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Theoretical Possibilities of Galaxy Travel

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Abstract

The distance to a stellar system is very immense, therefore the travel to the fixed star nearest to the Earth using the present propulsion technology will require tens of thousands years. In order to overcome such a limit of the space travel between fixed stars, research and development of a new propulsion theory and navigation theory are indispensable.

Space propulsion physics such as propulsion theory and navigation theory give us a concrete theoretical method toward galaxy exploration like a well-known Star Trek movie.

Unfortunately, however, there is no concrete explanation from the physical point of view of the propulsion method of the Star Trek starship and the principle of warp navigation, that is, the space propulsion theory and the space navigation theory.

This paper is an attempt to explain Star Trek's space navigation by applying the hyper-space navigation theory to the field propulsion theory that the author has published in international conferences and peer-reviewed journals since 1993 [1-6].

Keywords: Starship; Star Trek; Galaxy; Space-Time; Interstellar Travel; Star Flight; Field Propulsion; Space Drive; Imaginary Time; Hyperspace; Wormhole; Time Hole; Astrophysics

Introduction

Space development in the 21st century, unless there is a groundbreaking advance in the space transportation system, the area of activity of human beings will be restricted to the vicinity of the Earth forever and new knowledge cannot be obtained. The goal of traveling to the universe of humanity in the 21st century needs to extend not only to the manned solar system exploration but also to far-reaching stellar exploration in the future. This paper describes one way to implement space propulsion and space navigation to travel to the faraway galaxy. It is not an imagination, but a content that demonstrates its potential within an established physics framework. Although it is written for the general public, when it comes to space propulsion physics, the content itself requires the terms and concepts described in books related to space astronomical physics. In this paper, most of the mathematical formulas showing the concept are omitted (see references for formulas [1-6]. We focus on concepts and ways of thinking.

The distance to the star system is tremendous. It is well known that current exploration technologies such as chemical rockets are not possible for star exploration that requires light years, as well as manned planet exploration within the solar system. Research and development of new propulsion theory and navigation theory is indispensable to overcome the limitations of interstellar space travel.

As one of the solutions, this paper introduces the promising concept of space drive propulsion theory, which is a representative example of field propulsion, and hyper-space navigation theory (time hole) characterized by imaginary time.

The propulsive force of the starship is a pressure thrust that arises from the interaction of space-time around the starship and the starship itself; the starship is propelled against the space-time continuum structure.

On the other hand, interstellar travel using Special Relativity is well known as navigation theory, but it is unrealistic navigation theory. This is because there is an extreme time gap between Earth time and starship time. This is a phenomenon well known as the Urashima effect (twin paradox). Hundreds or thousands of years already pass when you return to your home planet, even if you can reach the target star over several years. No family members, friends or acquaintances to know exist there, it is literally a one-way ticket space trip.

Space warp navigation using wormholes based on General Relativity is also well known. Unfortunately, the size of wormholes (~ 10^{-35}m) is much smaller than atoms, and the size of wormholes is expected to fluctuate theoretically due to instability. Space warp navigation using wormholes is technically difficult. Moreover, it can be said that it is a wormhole navigation that does not know where to go and where to return. This navigation has the basic theoretical and technical problems.

In this way, not only the propulsion theory but also a new navigation theory is indispensable for exploring star systems that require a cruising range of light years. Realistic star exploration can be realized by combining propulsion theory and navigation theory. There is no propulsion theory that can exceed the speed of light. This paper describes realistic means of traveling in the galactic system by combining field propulsion theory based on the physical structure of spacetime and new navigation theory.

By the way, as is well known in Figure 1, Star Trek is a masterpiece that has been known worldwide since 1966 as a science fiction set in the famous galaxy universe. A starship arrives at a star system in a short period of time to a star system that is tens, hundreds and thousands of light years away from the Earth. This method of making a starship reach a distant star system is skillfully expressed in the movie using images. Unfortunately, however, there is no concrete explanation from the physical point of view of the propulsion method of the starship and the principle of warp navigation, that is, the space propulsion theory and the space navigation theory.

Figure 1: Star ship Exploration: (a) Star system; (b) Star Trek (USS Enterprise (NCC-1701-A)).

This paper addresses the latest advances in Space Propulsion Physics and Intergalactic Exploration: it introduces a method – a possibility - for overcoming the "light barrier" (the seeming "wall-of-light" in 4-D space-time) that would prevent faster-than-light flight relative to Earth. And this would be done by "jumping" over this barrier in a higher-dimensional "hyper-space" as being characterized by imaginary time. A hyper-space navigation theory to "jump the light-barrier" is introduced.

And, for space travel, combustion-heating-expulsion takes place in the chambers of solid or liquid propellant chemical rockets for almost 90 years since Robert Goddard's first chemical liquid rocket launch in 1928. But now, almost 90 years later, chemical rockets have reached a plateau in the thrusting performance that they can achieve. And though remarkable, it is woefully insufficient for propelling starships economically, swiftly, safely over the enormously long gulfs of inter-planetary and interstellar space that much of humanity dreams of going.

Instead of conventional chemical propulsion systems, field propulsion systems, which are based on General Relativity Theory, Quantum Field Theory and other exotic theories, have been proposed by many researchers to overcome the speed limit of the conventional space rocket. Field propulsion system is the concept of propulsion theory of starship not based on momentum thrust but based on pressure thrust derived from an interaction of the starship with external fields. Field propulsion system is propelled without mass expulsion. The propulsive force is a pressure thrust which arises from the interaction of space-time around the starship and the starship itself; the starship is propelled against space-time structure.

Stellar system exploration which requires the cruising range of a light-year unit needs not propulsion theory, but navigation theory such as worm holes and time holes. The realistic interstellar exploration can be possible by combining both a field propulsion theory with a hyper-space navigation theory (i.e., time-hole navigation).

The following Chapter 2 explains space navigation using Hyper-Space navigation theory and Chapter 3 briefly introduces the concept of field propulsion.

2. Star flight method: To the stars

Three ways to the interstellar travel

Three methods are considered to reach the star rapidly. The basic principle is the following equation which is known to every one:

$$L_{star} = V_{starship} \times t, \quad (2.1)$$

where L_{star} is the distance to the star, $V_{starship}$ is the speed of starship, t is the time.

The distance to a stellar system "L_{star}" is enormous. An extremely long time is required, even if the starship would travel at the speed of light "c".

To reach the star rapidly, three parameters, such as "speed", "distance" and "time" shall be controlled.

<Change speed> $L_{star} = (nc) \times t$, (2.2)

where "nc" is n-fold increase in speed of light "c". Here, n is real number greater than 1.

There is no propulsion theory exceeds the speed of light, moreover, Special Relativity restricts the maximum speed to the speed of light; therefore this method is impossible.

<Change distance> $\dfrac{L_{star}}{n} = c \times t$ (2.3)

The so-called "wormhole" is utilized [7]. By using wormhole, shorten the distance as $L_{star}/n \approx$ a few meters, as shown in Figure 2. For example, one meter in a wormhole corresponds to a few light years in actual space.

<Change time> $L_{star} = c \times (nt)$ (2.4)

The time "t" in an imaginary time hole is equivalent time of n-fold time in actual space, as shown in Figure 3.

Figure 2: A wormhole creates a shortcut from Earth to Alpha Centauri.

Figure 3: An Imaginary Time Hole creates a shortcut from Earth to Alpha Centauri.

For example, one second in an imaginary time hole corresponds to one million seconds in actual space.

Subsequently, interstellar travel through the imaginary time hole is described as the following section.

Hyper-space navigation (Time Hole Navigation)

Figure 4 shows the plane of existence of ordinary x-ct space-time. This is with a vertical coordinate ikτ, which is orthogonal to those which describe space travel (x) and time travel (ct) on an x-ct space-time plane of existence. And this x-ct plane is seen to be embedded in the volume of the higher-dimensional x-ct-ikτ realm rising above it [8].

Figure 4: Trajectory faster-than-light flight [8].

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: 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. 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.

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, that is, the velocity V becomes the imaginary velocity in Hyper-Space. Substituting "t→it, V→-iV" into the Lorentz transformation equations of Minkowski space formally gives the Lorentz transformation of Hyper-Space corresponding to that of Real-Space is found. These lead to more important equations, which are omitted here and only the navigation results are introduced in the next section. Now, consider the navigation with the help of both Lorentz transformations, especially the Lorentz contraction of time [1-6].

Star flight for stellar system

Next, a comparison is made between interstellar travel 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 Figure 5)]:

A starship can travel to the star 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 the 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 travel by this method is non-realistic, i.e., it would just be a one-way trip to the stars.

EARTH time : $t=410/0.99999 \sim 410$ years

Starship time : $t'(\Delta t'_{RS})=[1-(0.99999c/c)^2]^{1/2}\times 410 \sim 1.8$ years.

Figure 5: Interstellar Travel by Special Relativity.

[Hyper-Space Navigation allows the following (see Figure 6)]:

A starship can travel to the stars 410 light years distant in 1.8 years: Due to the continuity of starship time between Real-Space and Hyper-Space (The elapsed time in the starship shall be continuous. This gives a strong condition for the system).

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., 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 from 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.

Starship time: $t'(\triangle t'_{HS})=1.8$ years

EARTH time: $t(\triangle t_{EHS})=(1/[1+(0.99999c/c)^2]^{1/2})\times 1.8=$
$(1/\sqrt{2})\times 1.8 \sim 1.3$years

Range:$L=0.99999c\times 1.3\times([1+(0.99999c/c)^2]^{1/2}/$
$[1-(0.99999c/c)^2]^{1/2})=0.99999c\times 1.3\times 316\sim 410$light years.

Figure 6: Interstellar Travel by Hyper-Space Navigation.

Figure 7 shows such a realistic method for the interstellar travel using Hyper-Space navigation system (i.e., Time Hole; Figure 3). In order to reach the target star, the starship which left the Earth at a velocity of approximately 0.1c to 0.2c moves and escapes completely from the Solar System (with Figure 7). 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 derived equations (these equations are omitted in this paper: refer to [1-6]), the crew can calculate the range by the measurement of starship time. After the calculated time has

Figure 7: Interstellar travel to the star.

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 star. 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 (Time Hole). The ratio of tunnel passing time to earth time is 1.4:1 and both times elapse. Hyper-Space navigation method can be used at all times and everywhere in Real-Space without any restrictions to the navigation course.

Concerning a concept on technical method of plunging into Hyper-Space and returning back to Real-Space, the following study is necessary: 1) Many-Particle Systems for Starship, 2) Wave function of Starship by Path Integrals, 3) Quantum Tunneling Effect, 4) Reduction of Wave function, 5) Starship Information Content Restoring.

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 Travel". As a matter of fact, the problem of interstellar travel consists much more in navigation theory than in propulsion theory.

Because, there is no propulsion theory capable of causing a starship to travel at a velocity faster than the speed of light.

Also, Figure 8 schematically shows the navigation of Figure 7.

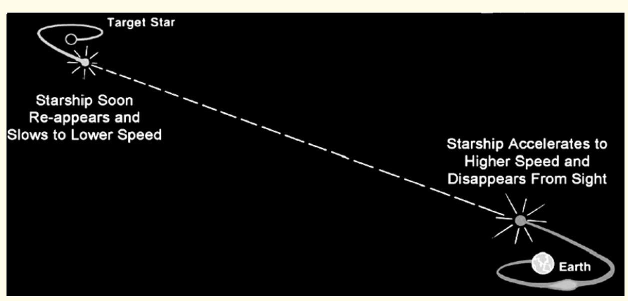

Figure 8: Interstellar Travel to the Star [6,8].

Starship accelerates away from the Earth, disappears and reappears after Hyper-Space navigation. But during these Hyper-

Space navigation of disappearance, the starship, in effect, leaps high above space-time and over stupendous distances to reach speeds that are substantively billions of times light-speed.

Starship flight can also be viewed from the perspective of an Earth observer who is watching a starship fly away – accelerating in the direction of its target (a planet in another solar system) and then vanishing from sight as its initial acceleration ends. The starship then re-appears after Hyper-Space navigation - at the speed it disappeared at. But the starship is now suddenly 400 light-years away - very near to its destination. By plunging into Hyper-Space featuring an imaginary time (i.e., Imaginary Time Hole), the starship detours the imaginary time tunnel (see Figure 3), apparently exceeds the speed of light.

Finally, we compare the navigation features of the wormhole and the time-hole. Both navigation methods allow interstellar travel in a short period of time, but the features of the navigation, theoretical and technical issues are different.

Concerning the wormhole, regrettably, since the size of wormhole ($\sim 10^{-35}$m) is smaller than the atom, 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. Moreover, since the solution of wormhole includes a singularity, this navigation method theoretically includes fundamental problems: it is reported from numerical calculation that the wormhole solution considered by Thorn is an unstable solution.

It is premised on the existence of negative energy with high density (about the center of a neutron star) which is difficult with the current technology, and it is completely unknown how to go through the wormhole or where the exit is.

In contrast to this, as described above, a plunging into Hyper-Space characterized by imaginary time would make the interstellar travel possible in a short time. We may say that the present theoretical limitation of interstellar travel by Special Relativity (time paradox) is removed. The Hyper-Space navigation theory discussed above would allow a starship to start at any time and from any place for an interstellar travel to the farthest star systems, the whole mission time being within human lifetime (Figure 7, Figure 8).

Navigation Scenario between Real-Space and Hyper-Space

A brief introduction to the concept of navigation scenario is described here, so please refer to the references for details [1,4,6,12].

Figure 9 shows the navigation scenario of starship passing through Hyper-Space region. Although the starship is a massive body of M at a certain time, the starship is formed a fine-grained structure as a many-particle systems of $m_{PL} \times N$. Here, m_{PL} is Planck mass. The wave function of starship is required at the time. To do so, the starship turns on a fine-grained structure technology. After that, the starship composed of many-particle systems plunges into Hyper-Space by quantum tunneling effect.

Figure 9: Navigation scenario of Starship.

Then, the starship turns off a fine-grained structure technology and continues the travel in Hyper-Space. In order to jump out from Hyper-Space, the starship turns on a fine-grained structure technology again and plunges into Real-Space by quantum tunneling effect. After that, the starship turns off a fine-grained structure technology again, then decelerates and continues the travel in Real-Space.

Finally, let us supplement the properties of Hyper-Space with a few more words on referring to Figure 10. The Real-Space offered by Minkowski metric and Hyper-Space offered by Euclidean metric coexist, that is, the parallel space exists. And each space is isolated by potential barrier. The fracture of continuity of space means the crush of this potential barrier.

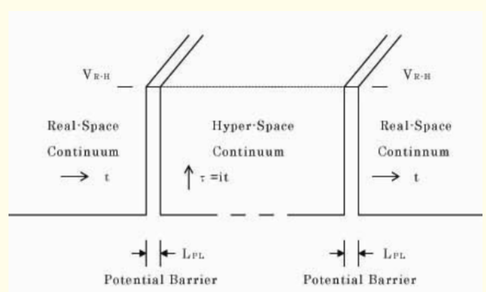

Figure 10: Properties of Hyper-Space.

Hyper-Space shall be also continuum like Real-Space. One and only difference is either real time or imaginary time.

Wave function of starship by path integrals

The quantum tunneling is the quantum effect that the matter passes through the inaccessible region by its wave function. Forming a fine-grained structure as many-particle systems implies the matter wave. In quantum mechanics, since a giving its wave function specifies the state of system, we consider here the wave function of starship by using the path integral approach. On referring to Figure 11, $\varphi(x_{a1},\cdots x_{aN},t_a)$ is the wave function of many-particle systems of N particles when the starship is formed a fine-grained structure at the point a. The wave function $\varphi(x_{b1},\cdots x_{bN},it_b)$ of many-particle systems after passing through the potential barrier is given by using the path integral expression:

where $\int[dx_{aN}] = \int\cdots\int dx_{a1}dx_{a2}\cdots dx_{aN}$.

Let d and c represent the position of potential barrier, and let t_d and it_c(imaginary time) be the time of position of d and c. The total amplitude which goes from the point in space-time (x_a,t_a) to (x_b,it_b), i.e., Feynman Kernel K(b,a) is given by

$$K(b,a) = \int\int[dx_{cN}][dx_{dN}]K(b,c)K(c,d)K(d,a)\,. \quad (2.6)$$

All paths between Real-Space and Hyper-Space are divided into two parts.

The time is real time for between a and d, and imaginary time for between c and b. Finally, as point d comes closer and closer to point c, the real time t gets closer and closer to imaginary time it, i.e., analytic continuation.

Each kernel is represented as follows:

$$K(d,a) = K(x_{d1},\cdots x_{dN},t_d;x_{a1},\cdots x_{aN},t_a) = \int_a^d dx\cdot\exp[i/\hbar\cdot\int_{ta}^{td}dtL(\dot{x},x,t)],$$

$$K(b,c) = K(x_{b1},\cdots x_{bN},it_b;x_{c1},\cdots x_{cN},it_c) = \int_c^b dx\cdot\exp[-1/\hbar\cdot\int_{tc}^{tb}dtL(\dot{x},x,it)],\quad (2.7)$$

Where L is the Lagrangian for system.

Figure 11: Wave function of Starship.

In the case of starship, the Lagrangian is a free particle system and given by

$$L = \sum 1/2\cdot m_{PL}\dot{x}_N{}^2\,. \quad (2.8)$$

Taking the limit as (d-c) approaches zero, we get

$$K(b,a) = \int[dx_{d\to c,N}]K(b,c)K(d\to c,a)\ ,$$

$$\varphi(x_{b1},\cdots x_{bN},it_b) = \int_{-\infty}^{+\infty}[dx_{aN}]K(b,a)\varphi(x_{a1},\cdots x_{aN},t_a)\,. \quad (2.9)$$

The wave function of starship is to be found out as above. To find out the kernel is equal to solve the following Schrödinger equation

$$H\varphi(r_1,\cdots r_N) = i\hbar\frac{\partial\varphi(r_1,\cdots r_N)}{\partial t}, \quad (2.10)$$

where H is the Hamiltonian operator.

The wave function of starship in Hyper-Space can be represented by the wave function in Real-Space.

The above-mentioned Hyper-Space navigation can be freely performed at any time in any place of real space, and there is no restriction. Starship navigation is free to fly to the destination with the intended course and time, unlike navigation using a wormhole that does not know where to go and where to return. Furthermore, we may say that the present theoretical limitation of interstellar travel by Special Relativity is removed. The Hyper-Space navigation theory discussed above would allow a starship to start at any time and from any place for an interstellar travel to the farthest star systems. The whole mission time is within human lifetime.

Hyper-Space navigation system requires two types of propulsion systems. One is a propulsion system capable of accelerating the starship to the quasi-light speed in a short time. The other is an interstellar propulsion system for Hyper-Space navigation that rushes into the Hyper-Space after achieving the quasi-light speed and jumps out of the Hyper-Space into the Real-Space. It is essential that the starship be equipped with these two types of propulsion engines. Their propulsion engines are named as field driver, that is, space drive propulsion engine using in Real-Space and interstellar propulsion engine using between Real-Space and Hyper-Space. Interstellar propulsion engine is fine grained engine making the many-particle system of starship to jump over barrier and enter Hyper-Space.

3.Outline of field propulsion

The basic propulsion principle and the overall concept of field propulsion are described here briefly. See the references for details [9-15]. The concept of field propulsion is mainly classified into General Relativistic Field Propulsion and Quantum Field Propulsion.

All existing methods of propulsion systems, i.e., chemical propulsion, electric propulsion (Ion thruster, MPD [Magneto Plasma Dynamic] 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.

Alternatively, the concept of "Field Propulsion" is propelled by 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 spaceship and the spaceship itself. The spaceship is propelled against 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 to be found in General Relativity, Quantum Field Theory, Quantum Cosmology and Superstring Theory including D-brane to bring about the best propulsive performance.

In this chapter, we describe relatively well-considered space drive propulsion as a representative example of field propulsion.

The space drive propulsion system proposed here is one of field propulsion system utilizing the action of the medium of the strained or deformed field of space, which is based on the propulsion principle of the kind of pressure thrust. Figure 12 shows the basic propulsion principle of common to all kinds of field propulsion system. As shown in Figure 12, the propulsion principle of field propulsion system is not momentum thrust but pressure thrust induced by a pressure gradient (or potential gradient) of the space-time field (or vacuum field) between bow and stern of a spaceship. Since the pressure of the vacuum field is high in the rear vicinity of the spaceship, the spaceship is pushed from the vacuum field. The pressure of vacuum field in the front vicinity of the spaceship is low, so the spaceship is pulled from the vacuum field. In the front vicinity of the spaceship, the pressure of vacuum field is not necessarily low but the ordinary vacuum field, that is, just as only a high pressure of vacuum field in the rear vicinity of the spaceship. The spaceship is propelled by this distribution of pressure of the vacuum field. Vice versa, it is the same principle that the pressure of vacuum field in the front vicinity of the spaceship is just only low and the pressure of vacuum field in the rear vicinity of the spaceship is ordinary. In any case, the pressure gradient from the vacuum field (potential gradient) is formed over the entire range of the spaceship, so that the spaceship is propelled by the pressure gradient.

Figure 12: Fundamental propulsion principle of Field propulsion.

Here, we must pay attention to the following. Spaceship cannot move unless the spaceship is independent of pressure gradient of vacuum field. No interaction is present between pressure gradient of vacuum field and spaceship. Spaceship does not move as long as the propulsion engine generates the pressure gradient or potential gradient in the surrounding area of spaceship, due to the interaction between pressure gradient of vacuum field and spaceship. This is because an action of propulsion engine on space is in equilibrium with a reaction from space. It is consequently necessary to shut off the equilibrium state to actually move the spaceship. 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 vacuum field to return to ordinary vacuum field. In the meantime, the spaceship is independent of pressure gradient of vacuum field. It is therefore possible for the spaceship to proceed ahead receiving the action from the vacuum field.

In general, a body cannot move carrying, or together with, a field that is generated by its body from the standpoint of kinematics. In other words, the body cannot move unless the body is independent of the field. This is because an action on the field and a reaction from the field are in the state of equilibrium.

As mentioned above, since the propulsion 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 a high frequency.

Concerning the propulsion principle of field propulsion system, the distribution of field as shown in Figure 12 is fundamental; accordingly, several kinds of propulsion systems have been proposed. Even if any propulsion system is selected, whether the constituents of pressure gradient or potential gradient generated by propulsion engine are curvature, metric, zero-point radiation pressure or entropy, the propulsion principle of field propulsion system is the identical.

Further, as is already explained, all propulsion systems based on the momentum thrust receive the reaction thrust by expelling the propellant mass. However, since no propellant is necessary for field propulsion, field propulsion is well called a propellant-less propulsion.

In conclusion, a condensed summary of the propulsion principle of space drive propulsion system as a representative field propulsion is shown as Figure 13.

Figure 13: A condensed summary of space drive propulsion principle.

As is well known in General Relativity, in the curved space region, the massive body "m (kg)" existing in the acceleration field is subjected to the following force F^i (N):

Setting i=3(i.e. direction of radius of curvature:r), we get:

$$F^3 = F = m\alpha = m\sqrt{-g_{00}}c^2\int_a^b R^{00}(r)dr = m\sqrt{-g_{00}}c^2\Gamma^3_{00}, \quad (3.1)$$

where α : acceleration (m/s^2), g_{00}: time component of metric tensor, a-b: range of curved space region(m), x^i: components of coordinate (i=0,1,2,3), c: velocity of light, R^{00}: major component of spatial curvature(1/m^2).

The acceleration (α) of curved space and its Riemannian connection coefficient (Γ^3_{00}) are given by:

$$\alpha = \sqrt{-g_{00}}c^2\Gamma^3_{00}, \quad \Gamma^3_{00} = \frac{-g_{00,3}}{2g_{33}}, \quad (3.2)$$

where c: velocity of light, g_{00} and g_{33}: component of metric tensor, $g_{00,3}$: $\partial g_{00}/\partial x^3 = \partial g_{00}/\partial_r$. We choose the spherical coordinates "$ct=x^0$, $r=x^3$, $\theta=x^1$, $\varphi=x^2$ " in space-time.

Concerning Field Propulsion, see the references for theoretical formulas [9-15].

Conclusion

The efforts of Robert Goddard and Von Braun's predecessors led to the successful landing of human beings on the moon and the exploration of the solar system planets by unmanned spacecraft. The development and achievements of the chemical rocket that supported it are great. Future developments such as ion thrusters, which are the subsequent electric propulsion, and hall thrusters under development, are desired.

However, since thrust and acceleration performance is insufficiency in order to challenge the solar system exploration and stellar system exploration, so a field propulsion of high acceleration that can be generated in a short time is necessary.

Also, there is no propulsion theory that exceeds the speed of light; even the field propulsion, its maximum theoretical speed is the quasi-light speed near the speed of light. For this reason, stellar system exploration as which the cruising range of a light-year unit is required needs not propulsion theory, but navigation theory such as wormholes and time holes. The realistic interstellar exploration can be possible by combining both a space drive propulsion theory with a hyper-space navigation theory (i.e., time-hole navigation). Hyper-Space navigation can be used at all times and everywhere in Real-Space without any restrictions to the navigation course.

Accordingly, space navigation of a starship like Star Trek can be said to become possible from above theories.

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