S' coordinates. The elapsed time in the starship will be continuous. Considering the continuity of starship time between Real-Space and Hyper-Space, we get

$$\Delta t'_{RS} = \Delta t'_{HS}. \tag{7}$$

Now Eq.(7) gives, from Eqs.(5)and(6),

$$\Delta t_{ERS} = \Delta t_{EHS}([1+ (V_S/c)^2]^{1/2}/ [1- (V_S/c)^2]^{1/2}). \tag{8}$$

Eq.(8) is the time transformation equation of earth time between Real-Space and Hyper-Space. From Eq.(8), when V_S=0, we get

$$\Delta t_{ERS} = \Delta t_{EHS}. \tag{9}$$

Namely, in the reference frame at rest, the elapsed time on the earth coincides with both Real-Space and Hyper-Space. However, as the velocity of starship approaches the velocity of light, the earth time between Real-Space and Hyper-Space becomes dissociated on a large scale.

Since an observer on the earth looks at the starship going at V_S~c and loses sight of it as it plunges into Hyper-Space, it is observed that the starship keeps the same velocity and moves during the elapsed time Δt_{ERS}(at V_S~c) observed from the earth. Therefore, the range of starship of an observer on the earth is given by

$$L = V_S\Delta t_{ERS} \sim c\Delta t_{ERS}. \tag{10}$$

For instance, in the case of V_S=0.999999999c, from Eqs.(8)and(6), we get

$$\Delta t_{ERS} = \Delta t_{EHS}\times 31622\ , \quad \Delta t'_{HS} = \Delta t_{EHS}\times 1.4. \tag{11}$$

One second in Hyper-Space corresponds to 31,622 seconds in Real-Space. Similarly, one hour in Hyper-Space corresponds to 31,622 hours(3.6 years) in Real-Space.

While the starship takes a flight for 100 hours ($\Delta t'_{HS}$=100hr; V_S=0.999999999c) shown by a clock in the starship in Hyper-Space, 70 hours (Δt_{EHS}=70hr;V_S=0) have elapsed on the earth in Hyper-Space. Since this elapsed time on the earth in Hyper-Space is in the reference frame at rest, the time elapsed in it is the same as the time elapsed on the earth in Real-Space ([Δt_{EHS};V_S=0] = [Δt_{ERS};V_S=0] = 70hr). Therefore, there is not much difference between the elapsed time (70 hours) of an observer on the earth in Real-Space and the elapsed time (100 hours) of starship during Hyper-Space navigation. However, this elapsed time of 70 hours (Δt_{EHS}=70hr;V_S=0) on the earth in Hyper-Space becomes the elapsed time of 253 years (Δt_{ERS}=70×31,622=2,213,540hr;V_S=0.999999999c) on the earth in Real-Space, because the starship flies at the velocity of 0.999999999c. These 253 years represents the flight time of starship observed from the earth in Real-Space. Therefore, by plunging into Hyper-Space having the properties of imaginary time, from Eq.(10), the starship at a quasi-light velocity can substantially move a distance of approximately 253 light years. In this way, the starship at a quasi-light velocity can travel to the stars 253 light years away from us in just 100 hours.

The above numerical estimation depends on the velocity of starship. For instance, in the case of V_S = 0.99999c, we get

$$\Delta t_{ERS} = \Delta t_{EHS}\times 316\ , \quad \Delta t'_{HS} = \Delta t_{EHS}\times 1.4. \tag{12}$$

On the contrary, in the case of V_S=0.999……999c, a gap between Δt_{ERS} and Δt_{EHS} rapidly increases. That depends on how the starship can be accelerated to nearly the velocity of light.

STAR FLIGHT FOR STELLAR SYSTEM

Next, a comparison is made between navigation by Special Relativity and Hyper-Space Navigation. The condition is the same for both cases of navigation, that is, the distance between the earth and the star is 410 light years (i.e. Pleiades star cluster) and the velocity of starship is 0.99999c.
Special Relativity allows the following (see Fig. 7) :

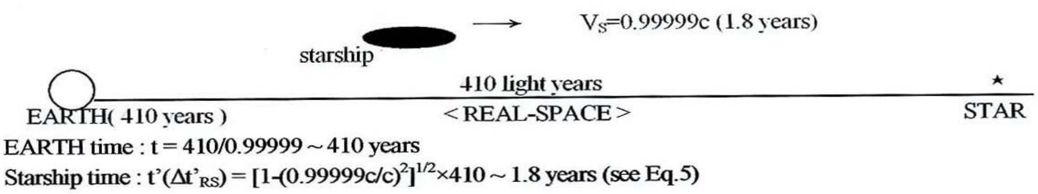


FIGURE 7. Interstellar Travel by Special Relativity.

A starship can travel to stars 410 light years distant from us in 1.8 years. However, there exists a large problem as is well known, i.e., the twin, or time, paradox. If the starship travels at a velocity of 0.99999c, it will arrive at the Pleiades star cluster 1.8 years later. It will seem to the crews in the starship that only 1.8 years have elapsed. But to the people on earth it will have been 410 years. Namely, since the time gap between starship time and earth time is so large, the crew coming back to the earth will find the earth in a different period. This phenomenon is true in our Real-Space. Interstellar navigation by this method is non-realistic,i.e., it would just be a one-way trip to the stars.

Hyper-Space Navigation allows the following (see Fig. 8) :

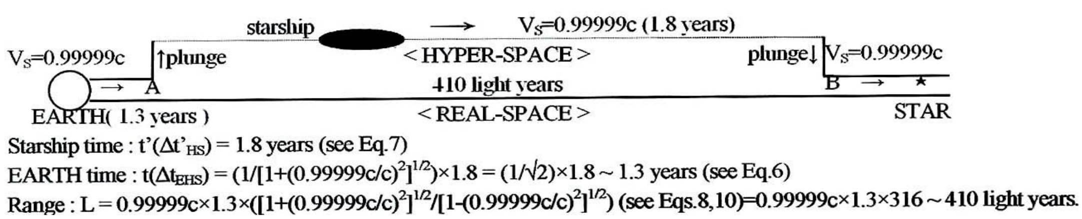


FIGURE 8. Interstellar Travel by Hyper-Space.

A starship can travel to the stars 410 light years distant in 1.8 years. During Hyper-Space navigation of 1.8 years, just 1.3 years have passed on the earth. Therefore, the time gap between starship time and earth time is suppressed. After all, the range and travel time of starship is the same for both kinds of navigation, and travel to the stars 410 light years away can occur in just 1.8 years in both cases. However, by plunging into Hyper-Space featuring an imaginary time, i.e. a Euclidean space property, just 1.3 years, not 410 years, have passed on the earth. There is no time gap and no twin or time paradox such as in Special Relativity. Additionally, a starship can travel to the star Sirius 8.7 light years distant us in 0.039 years (14 days). During Hyper-Space navigation of 14 days, just 0.028 years (9 days) have passed on the earth.

Figure 8 and figure 9 show such a realistic method for the interstellar travel. In order to reach the target stars, the starship which left the earth at a velocity of approximately 0.1c to 0.2c moves and escapes completely from the Solar System. After that, the starship is accelerated to nearly the speed of light in Real-Space and plunges into Hyper-Space at point A. In Hyper-Space, the time direction is changed to the imaginary time direction and the imaginary time direction is at right angles to real time. The course of starship is in the same direction,i.e.x-axis. With the help of Eqs.(6),(8) and (10), the crew can calculate the range by the measurement of starship time. After the calculated time has just elapsed, the starship returns back to Real-Space from Hyper-Space at a point B nearby the stars. Afterward, the starship is decelerated in Real-Space and reaches the target stars. It is immediately seen that the causality principle holds. Indeed, the starship arrives at the destination ahead of ordinary navigation by passing through the tunnel of Hyper-Space. The ratio of tunnel passing time to earth time is 1.4:1 and both times elapse. Hyper-Space navigation can be used at all times and everywhere in Real-Space without any restrictions to the navigation course. This implies that Real-Space always coexists with Hyper-Space as a parallel space. The factor that isolates Real-Space from Hyper-Space consists in the usual-experience "real time" of the former as opposed to the "imaginary time" characterizing the latter. The Real-Space (3 space axes and 1 time axis) and Hyper-Space (3 space axes and 1 imaginary time axis) coexist; the parallel space-time exists as a five dimensional space-time (3space axes and 2 time axes).

While the conceptual framework discussed above is highly speculative, it is in the wake of most of the current international trends on the subject of "Interstellar Flight". Indeed, the problem of interstellar flight consists much more in a navigation theory than in propulsion, as there is no propulsion means, including field propulsion, capable of causing a starship to travel at a velocity faster than the speed of light.

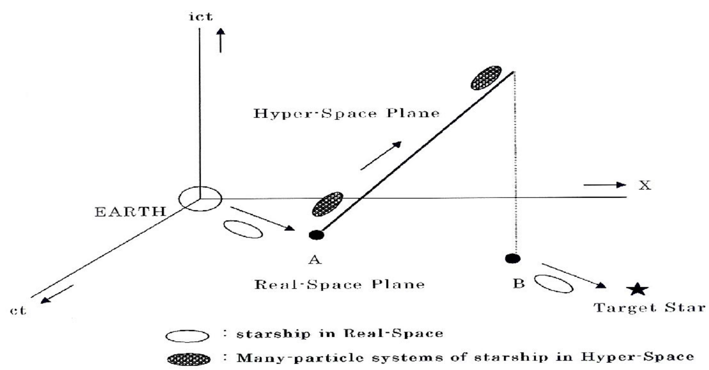


FIGURE 9. Interstellar Travel to the Star.

CONCLUSION

Plunging into Hyper-Space characterized by imaginary time would make interstellar travel possible in a short time. It may be said that the present theoretical limitation of interstellar travel by Special Relativity is removed. The Hyper-Space navigation theory discussed would allow a starship to start at any time and from any place on an interstellar journey to the farthest star systems, the whole mission time being within a human lifetime. The practical interstellar exploration combines propulsion theory such as field propulsion with above-mentioned navigation theory. Concerning the field propulsion, aforementioned propulsion systems are just only the theoretical study at present. Therefore they currently exist as speculative. However, there exists one common technology for all kinds of field propulsion. It strongly depends on a concrete technology for the excitation of the space vacuum; the energy is poured into space vacuum and the thrust is extracted from space vacuum. We believe that there exists underdeveloped technology and overlooked sufficiently supportive experiments.

NOMENCLATURE

α	=acceleration of starship (m/s^2)
λ	=arbitrary Higgs Self-Coupling in the Higgs Potential (λ is not known and is not determined by a gauge principle, presumably $\lambda>1/10$)
c	=speed of Light (3×10^8 m/s)
G	=Gravitational Constant (6.672×10^{-11} Nm^2/kg^2)

ϕ_0	=non-zero vacuum expectation value of Higgs Field
x, t	=coordinates in S for the rest coordinate system (V=0)
x', t'	=coordinates in S', moving relative to S at the constant velocity V along the x-axis.
$\Delta t'$	=time difference measured in S'
Δt	=time difference measured in S
$\Delta L'$	=length measured in S'
ΔL	=length measured in S
V	=velocity of starship
Vs	=velocity of starship
L	=range of starship of an observer on the earth
Δt_{ERS}	=the time of an observer on the earth in Real-Space, i.e. earth time
$\Delta t'_{RS}$	=the time shown by a clock in the starship in Real-Space, i.e. starship time
Δt_{EHS}	=the time of an observer on the earth in Hyper-Space, i.e. the equivalent earth time
$\Delta t'_{HS}$	=the time shown by a clock in the starship in Hyper-Space, i.e. the starship time.

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