

# Whether Human Beings can use Wormholes or Warp drive Propulsion to Achieve Faster-than-light Astronautic Travel

**Abstract:** The 《European Physics Journal C》 recently reported on the research of faster-than-light astronautic travel led by American physicist H.White using the warp drive theory proposed by M.Alcubierre in 1994. It is said that warp bubbles of nanometer size have been created by numerical simulation. In China, 《Science and Technology Daily》 reported and interviewed theoretical physicists, which aroused widespread interest. The author of this paper has studied on the faster-than-light problem for many years, and this is a scientific paper for discussion.

Many physicists have repeatedly turned to general relativity (GR) for the feasibility of faster-than-light astronautic travel, bypassing the difficulties caused by special relativity (SR). This article argues that this should not and need not be done. Because SR's "ban" on faster-than-light motion is wrong, it can be ignored.... This paper also argues that theoretical physicists and aviation and aerospace experts (and engineering experts) think differently about the same faster-than-light astronautic travel problem; In this regard, a comparison between the first half and the second half of the article will make it clear that the former pay attention to mathematical analysis; the latter believe that mathematical analysis is necessary, but more attention should be paid to the study of physical reality.

Wormhole or warp drive propulsion require extreme spacetime bending and great negative energy, which are not achievable. Therefore, we should still pay attention to basic research. For example, we can learn from the experience of breaking sonic barrier in aeronautical engineering to achieve supersonic flight. Existing high-energy particle accelerators could be modified to look for faster than light particles, and so on.... Regarding negative energy and special matter, we believe that the concept of negative energy, first proposed by P. Dirac, is only a means or tool of analysis and does not necessarily exist in fact. However, several possible ways of generating negative energy are also provided for discussion. Finally, this paper emphasizes the importance of the study of EM drive, because it is the project that the national space communities can actually engage in R&D on.

**Key words:** Faster-than-light (FTL); Special relativity (SR); General relativity (GR); Light barrier; Negative energy; Warp drive; EM drive

## 1 Introduction

Flying outside the Earth system is called space flight, and beyond the solar system is called astronautics. The universe is just so big—Proxima Centauri is 4.3ly from Earth and Sirius is 8.8ly (ly is light-year, 1ly=9.5×10<sup>12</sup>km). The speed of light in vacuum  $c=299792458\text{m/s}\cong 3\times 10^5\text{km/s}$ , it would take years to get there at the speed of light! Einstein's 1905 paper "On the electrodynamics of moving bodies"<sup>[1]</sup> developed the theory of special relativity (SR), which asserted that faster-than-light motion was impossible. However, Einstein's 1915 paper proposed the theory of general relativity (GR)<sup>[2]</sup>, and some physicists think it is possible to have faster-than-light motion

without violating SR, based on GR's theory of spacetime bending. In 1988, M.Morris and K. Thorne<sup>[3]</sup> published a paper in PRL entitled "Wormholes, time machines, and weak energy conditions"; Worm holes, the paper says, could solve the difficulties of interstellar travel by building a very large curvature for spacetime. Try to build and maintain the wormholes needed for interstellar travel; And wormholes can even create time machines and shock causality. In 2000, L.Ford et al<sup>[4]</sup>. said in their paper that if wormholes could exist, they would become spherical portals to distant places. It doesn't violate the laws of physics, but it does require a lot of negative energy. Since the force of negative energy is repulsive, it prevents the wormhole from collapsing. Moreover, unlike space bending, which acts as a converging lens, negative energy acts as a diverging lens on light, which is necessary for entry into and exit from the wormhole.

Relativistic scholars proposed a faster-than-light spaceflight scheme called Warp drive based on GR without violating SR. In 1994, M.Alcubierre<sup>[5]</sup> envisioned a method of faster-than-light spaceflight based on GR theory: a "spacetime bubble"(or "warp bubble") of curved spacetime, with a spaceship inside it. If the spacetime in front of the bubble contracts and the space time behind it expands, the distance to the destination will be shortened and the distance from the departure point will be increased. This would mean that the spacecraft was moving, but it was actually stationary relative to the neighboring world, and of course there was no need to worry about the "upper limit of light speed"of SR theory, which meant that the spacecraft could travel faster than the speed of light without violating the prevailing theory of physics. But calculations show that this requires negative energy to surround the spacecraft. Since the law of conservation of energy cannot be violated, great negative energy is accompanied by an equal amount of great positive energy. No one knows how to get at this enormous power, and the solution is impossible even without error. So the concept has been ignored by the scientific community, except in science fiction movies.

Wormhole and warp drive propulsion are the products of GR theory, based on the concept of spacetime integration and curved spacetime. Although it is well known that SR asserts that "faster-than-light motion is impossible", GR denies this statement in practice, indicating that relativity has internal inconsistencies. But these studies all assert that "exotic matter with negative energy is needed".

The author did not accept the integration of space and time and curved spacetime<sup>[6,7]</sup>; Now, personal views aside for the moment. We note that while many physicists espouse the theory of relativity, they firmly believe that faster-than-light space travel must be pursued in the future so that humans can explore beyond the solar system (or even the Milky Way), which is consistent with the author's view. Research trends in the United States (e.g., K.Thorne's insistence on wormholes and H.White's insistence on warp drive propulsion) have brought the issue back to the public. Therefore, I decided to participate in the discussion and contribute some of my own views.

For example, in the year of 2012, NASA scientist H.White said at a conference that the shape of the warp bubble could be improved to reduce the unrealistic energy requirements. His comments, and the meetings NASA held about them, were encouraging. In early 2022, the journal 《European

Phys. Jour. C》 reported that White and his team had made a nanoscale warp bubble<sup>[8]</sup>; Interest has also increased dramatically.

## 2 Wormholes and spacetime bending

In 2014, The American science fiction film "Interstellar" is hot in all countries. The story imagines that in a future where humans are on the verge of extinction, NASA is trying to get people to leave Earth and fly to Saturn, and then travel through a wormhole to another galaxy. The journey from Saturn's orbit to the center of Andromeda was made at faster-than-light speed because it took so little time and the distance was so great( $5 \times 10^6$ ly). The film was made with the help of physicist Kip Thorne of the California Institute of Technology(CIT), one of the authors of the wormhole theory. Thanks to special spacetime tunnel like wormholes, with one end in the orbit of Saturn and the other in the center of Andromeda, a hero can make the trip in seconds that would take light more than five million years to make. This is a fascinating part of the film.

In 1916, at the beginning of GR, L.Flamm<sup>[9]</sup> pointed out that Schwarzschild solutions to Einstein's gravitational field equation described empty spherical wormholes if the topology was properly chosen. This was the earliest discovery, only a few months after the equations of the gravitational field were published. In 1935, Einstein and N.Rosen proposed that wormholes were actually warped, deformed spaces, that could connect two different points in cosmic spacetime. The result is a tunnel-like structure that can be straight or bent. Thus, a wormhole is a tunnel through time and space that allows almost instant travel between distant locations. In the 1950s, J.Wheeler et al., and in the 1980s, K.Thorne et al.

Another imagines a "superspace" in which the curved spaces of our universe and those of other universes can be drawn as 2D images embeded in a higher-dimensional hyperspace. Hyperspace is just an imaginary tool, but it's useful for explaining wormholes. Thorne<sup>[10]</sup> imagines a wormhole that goes through hyperspace. It could have two holes, like one on Earth and other on Vega. The two openings are connected by a hyperspace tunnel, perhaps only 1km long. In this way, one can enter from an opening near the Earth and exit from an opening near Vega, 26ly away. There's a famous diagram, which seems to have come from J.Wheeler's paper, that imagines our universe as a 2D curved surface, strongly curved, with a distance of 26ly along the surface, but a distance of 1km between the two holes. Wheeler's young assistant professor, M.Kruskal discovered the evolution of globular wormholes from solving the equation of the gravitational field—starting with no wormhole, with a singularity near Earth and a singularity near Vega; The two may then grow in hyperspace, meet, and annihilate, creating wormholes when they do. Then it shrinks and disappears. The time between creation and disappearance of a wormhole is very short.

K.Thorne calculations based on the equation of the gravitational field lead to the following finding: (1)Some exotic materials is needed to provide the gravitational force that pushes open the walls of wormhole; (2)The exotic matter penetrating the wormhole should have a negative energy density; But this is true from view of the light beam passing through the wormhole, and the energy

density is still positive for the wormhole reference frame. As mentioned earlier, Wheeler suggested that wormholes could be self-destructing based on his quantum bubble hypothesis, in which virtual particles mysteriously appear and disappear all the time. Unfortunately, Wheeler's theory suggests that these flickering wormholes are tiny, on the Planck order of magnitude, or about  $10^{-33}$  cm in length. In other words, wormholes are almost impossible to measure. To make them big, they have to have exotic matter; Because the negative properties of exotic matter might push the perimeter of the wormhole outward, making it large and stable enough for a person or spacecraft to pass through.

If we hope a wormhole can use to travel, it must at least allow the signal to pass through as light. The light at the entrance is convergent and the light at the exit is divergent. In order for the converging light to become astigmatism somewhere in the middle of the wormhole, this conversion must be done with negative energy. And since the force of gravity of negative energy is actually a repulsive force, it prevents the wormhole from collapsing. ... So everything depends on the possibility of generating negative energy. In 1978, L.Ford an American physicist, proposed a theory called "Quantum inequality", saying that "the amount of allowable negative energy is inversely proportional to its time and space scale", that is, the larger the negative energy is, the shorter the duration of its existence. Conversely, if the negative energy is weak, it can last for a long time. Moreover, for the greater negative energy, the corresponding positive energy comes closer to it. In the Casimir effect<sup>[11,12]</sup>, the plates have to be very close together to get a lot of negative energy. In 1996, Ford et al. proved that the wormhole radius was less than  $10^{-30}$  cm. To get a macroscopic wormhole, the negative energy needs to be concentrated in a very thin (say,  $10^{-19}$  cm) area. ... In short, although quantum theory allows negative energy, it imposes strict limits on its value and duration, making wormholes a moot idea at this stage.

Ford and Roman explain the laws of nature associated with negative energy. Some mechanisms, such as making black holes thermodynamically compatible, suggest that negative energy can exist. but it's impossible to produce negative energy without limit, because that would contradict the second law of thermodynamics. Imagine, for example, a exotic matter generator that steadily supplies a negative energy flow outwards; However, due to the law of conservation of energy, it must have a positive energy flow as a by-product. If the two are directed in different directions, they become an inexhaustible source of energy for the positive energy region, and thus can be made into perpetual motion machines. But that's impossible according to the second law of thermodynamics.

Ford and Roman's paper, "Constraints on Negative Energy Density in Flat Spacetime," states that, unlike classical physics, in quantum field theory energy density can become negative at a point in spacetime without limitation. This violates known classical energy conditions, such as the weak energy condition. Specific examples, such as the Casimir effect and the squeezed states of light, they are supported by practical observations. The theoretical expectation of black hole evaporation also includes negative energy density. On the other hand, if the laws of quantum field theory are not limited to negative energy, they may produce significant macroscopic effects that violate the second law of thermodynamics, such as wormholes, warp drive propulsion, and time machines.

Ford and Roman derived the negative energy bound as seen by an inertial frame observer for the free massless scalar field of 4-dimensional Minkowski spacetime (flat spacetime). Limits on the amplitude and duration of negative energy; Quantum inequality is written in a similar form to the uncertainty principle:

$$\hat{\rho} \geq -\frac{k}{t_0^4} \quad (1)$$

Where  $\hat{\rho}$  is the energy density integral and  $t_0$  is the time characteristic width. Therefore, the longer the time required to maintain, the less negative energy can be obtained. In summary, analytical calculations show that wormhole sizes are strictly limited.

Go back to the 1988 paper by M.Morris and K.Thorne<sup>[3]</sup>, a wormhole is a short "handle" of a spatial topology that connects widely separated regions of the universe. The Schwarzschild metric describes a wormhole if the topology is chosen correctly. However, the wormhole's boundaries prevented two-way operation, and its throat snapped so fast that it could not pass even in one direction. To prevent pinching (singularities) and boundaries, crossing the neck must be at non-zero pressure and energy. Then two questions arise: (i) does quantum field theory allow the type of pressure-energy tensor required to maintain a bidirectionally passable wormhole? (ii) Do the laws of physics allow the establishment of wormholes in the universe where the space parts are initially simply connected? If the laws of physics allow a traversable wormhole to exist, might they also allow such a wormhole to be transformed into a "time machine" that defies causality?

Wormhole creation must be accompanied by the choice of closed time-like curves and/or a discontinuous future light cone, which also defies weak energy conditions. The spacetimes created by such wormholes are known, but what is not known is whether the pressure-energy tensor specified by Einstein's equation in those spacetimes is allowed by quantum field theory.

Wormhole creation with great spacetime curvature will be controlled by the laws of quantum gravity. A plausible case requires quantum foam. For a topological type with a length scale of the order of Planck-Wheeler length, there is a finite probability amplitude:

$$\sqrt{\frac{G\hbar}{c^3}} = 1.3 \times 10^{-33} \text{ cm} \quad (2)$$

Imagine an advanced civilization pulling the wormhole out of the quantum bubble and magnifying it to classical size. This may be analyzed by developing calculations of spontaneous wormholes produced by quantum tunneling.

In addition, for any passable wormhole, a double ball encircled one entrance (but its outer spacetime was almost flat), as seen from the other entrance through the wormhole, is an outer bound surface. This means that without an event horizon, the pressure-energy tensor  $T_{\mu\nu}$  of the wormhole must violate the average weak energy condition(AWEC); That is, to go through the wormhole we will have a zero geodesic, with a tangent vector equals theta, along which we will have theta  $k^\mu = dk^\mu / d\zeta$ , and then

$$\int_0^\infty T_{\mu\nu} k^\mu k^\nu d\zeta < 0 \quad (3)$$

Thus, if it can be shown that quantum field theory prohibits violations of AWEC, it may rule out the possibility of advanced civilizations maintaining permeable wormholes.

#### 4 Alcubierre spacetime metric analysis

Miguel Alcubierre, a Mexican physicist who worked in the UK for a long time, wrote his famous paper [5] entitled "The warp drive hyper-fast travel within general relativity". Firstly, he using the language of the 3+1 formalism of GR, because it will permit a clear interpretation of the results. In this formalism, spacetime is described by a foliation of spacelike hypersurfaces of constant coordinate time  $t$ . The geometry of spacetime is then given in terms of the following quantities: the 3 metric  $\gamma_{ij}$  of the hype-surfaces, the lapse function  $\alpha$  that gives the interval of proper time between nearby hypersurfaces as measured by the Eulerian observers, and the shift vector  $\beta^i$  that relates the spatial coordinate systems on different hypersurfaces. Using these quantities the metric of spacetime can be written as:

$$\begin{aligned} ds^2 &= -d\tau^2 = g_{\alpha\beta} dx^\alpha dx^\beta \\ &= -(\alpha^2 - \beta_i \beta^i) dt^2 + 2\beta_i dx^i dt + \gamma_{ij} dx^i dx^j \end{aligned} \quad (4)$$

As long as the metric  $\gamma_{ij}$  is positive definite for  $t$  all values, spacetime is guaranteed to be completely hyperbolic modal.

Suppose the ship is moving in  $x$  coordinates; Want to find a metric that "pushes" the spacecraft along an orbit described as a random function  $x_s(t)$  of time; Therefore it is written under normalized conditions:

$$\begin{aligned} \alpha &= 1 \\ \beta_x &= -v_s(t) f(r_s), \quad \beta_y = \beta_z = 0 \\ \gamma_{ij} &= \delta_{ij} \end{aligned}$$

Where  $v_s(t) = dx_s(t)/dt$ ,  $r_s(t) = [(x - x_s(t))^2 + y^2 + z^2]^{\frac{1}{2}}$ , and the  $f(r_s)$  is:

$$f(r_s) = \frac{\tanh[\sigma(r_s + R)] - \tanh[\sigma(r_s - R)]}{2 \tanh(\sigma R)} \quad (5)$$

So the metric can be written

$$ds^2 = -dt^2 + [dx - v_s f(r_s) dt]^2 + dy^2 + dz^2 \quad (6)$$

Therefore, the spacetime structure can be described as follows: The 3D geometry of hypersurfaces is always flat. A time-like curve perpendicular to a hypersurface is geodesic, and spacetime is always flat except for a few regions.

Consider the external curvature tensor  $K_{ij}$ , which describes how 3D hypersurfaces are embeded Into 4D spacetime:

$$K_{ij} = \frac{1}{2\alpha} (D_i \beta_j + D_j \beta_i - \frac{\partial g_{ij}}{\partial t}) \cong \frac{1}{2} (\partial_i \beta_j + \partial_j \beta_i) \quad (7)$$

Introduce the concept of volume expansion angle:

$$\theta = -\alpha \text{Tr} K$$

It can also be illustrated that the volume expands behind the spacecraft and compresses in front. The trajectory of the spacecraft is actually a time-like curve, with eigentime equal to coordinate time. The spacecraft flies on geodesic and has no time dilation.

It can be shown that  $d\tau = dt$ , so the ship is moving on a time-like curve. Therefore, it can be

concluded that when the spacecraft is flying, it does not experience time dilation. This also directly proves that the spacecraft flies on geodesic. This means that even if the coordinated acceleration is an arbitrary function of time, the intrinsic acceleration along the flight path of the spacecraft will be zero.

To see how one can use this metric to make a round trip to a distant star in an arbitrary small time, let us consider the following situation: Two stars  $A$  and  $B$  are separated by a distance  $D$  in flat spacetime. At time  $t_0$ , a spaceship starts to move away from  $A$  at a speed  $v < 1$  using its rocket engines. The spaceship then stops at a distance  $d$  away from  $A$ . We will assume that  $d$  is such that  $R \ll d \ll D$ . It is at this point that a disturbance of spacetime of the type described, centered at the spaceship's position, first appears. This disturbance is such that the spaceship is pushed away from  $A$  with a coordinate acceleration that changes rapidly from 0 to a constant value  $a$ . Since the spaceship is initially at rest ( $v_s = 0$ ), the disturbance will develop smoothly from flat spacetime.

When the spaceship is halfway between  $A$  and  $B$ , the disturbance is modified in such a way that the coordinate acceleration changes rapidly from  $a$  to  $(-a)$ . If the coordinate acceleration in the second part of the trip is arranged in such a way as to be the opposite to the one we had in the first part, then the spaceship will eventually find itself at rest at a distance  $d$  away from  $B$ , at which time the disturbance of spacetime will disappear (since again  $v_s = 0$ ). The journey is now completed by moving again through flat spacetime at a speed  $v$ .

Moreover, we see that when a spacecraft travels in flat spacetime, time dilates only from the beginning and end of the flight. Since the round-trip is only twice the distance, we can get back to planet  $A$  in any small intrinsic time, both from the ship's point of view and from the planet's point of view. The spacecraft will be able to travel faster than light. However, it will always maintain a time-like trajectory; That is, in its local light cone, the light itself is also pushed along by the warping of spacetime.

The above analysis is based on: the three-dimensional geometry of hypersurfaces is always flat; Information about spacetime curvature will determine the time lapse indicating that the time-like curve perpendicular to the hypersurface is geodesic; The latter is contained in the external curvature tensor  $K_{ij}$ , which describes how 3D hypersurfaces are embedded into 4D spacetime. ... The problem is that the metric described above has an important shortcoming: it violates three major energy conditions (weak energy condition, principal energy condition, and strong energy condition). The weak energy condition and the main energy condition require the energy density to be positive for all observers. If one could calculate the Einstein tensor from the metric and use the 4-dimensional velocities of Euler observers, it would be shown that those observers would see the following energy density:

$$T^{\alpha\beta} n_\alpha n_\beta = \alpha^2 T^{00} = \frac{1}{8\pi} G^{00} = -\frac{1}{8\pi} \frac{v_s^2 \rho^2}{4r_s^2} \left( \frac{df}{dr_s} \right)^2 \quad (8)$$

The fact that this expression is always negative indicates that it violates both the weak energy condition and the principal energy condition, and it can also be proved that it violates the strong

energy condition using similar methods.

We see that when it happens in a wormhole, it takes exotic matter to do faster-than-light (FTL). But even if we believe that exotic matter is forbidden, it is well known that quantum field theory allows the existence of negative regions in some special environments (such as the Casimir effect). The need for exotic matter does not eliminate the possibility of using spacetime warps like those described above for super-fast interstellar travel.

Anyway, the calculations show that there has to be negative energy, and it has to surround the starship. It's very difficult to do that; The first is to require vast quantities of exotic matter. For example, it was later proved that a warp bubble moving at  $v=10c$  has a wall thickness of  $10^{-30}$  cm. Assuming a starship size of 200m, the negative energy required is equivalent to ten billion times the mass of the observable universe! Other improvements have been proposed, but not much in terms of implementability. ... According to astrophysicists, Warp drive could be a reality within the next 100 years, making Star Trek-style space travel possible. That's according to J. Lewis, a professor at Sydney University in Australia, who told ABC news that the futuristic concept is part of the theory of relativity, which describes how we can warp time and space. So you can travel through the universe as fast as you want. It's theoretically possible, but can we build a warp drive? We have clues that there are materials out there, but whether we can assemble them all and build a warp drive remains to be seen.

The physicist's view—that future space flight will inevitably require FTL travel —has long been advanced by Chinese scientists, including Song Jian, Lin Jin and me.<sup>[14-16]</sup> And we've already noticed inconsistencies in relativity—SR says that FTL motion is impossible, GR says it is possible (otherwise theory of wormholes and Warp drive wouldn't have happened). This inherent contradiction has led to the bizarre claim that future FTL spaceflight is still based on relativity.

#### **4 Discussion on Warp drive propulsion scheme**

It must be admitted that if GR is an airtight and perfectly correct theory, Alcubierre uses it to the extreme. He was followed by a number of similar papers, which seemed more to satisfy mathematical interests. And we just focus on one thing, is there any way we can do FTL space travel in the future? Is it just talk?

Warp drive is a theoretical prediction or vision for FTL space travel. The basic principle is that a spacecraft in a warp bubble can travel to the far reaches of the universe at an arbitrarily large speed while remaining stationary relative to the nearby space (frame of reference). This is because the spacetime in front of the warp bubble has been managed to contract, shortening the distance from its destination; At the same time, the spacetime behind the warp bubble expands, increasing the distance between the warp bubble and the starting point. Observers outside the disturbance region may observe the spacecraft traveling at FTL speed.

SR's belief that nothing can move at faster-than-light speeds "remains true" in GR, Alcubierre said. But the description would be more accurate--In GR, nothing can travel locally faster than the



speed of light.

Since human daily life is based on Euclidean space, it is natural to assume that if no matter can travel locally at FTL speed, then the two places are separated by an appropriate distance  $D$ , as measured by the observer who always stays in the starting position, the round-trip time between the two places cannot be less than  $2D/c$ . Of course, we know from our study of SR that if a person is flying back and forth at close to the speed of light, his measured time is smaller. But within the framework of GR, and without introducing exotic topologies (wormholes), it may come as a surprise to many that one can actually make this round trip in less time than measured by a stationary observer. But the idea is easy to understand if we think about the early expansion of the universe and consider the relative separation velocities of two observers moving together. If the relative velocity is defined as the rate of change of the proper space distance in intrinsic time, a value much larger than the speed of light is obtained. This does not mean that the observer will travel at FTL speed, they will always move within a local cone of light; The great speed of separation comes from the expansion of spacetime itself. The above example shows how to use the expansion of spacetime to move away from a place at an arbitrarily large speed. You can also use the contraction of spacetime to get to a place at any speed. In this way, spacecraft would be propelled away from Earth and toward distant stars through "spacetime" itself. We can reverse this process and return to Earth.

After the paper of Alcubierre was published, the response seemed to be more enthusiastic than wormhole (see [14-20]). However, most of them are still mathematical analysis, and there are few articles discussing how to design and realize them physically. But some papers are novel, such as Santa-Pereira's, "Using fluid dynamics to deal with curved phases to advance spacetime geometry"<sup>[20]</sup>, which is similar to the Chinese scientists use of aeromechanics to deal with problems related to relativity<sup>[21]</sup>. In addition, reference [20] suggests that the use of negative energy density may be avoided. The Alcubierre Warp drive metric is a kind of spacetime geometry with spacetime distortion called warp bubble. One of the giant particles gets global FTL. The solution of the field equation of Alcubierre metric with fluid material as gravity source is given. The energy-momentum tensor under consideration has two types of fluid: perfect fluid and parameterized perfect fluid (PPF), which is an exploratory and more flexible model aimed at exploring the possibility of Warp drive solutions with positive matter density components. It has been shown that the Alcubierre metric relates this geometry to Burgers' equation, which describes the motion of shock waves in an inviscous fluid but brings the solution back to a vacuum. The same thing happens in two quarters of a perfect fluid. Other solutions for ideal fluids show that flexural drive of positive matter density is possible, but at the cost of complex drive regulation function solutions. With regard to PPF, a solution is also obtained, showing that positive matter density can produce velocity. The weak energy, principal energy, strong energy and zero energy conditions for all subclasses of study were calculated to satisfy the requirements of perfect fluid and to generate constraints in the PPF, thus making it possible for the density of positive matter to also produce warp bubbles. Combining all

the results, the energy-momentum tensor describing a more complex form of matter or field distribution yields solutions to field equations with Warp drive metric, where negative matter density may not be a strict prerequisite for obtaining Warp velocity."

However, the author believes that negative energy density can not be invoked, and this argument still needs to be tested over time, because the above situation is only the result of fluid dynamics analysis.

## **5 The conceptual confusion of space and time integration**

We have discussed in detail the basic theory of wormhole and warp drive propulsion. This is contrary to the author's intention, because we do not fundamentally agree with relativity, especially with its two foundations: the integration of space and time and the curvature of spacetime<sup>[6,7]</sup>. As is known to all, both SR and GR take space and time integration as the starting point. This concept comes from Minkowski. All the relativity literature talks about spacetime, but what does spacetime really mean? People don't actually know. The textbook description gives the impression that Minkowski's approach, while having some mathematical expressiveness benefits, but violates physical reality. It is practically impossible and meaningless to "add" a space vector to a time vector. Fundamentally, time and space should not be confused. We believe that space is continuous, infinite, three-dimensional, isotropic; Time is the symbol of the continuity and sequence of matter's movement. It is continuous, unidirectional, and passes evenly without beginning or end. Space and time exist independently of human consciousness. Moreover, space is space and time is time; they are fundamental quantities that describe the physical world. The so-called spacetime does not exist in Metrology and the International System of Units (SI), nor does it have measurable properties. It is unreasonable to confuse time and space, two completely different physical concepts, by artificially constructing a new parameter (so-called 4D spacetime) with physical quantities of different dimensions.

Therefore, in writing this paper, the author, contrary to his original intention, tries to take the position of relativists (including Thorne and Alcubierre), and consider the possibility of "FTL travel". Instead, what we of a basic concepts; This paper takes literature [8] as an example for illustration. Of course, we are not here to blame [8] authors and interviewees, but to say that relativity does have such conceptual holes and confusion. In [8], the Japanese physicist Michio Kakai is quoted as saying that there are two ways to move faster than light: extending space(warp drive, for example) and curving space(wormhole, for example); here he was say "space", not "spacetime".[8] Also says,"spacetime near the warp bubble is very warped"; But later it says: "The FTL drive of a warp drive can be attributed to space expansion." Now, it is spacetime warping, or is space warping?! Relativity itself (and those men who believe in it) does often confuse spacetime with space. This is inadmissible, because since the whole theory of relativity is based on the integration of time and space, how can use space replace spacetime?! However, in terms of the physical meaning of warp drive, it is possible to explain what is actually happening by saying that

space in front of the ship is shrinking while space behind the ship is expanding. In that case, space is enough without spacetime; But is it still relativity?!

It is a shame that this article about Warp drive had to stop to discuss the integration of time and space. The mark of space is length, the unit is meter; Time is measured in seconds. But spacetime cannot exist and stand as an independent physical quantity, nor can it be assigned its own unit. In astronomy and cosmology, the GR term "matter bends spacetime" often means "matter bends space". The idea of time bending has always been elusive—how can time be bent? Bending is a kind of geometrical description. For invisible time, it is meaningless to say whether time is curved or not. This concept has no physical reality....These old problems now affect our discussion of Warp drive, making "turning to GR for FTL travel" being a hollow and impractical idea.

According to reference [5], Alcubierre said: "We clearly see how the volume elements are expanding behind the spaceship, and contracting in front of it". At here he uses the word "volume"(i.e.space), and he didn't use the word "spacetime"!

## **6 How to obtain the negative energy**

The concept of negative energy was first put forward by P.Dirac in the 1920s, and in accordance with his ideas, positron was discovered, which was also the earliest antimatter. But Dirac is just using this concept to analyze the problem. He doesn't say that "there may be negative energy in nature" or that "negative energy can be artificially created," and the positrons carry positive energy. It is necessary to discuss the problem of negative energy because of the study of superluminal velocity.

The core of GR theory is spacetime bending. Normally matter gives spacetime a positive curvature, like a sphere. Wormhole theory led to the time machine, which states that in order to travel through time, spacetime needs to have a negative curvature, like a saddle. But the imagery may be hard to understand; Warp drive also seems to require negative curvature spacetime....The key point is that quantum laws(which are based on the uncertainty principle) allow the energy density to be negative in some places, as long as it can be compensated for by the positive energy density elsewhere, keeping the total energy density positive<sup>[22]</sup>.

To his credit, G.Feinberg<sup>[22]</sup> addressed negative energy as early as 1968 in his paper "The Possibility of Tachyon particles."He says: "another problem with tachyon particles arises from the fact that, for momentum vectors in phase space, the sign of the energy can be changed by Lorentz transformations," There is a more direct relation between the positive and negative energy solutions of the wave equation than the phase time momentum. This connection, to include tachyon particles, must include the presence of negative energy states. However, we shall see that the negative energy solutions for tachyon particles are very similar to those for ordinary particles, i.e.in quantum field theory these solutions are associated with creation operators instead of annihilation operators. In fact, Feinberg was the first to show that the FTL problem was related to the concept of negative energy. But we should also see that his ideas are contradictory—if the tachyon carries negative

energy, it leads to negative mass. However, the core of Feinberg tachyon theory is virtual mass (take  $m_0 = j\mu$ ,  $\mu > 0$ ), and the two are not compatible.

Later, many scientists pointed out that any FTL space program would use negative energy. For example, Russian astronomer S.Krasnikov(who proposed a one-way FTL spacetime channel, but not the same as a wormhole), as well as K.Olum in the United States, B.Bassett in the United Kingdom. Their thoughts are the same.

Now, we'll discuss a few possible ways to obtain negative energy, but they are not guaranteed success and are mentioned just to keep the mind active:

#### **A. Use the compressed vacuum state**

The concept of quantum vacuum is different from that of classical vacuum. Because there are fluctuations, there is a process of virtual particles that spontaneously emerge and disappear. Vacuums with fluctuations correspond to an average energy density of zero, but the scientists have come up with a way to make it less than zero. One example is a "compressed vacuum state" in which positive energy is present in one part of space and negative energy in another, but the two are balanced throughout space. This effect is said to be achieved by passing a laser beam through a non-linear optical material [see R.Slusher's 1988 article "Squeezing Light"]. Alternating positive and negative energies are created as photons enhance or suppress vacuum fluctuations.

#### **B. Use strong gravity to produce negative energy particles**

S.Hawking<sup>[23]</sup>, a British physicist, suggested that pairs of virtual particles exist in a vacuum, including cases where one is a particle and the other is an antiparticle; They were first created together, then separated, then came together and annihilated. Since energy cannot be created out of zero, one of the particle—antiparticle pairs has positive energy and the other has negative energy, but the latter has a short life and is a virtual particle. It has to find a partner and annihilate with it. ... Hawking thus proposed the concept of negative energy particles; In his view virtual particles (particles whose existence cannot be proved by measurement) have both positive and negative energies. If there is a black hole, where gravity is too strong, the energy of the real particle may also be negative. It is also possible that a negative energy virtual particle falls into a black hole and becomes a real particle or antiparticle. However, Hawking radiation is a positive energy particle.

Hawking's theory is based on quantum field theory, in line with the "quantum view of vacuum," while the idea that black holes evaporate through radiation was proposed in 1974. According to general relativity (GR), the curvature of spacetime near black holes is so large that it disturbs the vacuum fluctuations. It is this extreme curvature of spacetime that requires negative energy to come out and enter the black hole, which means positive energy will come out of the black hole. So the conservation of energy cannot always be violated, and black hole physics must be consistent with thermodynamics. This shows that classical physics is not bad, the law of conservation of energy, the law of thermodynamics are to be observed.... However, the existence of

negative energy particles is still a hypothesis in the author's opinion and lacks experimental proof.

### C. Search for negative energy from quasars

In the section of "Energy and momentum distribution of gravitational field" published by Hu Ning<sup>[24]</sup> in 2004, the complex derivation even showed the result that "the total energy of gravitational field is negative". The reason of the negative energy density is not accepted is that it leads to "negative mass". And we can't explain the attraction between stars without the concept of negative energy density. The gravitational energy and the energy stored in the gravitational field must be negative, which Hu Ning said is an insurmountable contradiction existing in linear gravitational field equation. The implication seems to be that more rigorous theoretical equations will overcome this paradox.

### D. Use Casimir effect<sup>[11,12]</sup>

It is generally believed that Casimir effect can be used to obtain negative energy. In 1948, Dutch physicist H.Casimir proposed in the paper, take two flat smooth metal plates, put them parallel to each other in a vacuum environment, if the distance  $d$  is very small, it will be found that there is a mutual attraction between them (later called Casimir force), it is not Newton's universal gravitation, the real existence is very strange. The great physicist W.Pauli had dismissed this as nonsense, but gradually accepted it at Casimir's insistence.

On the "negative energy vacuum" in Casimir effect, I published an English article in 2021<sup>[12]</sup>. Now summarize the main point. The quantized electromagnetic field is a quantum system with infinitely many harmonic oscillators. The ground state has zero-point vibration and corresponding zero-point energy (ZPE), and the zero-point vibration of all modes is the vacuum fluctuation of the quantum electromagnetic field—although the mean value is zero, the mean square value is not zero.

Therefore, quantum theory believes that vacuum has energy and the overall value is  $\frac{1}{2} \sum_i \hbar \omega_i$ .

Since the degree of freedom  $i$  (that is, the modulus of vibration  $i$ ) is infinite and the upper limit of  $\omega$  is infinite, this vacuum energy is divergent and unobtainable. However, it is possible to calculate and measure the change in the vacuum energy by placing two parallel metal plates, constructed an open cavity. The boundary conditions of the field change, and the harmonic oscillator frequency changes, causing the energy of the vacuum state to change. Although ZPE is still divergent after cavity placement, it cannot be observed. But the difference in energy before and after it can be calculated and observed. So this is the Casimir energy, which is called  $E_c$ . The corresponding force on the metal plate which is called the Casimir force  $F_c$ . Now,  $E_c$  equal to the difference between the ZPE of the vacuum between the plates and the ZPE of the absence of the plates:

$$E_c = \left[ \sum \frac{1}{2} \hbar \omega_i \right]_Y - \left[ \sum \frac{1}{2} \hbar \omega_i \right]_N \quad (9)$$

We can get a clearer idea of physics by putting it this way; In the above formula  $Y$ , for "Yes", is after the plate is inserted;  $N$  for "No", is no board case.

It is worth noting that the expressions of  $E_c$  and  $F_c$  given by the above derivation, and finally have a minus sign; What does it mean physically? There is a view that the Casimir energy is negative energy and the Casimir force between the two conducting plates is attracted to each other. "Negative energy" can be understood as "the emptiness between the plates is more empty than the

vacuum", which must produce inward force to bring the plates closer. Because of this, Lamoreaux's<sup>[25]</sup> measurements in 1997 were considered to "measure negative energy", But the question is debated.

Why do many people always think that Casimir energy  $E_c$  is negative energy? When two parallel metal plates are placed in engineering vacuum environment, the energy density between the plates is lower than that outside the plates due to quantum effect. It is generally believed that the energy density outside the plate is zero, so the energy density inside the plate is negative. This assertion led to the belief that Lamoreaux measured negative energy. However, the experimenter himself did not say that he measured the negative energy. Instead, he designed a sophisticated device to measure the Casimir force  $F_c$ , thus calculating that the Casimir energy  $E_c = (10 \sim 15) \text{J}$  and the spacing value  $d = 1 \mu\text{m}$ . This experiment was published in 1997, half a century after H.Casimir's paper. Casimir himself did not die until 2000(91 years old), and was very old in 1997 and 1998. It must have been a mixed feeling to hear that Casimir force was accurately measured.

#### **E. Use negative wave velocity**

The WKD experiment, which was published in 《Nature》 in 2000 under the title "Gain assisted superluminal light propagation"<sup>[26]</sup>, is a negative wave velocity (actually a negative group velocity) experiment. After the results were announced, heated discussion ensued. Some people do not agree that it is a FTL experiment, in order to prove their point of view, the analysis and calculation, but there is a negative energy density result<sup>[27,28]</sup>. Because of the interaction between the light pulses and the cesium (Cs) atomic gas in the experiment, the energy density of the electromagnetic field they calculated from electromagnetic theory was only the electromagnetic component of the internal energy of the cesium atomic gas. It is calculated that the negative energy density moves from the exit to the entrance at approximately negative group velocity  $v_g = -c/310$ . They found it difficult to interpret the negative energy density and speculated that it might mean "extracting energy from caesium atomic gas."

The final results are given in literature [28]. When the parameters in WKD experiment are substituted, the result is  $w < 0$  ( $w$  is the energy density). If considered as the electromagnetic energy density of the pulse in the medium, then it is negative! Furthermore, the energy density increases in the opposite direction of  $A(z, t)$ . Since it can be proved that the energy transmission velocity  $v_e$  is approximately equal to the group velocity  $v_g$ , it is known that  $v_e \cong v_g < 0$ , the energy density propagates in the opposite direction to the incident wave.

#### **F. Use metamaterials**

Metamaterials are known as super-materials. The broad concept includes photonic crystals (PC), left-handed materials (LHM), absorbing materials, stealth materials, etc., and the range is very wide. The narrow understanding is negative refractive index (NRI) materials, that is, left-handed materials character.

In 1964, V.Veselago<sup>[29]</sup> published the first paper on this subject, entitled "Electrodynamics of  $\epsilon$  ,  $\mu$  simultaneously negative". This paper proposes a new concept—although no matter with  $\epsilon < 0$  and  $\mu < 0$  occurring at the same time has been found in the past, its existence does not conflict with the existing laws of physics. Clearly, Veselago believes that negative refraction propagation occurs only if the permittivity and permeability are both negative.

Here we are concerned with energy relations; In isotropic media, the electric field energy density and magnetic field energy density are respectively:

$$w_e = \frac{1}{2} \epsilon E^2 \quad (10)$$

$$w_m = \frac{1}{2} \mu H^2 \quad (11)$$

Where E is electric field intensity, H is magnetic field; intensity; So  $\epsilon$  or  $\mu$  negative will lead to negative energy density. If space has both electric and magnetic fields, the total energy density is

$$w = w_e + w_m = \frac{1}{2} \epsilon E^2 + \frac{1}{2} \mu H^2 \quad (12)$$

If both  $\epsilon < 0$  and  $\mu < 0$  are true, then  $w < 0$ ; But if one of them is positive, then the total energy density is not necessarily negative.

The possibility of negative energy upsets Vesselago, because it has no place in classical physics. He used the concept of frequency dispersion to explain it; Under the condition of no dispersion and no absorption, if the constraint that the total energy cannot be zero is kept(which is consistent with the traditional understanding of energy), it is impossible for,  $\epsilon$  ,  $\mu$  to be negative, that is, there is no possibility to satisfy both  $\epsilon < 0$  and  $\mu < 0$  at the same time. However, the following expression is more general:

$$w = \frac{1}{2} \left[ \frac{\partial(\epsilon\omega)}{\partial\omega} E^2 + \frac{\partial(\mu\omega)}{\partial\omega} H^2 \right] \quad (13)$$

To keep the value  $w$  greater than 0, the value must be met:

$$\frac{\partial(\epsilon\omega)}{\partial\omega} > 0 \quad (14)$$

$$\frac{\partial(\mu\omega)}{\partial\omega} > 0 \quad (15)$$

Both inequalities do not mean that  $\epsilon$  and  $\mu$  cannot be negative at the same time; However, to satisfy the requirement of the above inequality, it ultimately depends on the relationship between  $\epsilon$  ,  $\mu$  and frequency.

Although Vesselago ruled out  $w < 0$  based on classical electrodynamics, experimental techniques developed decades after the publication of his paper brought the question to a conclusion. In March 2000, at a meeting of the American Physical Society, scientist D.Smith<sup>[30,31]</sup> of the University of California, San Diego (UC-SD) announced the completion of negative refractive index experiments in microwaves, making the LHM predicted many years ago.

## 7 Fundamental FTL research that does not rely on "spacetime bending"

Relativity is based on the integration of space and time and the curvature of spacetime, but both can be problematic<sup>[6,7]</sup>. As it turned out, SR prohibited FTL speed, and some physicists bypassed SR and turn to used GR for develop FTL theory, propagating wormholes or warp drive propulsion. Recent trends seem to have made warp bubble a buzzword, thanks to the persistence of the American physicist H.White in warp drive and the continued publication of papers in the «European Physics Journal C» .

In February 2022, China's «Science and Technology Daily» published an article by reporter Tang Fang<sup>[8]</sup> entitled "Warp bubbles found in the real world? Don't worry, faster than light travel is too early". The article said:

"Science fiction heroes often use a tool called a warp drive for faster than light interstellar travel. In the virtual universe of «Star Trek» , warp drive is a faster than light propulsion device. Inspired by this, and based on general relativity, physicist M.Alcubierre proposed the scientific concept of warp drive in 1994.

A team led by H.White, a physicist at the Defense Advanced Research Projects Agency (DARPA), has discovered a warp bubble in the real world, the «European Journal of Physics, Series C» reported recently. White's nanoscale warp bubble is thought to open the door to creating warp engines and ushering in the faster than light age.

In response, Li Li, an associate researcher at the Institute of Theoretical Physics, Chinese Academy of Sciences, told «Science and Technology Daily» in February that White's team did some numerical simulations and predicted that a certain microstructure could give a negative energy density distribution, which is similar to the negative energy needed to maintain the Alcubierre spacetime structure (warp bubble). But whether it can be linked to warp bubbles or warp engines remains to be seen."

when the author saw this report, the feeling are joy and sorrow. The good news is that FTL research is seeing a resurgence in the new century, even though we may not like the projects mentioned; The worrying is that the public is not aware of the fact that scientists in many countries (including China) have been working on FTL problems for decades, but they still seem to be "relying on GR", which we do not approve of or like. If GR does have a problem on correctness<sup>[7]</sup>, then we what to do? !

If we start with G.Feinberg's serious FTL research paper<sup>[22]</sup>, the history of related research is 55 years. Scientists from the United States, The United Kingdom, China, Russia, Italy and other countries participated in the research. Theoretical work and experimental work are abundant. In this case, it is well established that " any thing can't travel faster than the speed of light";<sup>[8]</sup> "No credible evidence of faster than light experiments has been found";<sup>[8]</sup> It all doesn't seem realistic. The 1993 SKC experiment<sup>[32]</sup>, for example, sped up photons by 70% to  $v=1.7c$  in a human lab — does this count as the faster than light motion of "anything"? Is it too much to erase the efforts and explorations of so many countries and workers in a few words?... Although I have been doing FTL



research for more than 20 years and have published many articles and books<sup>[33-38]</sup>, I am still willing to start from scratch. Here are a few highlights we'd like to address....Here is a list of some of the ideas and work that Chinese scientists have done in FTL research—it's probably better to do basic research than talks only about "human travel to the universe by FTL".

### **I. We do not agree with the research approach of "bypassing SR and resorting to GR"**

Many physicists, yearning for FTL spaceflight but fearful of the SR ban, found GR to be useful, and went in to tinker with mathematical formulases to turn physical problems into mathematical problems. Could this approach bring us closer to FTL space travel? That's impossible! For example, the negative energy problem, although the author also suggested some possible way means to obtain negative energy, but it is very difficult to have practical effect.

Interesting researchers are advised to first see if SR's ban on FTL speed is correct or not. According to the mass-velocity formula, the mass of the particle in motion is:

$$m = \frac{m_0}{\sqrt{1 - \beta^2}} \quad (16)$$

Where  $m_0$  is the rest mass of the particle, and  $\beta = v/c$ ,  $v$  is the particle velocity, and  $c$  is the speed of light. So the energy of the particle is :

$$E = \frac{m_0 c^2}{\sqrt{1 - \beta^2}} \quad (17)$$

Therefore, when the value of  $v$  gradually increases from a low value,  $E$  gradually increases; When  $v$  is equal to  $c$ ,  $E$  is infinite. If  $v > c$ ,  $E$  becomes imaginary. Both infinite and imaginary energies are meaningless in practice, so SR theory determines that "faster than light cannot exist".

These views, it must be said, are superficial. First of all, Lorentz's mass-velocity formula is derived for the electromagnetic mass of electrons<sup>[39]</sup>. Even if it applies to charged particles such as electrons and protons, it cannot be generalized to all motion bodies like SR. In fact, there is a lack of experimental proof that the mass-velocity formula can applies to neutral particles and objects, then the so-called "light barrier" may not really exist.

In addition, the electron is not an ordinary motion of particle, but a special charge of the particle motion. So the energy is not infinite even if  $v$  is equal to  $c$ . In addition, it can be proved that when the velocity  $v$  increases, both the charge  $q$  and the force  $F$  of the moving body will decrease. This explains the Kaufmann experiment of 1901. Similarly, the analysis showed that the Bertozzi experiment in 1964 also did not prove that over the speed of light  $c$  was impassable.

Secondly, it is well known that photons travel at the speed of light ( $v = c$ ) which is fine, and the speed of photons( $c$ ) is not obtained by acceleration, but is inherent. Moreover, there may be FTL particles in nature whose speed is not obtained by means of acceleration. That is, a particle moving at subluminal speed ( $v < c$ ) may not be able to accelerate to superluminal speed, but a Feinberg tachyon may have an imaginary rest mass:

$$m_0 = j\mu \quad (18)$$

Where  $\mu$  is a real number. In this case, even  $v > c$  ( $\beta > 1$ ), does not appear imaginary energy.

Nature is very complex, and science has long used neutrinos as an example of how Tachyon might have existed.

Let  $\beta = v/c$ , ( $v$  is the moving body velocity), it can be seen that there is a factor  $(1 - \beta^2)^{-1/2}$  in SR that works everywhere, which is called the light speed limit factor by the author, and it is this factor that creates the light barrier. In 2001, Cao Shenglin<sup>[40]</sup> pointed out that there was no need to assume tachyon with imaginary rest mass as Feinberg did. In his theory, the speed limit factor  $(1 - \beta^2)^{-1/2}$  becomes  $(1 - \beta^2 + \beta^4)^{-1/4}$ , and there is no need to deny FTL motion. The crux of the matter, he argues, is that Lorentz transformation(LT) only works in subluminal speed systems. Einstein's past use of the local characteristics of LT to deny the possibility of FTL motion was neither sufficient nor necessary. Now we write the equations of moving mass and energy derived by Cao Shenglin:

$$m = \frac{m_0}{\sqrt[4]{1 - 2\beta^2 + \beta^4}} \quad (19)$$

$$E = \frac{m_0 c^2}{\sqrt[4]{1 - 2\beta^2 + \beta^4}} \quad (20)$$

Since  $1 - 2\beta^2 + \beta^4 = (1 - \beta^2)^2 = (\beta^2 - 1)^2$ , when  $\beta < 1$ , the formula consistent with SR theory is immediately obtained. If it is  $\beta$  greater than 1, it can be written:

$$m = \frac{m_0}{\sqrt{\beta^2 - 1}} \quad (21)$$

$$E = \frac{m_0 c^2}{\sqrt{\beta^2 - 1}} \quad (22)$$

The denominator is still a real number. So the theory does not require FTL particles (or any physical matter) to have virtual mass. It can be seen from Equation (22) that, when  $v$  increasing ( $\beta$  increasing), the energy  $E$  decreases; As  $v$  decrease ( $\beta$  decrease), the energy  $E$  increases. This is exactly what A.Sommerfeld expected of FTL particles in the early 20th century — that FTL particles would speed up as their energy was reduced and slow down as their energy increased.

So is it possible for nature to have natural FTL particles? The most likely candidates are neutrinos. These are tiny but ubiquitous particles that have no electric charge, come in three types:  $e$  particle,  $\mu$  particle and  $\tau$  particle. It have physical properties somewhat similar to photons. It was long thought to be a FTL particle. ... In 2015, Huang Zhixun<sup>[41]</sup> published a paper "On different explanations of phenomena following supernova explosion in 1987". On February 23, 1987, a supernova explosion occurred. 7.7 hours before the arrival of the first photons from 1987A, the first neutrino wave was detected by detectors under The Browne Peak in Italy, which contained five events. Three hours before the first photons arrived, the second neutrinoes arrived, 11 events were received by the Kamioka II detector in Japan, 8 events by the IMB detector in Ohio, USA, and 5 events by the Baksan detector in the former Soviet Union. How could this happened? It has never been properly explained. There are only three possibilities: ①photons travel at the speed of light, neutrinos at superluminal speeds; ②Neutrino velocity is  $c$ , photon's velocity is subluminal; ③

The neutrino's velocity is superluminal and the photon's velocity is subluminal. From the analysis of the situation at that time, something may have happened ① or ③. We think it might be ① !

From 2008 to 2011, the European Nuclear Research Center(CERN) organized multinational scientists to conduct experimental research on the speed of neutrinos. Neutrinos are emitted from CERN on the border between Switzerland and France, and received at the underground laboratory in Gran Sasso, Italy. The distance between the two places is 730km, and the distance measurement error is less than 10cm. The neutrino time of flight measurement error is less than 10ns. This was obviously a sophisticated experiment, yielding faster than light results<sup>[42]</sup>,  $v - c/c = 2.48 \times 10^{-5}$ . Then, the 174 scientists who took part in the experiment signed off on the papers to be published. But it turned out that the equipment was faulty, and the results were wrong—a major three year study (the OPERA Project) was destroyed (a loose cable connection), which is unthinkable even today....Anyway, this is over after a flurry of activity in 2011-2012: But some physicists still insist that neutrinos are tachyons<sup>[43-46]</sup>.

## II. We should pay attention to the comparative study of breaking the sound barrier and breaking the light barrier

In aeronautical engineering, the ratio of the speed  $v$  of an airplane to the speed  $c$  of sound in air ( $c$  also expressed the sonic speed for comparison purposes) is called a Mach number and the prescribed symbol is  $M_a = v/c$ . The so-called sound barrier breakthrough refers to the aircraft to achieve supersonic flight( $M_a > 1$ ). On October 14, 1947, the American X-1 rocket engine aircraft reached speed was  $v = 1078 \text{ km/h}$ , corresponding to  $M_a = 1.105$ . On February 28, 1954, the American F-104 fighter jet flew at twice the speed of sound ( $M_a = 2$ ).

The speed of light in vacuum  $c = 299792458 \text{ m/s}$ , it is  $8.8 \times 10^5$  times of the speed of sound (340m/s). With such a big difference, and the fact that the speed of light in vacuum  $c$  is one of the fundamental constants of physics(the speed of sound is not), they seems to be no comparison between the two realms put together. But the history of wave mechanics tells us otherwise. In 1759, L.Euler obtained the 2D wave equation for the first time, which is the analysis of the vibration of rectangular eardrum. Let  $f(x, y, z, t)$  represents the membrane displacement,  $c$  is a constant determined by the membrane material and tension, he obtained

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} = \frac{1}{c^2} \frac{\partial^2 f}{\partial t^2} \quad (23)$$

In his paper ("On the Propagation of Sound"), a further analysis resulted in the 3D wave equation:

$$\nabla^2 f = a^2 \frac{\partial^2 f}{\partial t^2} \quad (24)$$

Where  $f$  is the vibration (mechanical vibration or acoustic vibration) variable. Thus, wave equations were developed from the very beginning across mechanics and acoustics, the boundary between which is ambiguous to mathematicians. Due to the electromagnetic nature of light, the relationship between acoustics and optics can be understood as that between acoustics and

electromagnetism. The wave equation obtained from Maxwell equations is

$$\nabla^2 \psi = \frac{1}{v^2} \frac{\partial^2 \psi}{\partial t^2} \quad (25)$$

Where  $\psi$  is the wave function,  $v = (\epsilon\mu)^{-1/2}$ , and  $\epsilon$ 、 $\mu$  are the macro parameter of wave propagation medium. The consistency of equation (25) and equation (24) indicates that there is a unified rule in the fluctuation process.

As we know, the electrostatic field is a non-curl field, and the potential function satisfies the Laplace equation in the region where the bulk charge density  $\rho$  is zero. In aerodynamics, two basic functions are used to study fluid motion, namely potential function  $\phi$  and flow function  $\psi$ . When the flow velocity is low, the flow density in the plane flow is regarded as constant, and the two-dimensional flow is described by Laplace equation:

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0 \quad (26)$$

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0 \quad (27)$$

These are incompressible non-curl flow equations, and they are linear differential equations of order two. If the airflow speed increases to a certain extent,  $\rho$  should be regarded as a variable; The basic equation for a compressible fluid in plane non-curl flow is

$$\left(1 - \frac{v_x^2}{c^2}\right) \frac{\partial^2 \phi}{\partial x^2} - 2 \frac{v_x v_y}{c^2} \frac{\partial^2 \phi}{\partial x \partial y} + \left(1 - \frac{v_y^2}{c^2}\right) \frac{\partial^2 \phi}{\partial y^2} = 0 \quad (28)$$

$$\left(1 - \frac{v_x^2}{c^2}\right) \frac{\partial^2 \psi}{\partial x^2} - 2 \frac{v_x v_y}{c^2} \frac{\partial^2 \psi}{\partial x \partial y} + \left(1 - \frac{v_y^2}{c^2}\right) \frac{\partial^2 \psi}{\partial y^2} = 0 \quad (29)$$

Where  $c$  is the speed of sound; Obviously, if  $c \rightarrow \infty$ , the equation degenerates into a simpler Laplace equation, which is the case of incompressible fluid. We note that although the factor  $\left(1 - \frac{v^2}{c^2}\right)$  appear in equations, it does not appear that "the speed of sound  $c$  cannot be exceeded".

So why in optics, when  $c$  is the speed of light, then this factor that make the speed of light  $c$  "can't be exceeded"? !

There are many solutions for the compressible flow of ideal fluid, one of which is the perturbation linearization method. Referring to the situation of direct uniform flow, the flow velocity of incoming flow is specified as  $v_\infty$ , the sound velocity is  $c_\infty$ ; and Mach number is  $M_\infty$ ; Then the potential equation can be obtained after processing and linearization under 2D flow condition:

$$(1 - M_\infty^2) \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = \frac{\partial^2 \phi}{\partial t^2} \quad (30)$$

In the process of linearization, the limit of  $(1 - M_\infty^2)$  cannot be too large, it is not supersonic flow. It can't be transonic flow. We notice that in the subsonic flow field,  $M_\infty < 1$ ,  $(1 - M_\infty^2) > 0$ , the equation is elliptic; Its property is basically the same as that of the Laplace equation of incompressible flow. However, for the supersonic flow field,  $M_\infty > 1$ ,  $(1 - M_\infty^2) < 0$ , the equation

becomes hyperbolic, and the situation has great changes. In short, the equations of motion describing subsonic and supersonic velocities are of different types. However, the equations describing transonic flow are mixed and nonlinear, so it is very difficult to find the analytical solution. Thus came computational fluid dynamics, which is very similar to computational electromagnetism and uses the same methods (e.g., finite element method, finite difference method).

The so-called sound barrier refers to the fact that the speed of the aircraft has been hovering at the level of subsonic ( $M_a < 1$ ) for a long time, and the attempt to fly at the speed of sound ( $M_a = 1$ ) has encountered real difficulties. Early aircraft were slow enough to handle aerodynamic problems as incompressible fluids. When  $M_a \geq 0.4$ , the compressibility effect becomes obvious gradually, and the air density in front of the head increases sharply when approaching the speed of sound ( $M_a \rightarrow 1$ ). When  $M_a = 1$ , the disturbance in the fluid does not propagate relative to the aircraft, but instead concentrates to form a wave surface: when the nose meets the air in front of it, it compresses strongly, and the density increases to form an invisible wall (shock wave). The resistance caused is called wave resistance. It consumes about 75% of the engine's power, making it difficult. At this time, "near-sonic aerodynamics" and "supersonic aerodynamics" need to be developed. There were theoretical researches on transonic flow in the 1920s and 1930s, but the decisive progress was made in the 1940s. In 1945, American scientists put forward the swept-back wing theory, to overcome the impact of shock waves is to increase the speed of the aircraft to near the speed of sound. The effort to overcome the sound barrier was a collaborative effort of scientists, engineers and designers. From theoretical research to successful supersonic flight, it took only about 20 years for the scientific and aeronautical communities to work together to solve the problem.

In aerodynamics, the wave equation of the velocity potential of compressible fluid, linearized, can be expressed as

$$(1 - \beta^2) \frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} = \frac{\partial^2 \varphi}{\partial t^2} \quad (31)$$

Here we use the symbol  $\beta$  instead of the symbol  $M_a$ , in order to compare relativity with aerodynamics. In essence, the basic operation of wave mechanics is the identification and solution of differential equations. Qian Xuesen (1911-2009), together with T. von Karman (1881-1963), first proposed the concept of supersonic flow in the 1930s, providing a theoretical basis for aircraft to overcome the thermal barrier and sound barrier. Their theory is applied to the design of high subsonic aircraft. In fact, the small perturbation theory is advanced to nonlinearity in the subsonic region. Although it cannot be used in the calculation of supersonic problems, it avoids singularities, the infinite mass density does not appear at  $v = c$ .

Now let's look at the singularity problem. The above mentioned "when  $M_a = 1$ , the air density increases sharply to form a shock wave", does not say "when  $M_a = 1$ , the air density increases to infinity". Yang Xintie<sup>[21]</sup> pointed out that only subsonic flow was studied in the early stage. According to the small disturbance theory, for the flow in the shrink-pipe, if the mass density at

relative rest is set as  $\rho_0$ , the mass density at relative speed  $\beta$  will increase as:

$$\rho = \frac{\rho_0}{\sqrt{1-\beta^2}} \quad (32)$$

The above formula is identical with the mass-velocity formula of special relativity(SR). If the above equation is followed completely, the imaginary mass density will be calculated at supersonic speed. Later developments, however, proved that the infinite mass density was only mathematically infinite. Song Jian<sup>[47]</sup>, the former chief engineer of China's Aerospace Industry Ministry, pointed out that the density of the gas in a supersonic aircraft only increases six times as it passes through the sound barrier(there is no such thing as infinite value). In is under the premise of nonlinear processing, the supersonic experimental study and the related theoretical options and processing are optimized, resulting in the success of supersonic motion(flight). The singularity is no longer mentioned here. Then we conclude the following three equations:

Subsonic velocity ( $v < c$ ,  $\beta < 1$ ,  $M_a < 1$ ) ——

$$\rho = \frac{\rho_0}{\sqrt{1-\beta^2}} \quad (32)$$

Supersonic ( $v > c$ ,  $\beta > 1$ ,  $M_a > 1$ ) ——

$$\rho = \frac{\rho_0}{\sqrt{\beta^2 - 1}} \quad (33)$$

Sound speed ( $v = c$ ,  $\beta = 1$ ,  $M_a = 1$ ) ——

$$\rho = k\rho_0 \quad (34)$$

Where  $\beta$  is a Mach number,  $k$  is the coefficient, and  $\rho_0$  is the density at relative rest. Now that the whole thing is perfectly explained, faster-than-light motion research must go the same way.

However, the rule of formula (30) can only be realized through technical improvement. In the late 19th century, the development of steam turbines required the highest possible flow of air. Conventional narrowing of pipe sections in the hope of obtaining supersonic flow has failed. Swedish engineer Carl Laval(1845-1913) used shrinking section and then expanding section, that is, adding a section of expanding tube with gradually expanding section behind the shrinking nozzle, and found that as long as the pressure is high enough, there is supersonic flow in the expanding tube. This proves that infinity only exists in mathematical formulas. In the 1940s, scientists and engineers conducted wind tunnel experiments and built supersonic aircraft inspired by the Laval tube.

### III. FTL particles should be searched with improved techniques at high energy accelerators

Relativists will say that the technical practice of accelerators has long shown that increasing energy is an effective means, or even the only way, to accelerate the flight of particles (electrons or protons). And the accelerated particles can actually only reach very close value  $c$ , such as  $0.99999c$ ; Given this, how can Einstein's 1905 argument be opposed?... In this regard, the author puts forward the following views; First of all, "particles that have not been obtained with current

accelerators by  $v=c$  or  $v>c$  " is not the same as "there are no FTL particles in the universe". According to the electromagnetic field and electromagnetic wave principle design of the accelerator, in which the speed of flying charged particles can only be infinitely close to  $c$  but not reach  $c$ , is very natural, because the electromagnetic wave intrinsic velocity is  $c$ . That doesn't explain anything. Second, we do not deny that increasing electromagnetic energy can accelerate electrons, but this is not the same thing as proving the SR mass-velocity equation and the entire SR energy relationship. There is absolutely no experimental evidence for neutral particles(such as neutrons and atoms), so it makes no sense to suggest a general limit on speed. Moreover, the bigger problem is that Einstein only sees the electron as a general moving body of mass and speed, and does not consider the electron as a special moving body that carries an electric charge. Therefore, there is a lack of an electrodynamic theory which takes into account the effect of moving charge. Chinese scholar did the analysis and got significantly different results from Einstein<sup>[48]</sup>.

It must be noted that we have the support of accelerator experts in trying to find FTL particles with high energy particle accelerators. For example, professor Pei Yuanji<sup>[49]</sup> said in his article "Discussion on faster than light Experimental Scheme" in 2017:

"Up to now, charged particle dynamics have been based on the speed of light as a limit, on the dynamics of special relativity. Although the accelerators built so far have found no contradiction to this basic theory, the theoretical basis for all the parameters used to test the motion of particles is relativity, so any contradiction is hard to find. In order to find out if there is a contradiction, I propose an experimental method that may find some doubt, and if so, it can be further studied.

In the experimental device, the electron gun is an electron gun (such as photocathode microwave electron gun, external cathode independently tuned microwave electron gun, etc.) which can produce several MeV energy and ps( $10^{-12}$ s) beam length. Acceleration tube 1 and acceleration tube 2 are conventional acceleration structures (their phase velocities are close to 1 and equal to 1 respectively). They accelerate the electron beam to the relative energy of the electron beam  $\gamma=100$ , that is, the velocity of the electron beam reaches  $0.99995c$ . Acceleration tube 3 is specially designed to make the phase velocity of wave greater than the speed of light. The fluorescent targets of magnet analysis 1, 2 and behind are devices for beam energy measurement with energy resolution better than 0.1%. The beam bin is a device for absorbing an electron beam. K1 is a device that provides microwave power for conventional accelerators, and its pulse power is about 50MW. K2 is a device that provides microwave power for faster-light phase accelerators, and its output power is 25MW.  $\text{IA}\Phi$  is the element used to adjust the phase and power of the microwave power entering the accelerator tube 3".

Later, Professor Pei gave a detailed explanation of "energy simulation of electron beam in accelerator tube 3" and "test method", with several calculation diagrams attached. The goal is to find special phenomena that can be explained by electrons traveling faster than light.

In March 2019, the author received "Discussion on Superluminal Electron Accelerators" from Professor Yang Xintie. This is a research proposal jointly signed by many experts. In the "Project

Basis", the reason proposed is similar to Pei Yuanji, that is, "it is impossible to discover the contradictions of SR itself with instruments designed according to SR". The report proposes an exploratory experimental scheme in which the last of the three accelerators (No.3) is replaced by a specially designed superluminal accelerometer in which the phase velocity of the wave is greater than the speed of light. Here the electrons are expected to accelerate in the FTL direction (this region of energy does not increase but decrease).

Professor Yang is an expert in aerodynamics, and he believes that these problems have also been encountered in the development of continuum media mechanics. According to the small perturbation approximation theory, the point of sound velocity is also infinite. The subsonic equation calculates the supersonic speed, but it also produces imaginary values. But none of the mechanics thought that spacetime should be described....The algorithm for the compressible flow of an ideal fluid originally contains a space transform, but aeromechanics call it a compression transform, which is essentially the same.

In order to transform the existing accelerator to search for special electron, the author thinks that the experience of Laval tube used in supersonic aircraft, design should be learned. Coincidentally, the author is an expert in the study of waveguide theory in microwave technology. My monograph "An Introduction to the Theory of Waveguide Below Cutoff" has won the National Award of Excellent Scientific Books.<sup>[50]</sup> The special function in the cutoff waveguide (field intensity drops exponentially from the starting point), and the conic waveguide below cutoff mentioned in the book, may be suitable for accelerator transformation; So close up this paragraph for your reference.

#### **IV. The unique insights of space experts should be taken into account**

Theoretical physicists are respected, but they also have weaknesses. For example, replacing physics with mathematics, or even failing a formula, will make the whole project impossible. China is already a space power nation, and it has trained many space experts, some of whom are concerned about the future of FTL space travel. Their comments were instructive, and here are two examples.

The first example is Academician Prof. Song Jian. He is an expert in engineering cybernetics and aerospace technology. He used to be vice minister and chief engineer of the Ministry of Aerospace Industry of China. He told an academic conference in 2004:<sup>[51]</sup>

"Today's rocket engines are mainly chemical fuel engines with speeds of  $v \cong 10^{-5} c$ . Future deuterium fusion engines may have speeds as high as  $(0.05 \sim 0.1) c$ . If the spacecraft were traveling close to or even faster than the speed of light, it would take only a few years to travel to and from the nearest star....Einstein, in his 1905 paper, imagined a light barrier, saying that faster than light speed was impossible; But this is a guess, not a scientific law, because there is no experimental basis. From the technical point of view of optical barriers, with optical or radar round-trip signal time half to ranging, this is not to see the speed  $v \geq c$  target, it is impossible to judge the situation there. Therefore, ignorance of FTL conditions is no excuse for its non-existence....In addition, it is found that the engineering practice of autonomous navigation conflicts with SR dynamics even in the case



of  $v \ll c$ . For example, the dependence of engine thrust on its inertial velocity has never been observed."

Song Jian added:

"The light barrier problem in space is reminiscent of the sound barrier problem in aerospace engineering in the 20th century. Before the advent of supersonic aircraft, it was thought that the shock waves formed by aircraft approaching the speed of sound were impenetrable. But later theoretical analysis and wind tunnel experiments showed that the gas density at the head less than six times. The aviation community immediately began designing and building new planes, which flew at supersonic speeds in 1947....Does the light barrier have a similar future?"

Another example is Academician Prof. Lin Jin, a researcher at the China Academy of Launch Vehicle Technology, who is an expert on satellite navigation and inertial navigation. At the same academic conference, Lin Jin<sup>[51]</sup> presented a new theoretical model on autonomous inertial navigation, which is used to analyze and deal with the time definition, measurement mechanism and faster than light motion of inertial navigation. He argued that a moving particle could measure its own position, velocity and acceleration relative to a given inertial frame as a function of the intrinsic time of its own motion clock. In principle, there is no need to exchange information with the outside world, and there is no problem with the speed of signal transmission. Autonomous inertial navigation is based on the nature of the gravitational field, even if the world has no electromagnetic field, no light, pure inertial system still work, as usual, independent positioning, speed measurement. So why  $3 \times 10^8 \text{m/s}$  is the speed limit?! In short, the time definition of the inertial navigation spacecraft is the proper time of the spacecraft motion clock. As long as new power sources are developed in the future, there is no limit to the speed of the spacecraft. ...Lin also believes that photons should be restored to the ordinary status of other microscopic particles, even if they have a rest mass and their speed is not a limit speed.

Song Jian and Lin Jin, two space experts, are my friends, and I am also an aerospace fan. They have a thought-provoking way of looking at things; To be honest, these are words that theoretical physicists can't say!

## **V. Attention should be paid to the study of whether information can be transmitted at faster than light speed**

It is odd that messages, signals, which are not physical objects, are also on the SR's "no faster-than-light" list. NASA's Pioneer 10, launched in 1972, flew out of the solar system in January 2003, but stayed in contact with it for 11 hours, failing to complete command and communication in time. Relativity says not only that objects cannot travel faster than light, but that signals cannot travel faster than light. However, there is no such limitation in quantum theory. In August 2008, 《Nature》 published the experimental results of Swiss scientists, proving that the propagation speed of quantum entanglement is super luminal, that is,  $v_G = 10^4 c \sim 10^7 c$ ; <sup>[52]</sup> This is an important development and increases our confidence. The discussion of FTL communication is detailed in the

literature<sup>[53]</sup>.

## 8 Electromagnetic propulsion (EM drive) is the more practical method

It is interesting to compare Warp drive with electromagnetic propulsion (EM drive) and to see the trend of development. EM drive is a system based on electromagnetic energy drive<sup>[54-63]</sup>, i.e. the conversion of electromagnetic energy into thrust without the need for rocket fuel. According to classical physics, this should not be possible because the law of conservation of momentum is violated. The law states that if a system is acted upon by an external force, then the total momentum of the system remains constant; this is why conventional rockets require fuel. The foreign press has been saying that although researchers in the US, UK and China have argued for electromagnetic drive, they dispute the results because no one has a firm grasp of how it works. At the heart of the project is a microwave resonant cavity, which can also be seen as a closed cone-shaped waveguide (Figure 1). The non-uniform distribution of the electromagnetic field causes a thrust force that tends to accelerate the motion in the opposite direction. It has come through its early days of obscurity and is now attracting a great deal of attention from the scientific, technological, space and intelligence communities of various countries.

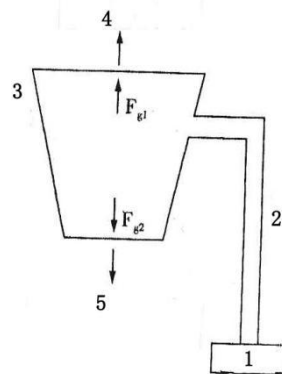


Fig.1 Schematic representation of the EM drive

(1 microwave source, 2 waveguide, 3 cavity, 4 direction of thrust, 5 direction of acceleration)

The UK Science Trends website reported on 2 August 2014 that "Incredible engine will change space travel forever", which was translated by the domestic newspaper 《Reference News》 as "Microwave engine may change space travel". The article says that senior British engineer R. Shawyer may soon be attracting a lot of attention. When he first built the engine now known as the EM drive, no one took it seriously. But that changed in 2012, when a group of Chinese scientists also built this engine, and succeeded. The EM drive is simple and light. Its thrust is generated by "microwaves bouncing back in a closed container". The engine design is so unusual that it would not work according to conventional mechanics. However, the engine can be powered by solar energy to generate microwaves. In addition, it does not require any form of propellant, so it can be used until the hardware stops working. In August 2013, a team from NASA built a slightly less powerful

engine, but one derived from a similar concept.

There was a period of confused thinking about the EM drive. First of all, where does its force come from? And what kind of force is it (for example, is it the Newton force, or is it the Casimir force?) Secondly, does it violate the principle of conservation of momentum to say that it can fly, but then not eject matter backwards? Researchers at a Chinese university proved they had done useful work in a 2011 paper<sup>[64]</sup>, but in 2013 the same authors arranged for a microwave radiation outlet from which they said a microwave beam could be ejected into the atmosphere or outer space<sup>[65]</sup>. This is a conceptual retreat into the category of chemically fuelled rockets, as if this is the only way to not violate conservation of momentum. Now, we say it is wrong. For a chemically fuelled rocket, let the rocket and fuel (propellant) masses be  $m_1$  and  $m_2$  and their corresponding velocities be  $v_1$  and  $v_2$ , then conservation of momentum requires:

$$m_1 \Delta v_1 = m_2 \Delta v_2 \quad (35)$$

If  $\Delta v_2 \neq 0$  (accelerated ejection after combustion), then  $\Delta v_1 \neq 0$  (rocket gains acceleration). So now why is this EM drive not ejecting material outwards but possibly having accelerated motion? Obviously, as long as there is force, the RF cavity does not need to be ejected outwards. In fact, the laws of conservation of momentum and energy are obeyed. .... However the above description may not be very satisfactory? !

At the 50th Joint Propulsion Technology Conference in July 2014, NASA scientists reported that test results showed that the RF resonant cavity thruster design, which is unique as an electronic propulsion device, produced thrust that could not be attributed to any classical electromagnetic phenomenon. D. Brady et al. note that NASA's tests were conducted on 8 August 2013, using a resonant cavity excited at 935 MHz to generate (30-50) mN of thrust on a low thrust torsion pendulum placed in a stainless steel vacuum chamber designed and built by NASA. Brady et al. suggest that one possible explanation for this type of propulsion is that it is caused by the interaction of quantum vacuum virtual plasma, which provides this anomalous thrust production from the RF test device. In this understanding, the purpose of the experimental activity at NASA was "to investigate the feasibility of using classical magnetic plasma dynamics to obtain propulsive momentum generated by quantum vacuum virtual plasma conversion". The microwave engine (called EM drive by Shawyer) under study was called the "quantum vacuum virtual plasma thruster" by Brady et al. These views are for reference. Whether the EM drive is relevant to quantum theory is a big question!

In conclusion, EM drive technology is now widely accepted. The acceleration and reaction forces generated in the opposite direction of the propulsive force obey Newtonian mechanics. In 2015, Zhixun Huang<sup>[66]</sup> says that thrusts of 10mN/kW to 1000mN/kW can already be generated. The basic device is a cone-shaped closed resonant cavity, using the TE<sub>01</sub> model. Due to the non-uniform field distribution in the cavity, the electromagnetic ensemble force  $F_E \neq 0$  provides the thrust for the autonomous accelerated motion of the cavity. It carries no fuel and the microwave

energy used in the thrusters is converted from solar energy, making it suitable for space flight. 88mN force was generated by Shawyer in June 2006 with 700W power and 96mN force was generated in May 2007 with 300W power. This shows that the (125-320)mN/kW level was reached early on. The force is small, but with force comes acceleration and the process of constant acceleration promises to eventually achieve very high speed.

It is important to note that the Chinese Academy of Space Technology (CAST) has been focusing on the development of this field since 2010, and has started to achieve results since 2012 with the independent development of several principle prototypes. After 10 years of effort, the team led by researcher Chen Yue has developed two innovative thrusters, one of which is a trapezoidal resonant cavity type (partially filled with dielectric inside); the other is a hemispherical thruster. They have both been granted patents recognised by the Chinese government. So, Chinese research is leading the way!

But we must not be blindly optimistic: for the EM drive to be practical, the thrust has to increase significantly (e.g. to several hundred N/W or more) and the acceleration has to be sufficient (e.g.  $0.5\text{m/s}^2$  or more) to make it possible for it to become an interstellar probe. In any case, the space community can do real research and development on the EM drive; it is much better than the unrealistic talk of the Warp drive.

## 9 Conclusion

In the 1990s, NASA proposed the Breakthrough Propulsion Physics Program, a revolutionary change in propulsion design principles. Alcubierre's Warp drive concept is also being looked at by NASA. In addition, the US Department of Defense Advanced Research Projects Agency (DARPA) has commissioned NASA to carry out research with the following objectives: to achieve propellant-less propulsion; to require very high speeds; to switch on completely new physics principles; etc. Even if the proposed solutions are not achievable for the time being, "new concept designs" are welcome. With organised encouragement, many new ideas emerged, for example.

- The use of a microwave resonant cavity that generates thrust after the injection of microwave energy (EM drive).

- Taking advantage of the general relativistic effect (Warp drive).

- Taking advantage of the Mach effect (e.g. J. Woodward, University of California, USA, designed and invented the thruster).

- Designing space propulsion using the BB effect (Biefeld Brown effect) is the use of high voltage electric fields.

- Utilizing the Plasma drive.

- Utilizing the quantum vacuum<sup>[67]</sup>, or quantum fluctuations<sup>[68]</sup>.

So on and so forth. In short, all kinds of physical principles can be considered for their practicality before deciding whether to invest in research and development or for information purposes only.

Although I have written this paper, my academic views remain unchanged and I still disagree

with GR's "spacetime integration" and "spacetime curvature". For example, one of the diagrams drawn in many current books (including Hawking's work) to illustrate the wormhole principle shows only "extremely curved space", not "extremely curved spacetime". The latter cannot be drawn because there is no physical image of the so-called spacetime. Even if GR were the correct theory, wormholes and Warp drive propulsion would not be possible. This article points out that EM drive is the project that the national space communities can actually engage in R&D on!

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