Hyper Fast Interstellar Travel Within General Relativity:The Alcubierre and Natario Warp Drive Spacetimes:From Science Fiction to Science Fact

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Hyper Fast Interstellar Travel Within General Relativity:The Alcubierre and Natario Warp Drive Spacetimes:From Science Fiction to Science Fact

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Abstract

Warp Drives are solutions of the Einstein Field Equations that allows superluminal travel within the framework of General Relativity.There are at the present moment two known solutions: The Alcubierre warp drive discovered in 1994 and the Natario warp drive discovered in 2001.The warp drive seems to be very attractive because allows interstellar space travel at arbitrarily large speeds avoiding the light speed limit,time dilatation and mass increase paradoxes of Einstein Special Relativity.This is an introductory article without mathematics written for the general public outlining a brief resume of the "status quo" of the warp drive science from an Historical perspective.We cover the 3 major obstacles raised by modern science against the physical integrity of the warp drive as a dynamical spacetime that can carry a ship at faster than light speeds.We show using a clear and accessible language that the Natario warp drive emerges as a "winner" against all the 3 obstacles and can be regarded as a valid candidate for faster than light space travel.Our goal in writing a non-technical paper on this subject is to captive the interest of potential common readers that might would appreciate this subject avoiding the details of complex mathematical explanations.

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1 Preface

The idea behind this work came from a request made by a fan of the science fiction series Star Trek.

The concept of the warp drive as a dynamical spacetime that carries a starship(Enterprise) at speeds much faster than the speed of the light was invented by the writer Eugene Wesley Roddenberry(the creator of Star Trek)[1] as a scientific conjecture to explain how starships could perhaps travel faster than the speed of the light avoiding the limitations of Einstein Special Relativity and the warp drive appeared in Star Trek in 1966 for the first time.

Almost forty years later two mathematicians Miguel Alcubierre and Jose Natario discovered that the warp drive as concept of a dynamical spacetime that carries a spaceship at superluminal speeds is not only science fiction but it is also supported by a serious and strong mathematical background and it is possible that maybe someday it will become a science fact.

Both Alcubierre and Natario named their theories as warp drives due to the resemblance between their mathematical formalisms and the Star Trek original idea of the warp drive.

A Star Trek fan came with the idea of a work that although non-mathematical such a work could explain in terms accessible to the general public the scientific developments of both Alcubierre and Natario about the warp drive as a dynamical spacetime that allows faster than light space travel however using a rigorous scientific criteria[2][3][4] and written in a language accessible to be read by everybody in order to promote enthusiasm by the warp drive theory among the general public and mainly among the community of Star Trek fans.

Such a fan outlined the important fact that there exists by now a great number of people among the Star Trek community that already became aware of the existence of both Alcubierre and Natario theories and these people might have interest to know more about these developments but avoiding the complicated mathematics behind the warp drive theory.

This work is an answer to a request made by a Star Trek fan.

Live Long..And Prosper

[1] see Wikipedia:The Free Encyclopedia

[2] For experienced readers:pay close attention to the footnotes.

[3] in order to make this text accessible to the general public we omitted or simplified some physical facts

[4] the correct explanation for the omitted or modified facts appears in the footnotes

2 Introduction:Einstein and the Light Speed Barrier

In 5 December 2011 NASA announced the confirmation of the discovery of the planet Kepler-22 by the Kepler Space Telescope.[5].This was a remarkable discovery because Kepler-22 is the first known planet orbiting the habitable zone of a Sun-like star and since this planet is $2,4$ times bigger than Earth in size and also have a gravitational field $2,4$ times stronger than the one of the Earth this planet can retain an atmosphere and perhaps oceans suited to harbor life.

However if we want to send a spaceship to Kepler-22 we will face a major problem:the distance between Kepler-22 and Earth is 600 light years.Electromagnetic waves the fastest thing we know takes 600 years to cover this distance.So sending a spaceship with astronauts to see if life exists there is actually impossible for our science because we cannot travel faster than the speed of the light.And the reason is the so-called Einstein light speed limit of Special Relativity.

In 1905 Einstein published his Special Relativity and this theory forbids faster than light motion.Light speed is the ultimate barrier,the ultimate speed in the Universe.No superluminal velocities are allowed.Let us explain why this happens.

Imagine that you are driving a car with a speed of 10 kilometers per hour and you collide with a wall.Perhaps in the collision you will suffer nothing except for some little damages in the car painting.
Now consider the same collision with the same wall but with a speed of 300 kilometers per hour.The car will probably be destroyed and you will die:Why?? Objects in motion have the so-called kinetic energy which means to say the energy due to the motion speed.At 10 kilometers per hour a collision is not dangerous but at 300 kilometers per hour the collision is lethal.And one more thing:in order to achieve a speed of 300 kilometers per hour you must accelerate the car burning gasoline which means to say you must give energy to the car.This energy is the kinetic energy

But due to the equivalence between mass and energy as demonstrated by Einstein kinetic energy means kinetic mass so a body at high speeds weights more than the same body at the rest.A car at a speed of 300 kilometers per hour weights more than the same car at 10 kilometers per hour. As fast a body is accelerated as higher the kinetic energy becomes and the body becomes more and more heavier demanding more energy to accelerate to even more fast speeds making this process more difficult. Since the Einstein equivalence between mass and energy is directly proportional to the square of the light speed this means to say that as closer to the light speed you approaches the speed of an object this object acquires an immense kinetic energy and an immense weight and if you want to get more closer to the light speed more and more energy is needed to impulse this immense weight making this process even more difficult because this energy would imply in more mass and would add more weight to the object..Ad Infinitum.

You would need an infinite amount of energy to reach the light speed and infinite amounts of energy are physically impossible.

[5]see Wikipedia The Free Encyclopedia

Then if you cannot reach the light speed then you cannot surpass it.This means to say that a manned trip from Earth to Kepler-22 would demand at least more than 600 years to be completed making this mission an impossible mission.[6]

This was the scenario depicted by Einstein Special Relativity of 1905.Interstellar space travel is impossible!!!.Well not really: In 1916 Einstein published a second theory of Relativity:The General Relativity and this theory admits a family of mathematical solutions that allows faster than light space travel.

This family of solutions was discovered by two brilliant mathematicians:Miguel Alcubierre from Mexico and Jose Natario from Portugal and because both Alcubierre and Natario in the development of their theories took inspiration from Star Trek this family of mathematical solutions of the Einstein field equations of General Relativity that allows faster than light space travel is simply called:The Warp Drive

[6]unless we place the astronauts in cryogenic hibernation but we dont know the effects of the low temperatures in human tissues in long exposures for a period of more than 600 years etc etc etc.And what happens if the cryogenic system fails in the middle of the trip????

3 The Warp Drive:Hyper Fast Interstellar Travel Within General Relativity:Miguel Alcubierre and Jose Natario

The warp drive as a solution of the Einstein Field Equations of General Relativity that would theoretically "allow" to travel faster than light was discovered by the Mexican mathematician Miguel Alcubierre from Universidad Nacional Autonoma de Mexico(UNAM)in 1994. He in that year published a revolutionary paper called "The Warp Drive:Hyperfast Travel Within General Relativity". The warp drive as conceived by Alcubierre was a bubble of spacetime with a spaceship inside the bubble at the rest with respect to its local spacetime system of reference feeling no g-forces and no accelerations that otherwise would destroy the ship concerning faster than light velocities and the bubble would be at the rest with respect to the outside Universe.Spacetime behind the bubble would expand moving away from the spaceship the departure point(Earth) and spacetime would contract in the front of the bubble bringing to the ship the destination point(Kepler-22) in a way the resembles a moving sidewalk.In a moving sidewalk the departure point is being moved away from an user and the destination point is moving closer to the user.A spaceship inside a warp drive would be able to attain large superluminal velocities effectively travelling faster than light.(see abs and pg 8 in [1] and pg 34 after eq 179 in [4]).

Seven years later another paper on the warp drive appeared. In 2001 the Portuguese mathematician Jose Natario from Instituto Superior Tecnico(IST) conceived a warp drive that do not expands or contracts.The ship is still immersed in a warp bubble and this bubble is carried out by the spacetime "stream" at faster than light velocities with the ship at the rest with respect to its local neighborhoods inside the bubble feeling no g-forces and no accelerations. Imagine an aquarium floating in the course of a river with a fish inside it...the walls of the aquarium are the walls of the warp bubble...Imagine that this river is a "rapid" and the aquarium is being carried out by the river stream...the aquarium walls do not expand or contract...an observer in the margin of the river would see the aquarium passing by him at an arbitrarily large speed but inside the aquarium the fish would be protected from g-forces or accelerations generated by the stream...because the fish would be at the rest with respect to its local spacetime coordinates system inside the aquarium.Jose Natario in 2001 wrote the revolutionary paper called "Warp Drive with Zero Expansion".The Natario warp drive is carried out by the spacetime stream just like a fish in the stream of a river.(See abs and pg 1 in [2],see also pg 5 in [2] for a mention to fluid mechanics.Natario dealt with the spacetime hydrodynamically).

This was a radical new concept of velocities.Before 1994 we knew only impulse velocities that needs kinetic energy to accelerate objects and these velocities are associated to the object being moved.It is the object that moves itself with a kinetic energy that implies in more mass and more energy to be accelerated resulting in more weight as the object approaches the light speed never achieving this one due to the light speed limit as seen in the previous section and this object is in motion inside a static spacetime geometry that do not moves at tll.

After 1994 a new concept of velocity appeared.The so-called warp velocity in which the object do not moves at all staying at the rest and in complete safety inside the so-called warp bubble and the spacetime geometry itself around the body moves away from the object the departure point and moves closer to the object the destination point.So in warp the object do not moves at all there are no kinetic energies that would make the body heavier so there are no light speed limits and it is the spacetime geometry that moves itself around the body.

Now we can understand why the warp drive allows faster than light space travel:The speed of motion of the spacetime geometry is not constrained by the light speed limit and can achieve arbitrarily large values(see pg 1 and 2 in [3] and pg 1 in [11]) and objects inside the warp bubble wether in Alcubierre or Natario warp drives do not moves at all so there are no kinetic energies resulting from the acceleration of the objects and no light speed limits.

In order to proceed to the next section two things must be made clear:

- 1)-In impulse speeds the spacetime geometry is static the spacetime do not moves at all and is the object((spaceship) that moves itself through the spacetime.The light speed limit is valid.
- 2)-In warp speeds the spacetime geometry is dynamic and moves itself around the warp bubble.The warp bubble acts as a protective "cocoon" that accommodates the object(spaceship) at the rest inside the bubble and the spacetime geometry transports the bubble from the departure point to the destination point with the object(spaceship) inside. The spacetime geometry moves around the bubble at arbitrarily large speeds not restrained by the speed of light and the object(spaceship) remains at the rest inside the bubble and do not moves at all.The light speed limit is not valid.

However the warp drive in order to pass from science fiction to science fact must solve 3 problems encountered by the science after the analysis of both Alcubierre and Natario ideas.

These problems are:

- 1)-Large amounts of negative energy needed to generate the warp bubble
- 2)-Collision with hazardous objects that may harm the ship(asteroids or comets) in a realistic interstellar spaceflight at superluminal speeds
- 3)-Horizons:Causally disconnected portions of spacetime(the warp bubble cannot be controlled by an astronaut from inside the bubble)

We will examine these problems in the next sections..and the possible solutions for the problems 1,2...and 3!!!.

4 Negative Energy in both Alcubierre and Natario Warp Drive Spacetimes

We have seen so far in the precious section the differences between the impulse velocity and the warp velocity.An object(a spaceship) inside a warp bubble do not moves at all and it is the spacetime geometry around the bubble that moves itself carrying the bubble from the departure point (Earth)to the destination point(Kepler-22)(Natario case) or moves away from the bubble the departure point(Earth) and moves close to the bubble the destination point(Kepler-22) while the bubble is at the rest(Alcubierre case)

Lets review the Natario example of the fish and the aquarium from the previous section.The spaceship is the fish and the aquarium is the warp bubble.The stream of a river carries the aquarium with the fish inside and in the same way the spacetime stream carries the warp bubble with the spaceship inside.

So there are three positions where an observer watching this situation can be placed:

- 1)-Inside the bubble:the region where the ship(or a fish) resides completely at the rest with respect to its local neighborhoods.
- 2)-Outside the bubble:the region where a faraway external observer(the rest of the Universe or an observer in the margin of the river) resides watching the bubble(or the aquarium) passing by him at large speeds
- 3)-In the warp bubble walls:the physical boundary limits of the bubble itself.corresponds to the glass in the walls of the aquarium

Graphical or artistic presentations of the Natario warp bubble are available at pg 7 fig 1 in [2] where the interior and exterior regions of the bubble are depicted or fig 2 pg 18 in [15] where a spaceship is depicted inside the bubble.The blue ring depicts the walls of the warp bubble

An artistic presentation of the Alcubierre warp bubble depicting the regions inside and outside the bubble with a spaceship inside the bubble can be seen at fig 2 pg 4 in [12].

Now it is time to ask a fundamental question:How is the warp bubble created in the first place??

The ordinary spacetime of our everyday lives is a "flat" spacetime geometry that do not moves at all by itself.However Einstein General Relativity allows curved or distorted spacetime geometries if we can generate the needed mass-energy configurations that will distort the spacetime geometry according to our needs.If we want a certain spacetime geometric configuration we need to generate a distribution of mass and energy specially tailored for the needed configuration.At least this is already possible...in mathematics.

So mathematically both Alcubierre and Natario generated their mass-energy configurations that distorted the ordinary spacetime "flat" geometry according to their needs generating the warp bubbles for each case and placing the spacetime geometry in motion around their warp bubbles and with spaceships at the rest inside their warp bubbles.

In order to do so both Alcubierre and Natario used mathematical structures called shape functions.The shape function is the responsible for the warp drive "miracle".By generating a shape function a ship creates the warp bubble around itself and triggers the motion of the spacetime geometry around the bubble while the ship remains at the rest inside the warp bubble.So it is the shape function that will trigger the warp "jump".Artistic presentations of the warp "jump" are depicted in fig 2 pg 35,fig 3 pg 36 and fig 4 pg 37 in [16]

We still dont know how to generate the shape functions from an experimental point of view.Mathematically the Alcubierre shape function can be seen in eq 6 pg 4 in [1] and the Natario shape function can be seen in eqs 74 and 75 pg 13 in [16].

Since the shape functions are the responsible for the warp drive "miracle" we need to examine in-depth the behavior of the shape functions:

Inside the bubble and outside the bubble the value of the shape functions for both Alcubierre and Natario warp drive spacetimes is always constant the shape functions never changes its values so we dont need to worry about this situation.Both shape functions have constant or fixed values[7]

For a curious reader:

- 1)-In the Alcubierre case the value of the shape function is always 1 inside the bubble and always 0 outside the bubble.(see eq 7 pg 4 in [1])
- 2)-In the Natario case the value of the shape function is always 0 inside the bubble and always $\frac{1}{2}$ outside the bubble(see pg 5 in [2]).

In the walls of the warp bubble in both Alcubierre and Natario cases the shape functions varies with different positions taken from different points inside the walls which means to say that the shape functions changes its values and we must analyze this situation because in this case the shape functions dont have constant or fixed values.

For a curious reader:

- 1)-In the Alcubierre case the value of the shape function in the warp bubble walls is always between 1 and 0.The shape function in this case change its value between these boundaries when crossing the walls of the warp bubble.This region is known as the Alcubierre warped region.
- 2)-In the Natario case the value of the shape function in the warp bubble walls is always between 0 and $\frac{1}{2}$. The shape function in this case change its value between these boundaries when crossing the walls of the warp bubble. This region is known as the Natario warped region.

The rate of change of the value of a function in a given point its called the derivative in that point.[8]If a function have constant or fixed values in a given point then the derivative of the function in this point is 0.

[7]remember that this work is being written for non-experienced readers so we are trying to be as clear as possible

[8]remember again that this text is being written for the general public with little to none background in mathematics so we need to introduce here the concept of the derivative of a function and in this case the derivative of the shape function

The derivatives of the shape functions for both Alcubierre and Natario warp drive spacetimes are 0 inside and outside the bubble but are not zero in the warp bubble walls.[9]

Now we are ready to address the problem of the negative energy in both Alcubierre and Natario warp drive spacetimes.As seen before a certain configuration of the spacetime geometry corresponds to a certain distribution of mass-energy specially tailored to generate it.In the case of both Alcubierre and Natario warp drive spacetimes the mass-energy configuration that generates the geometry of the warp drive spacetime is negative and violates all the known energy conditions.This was stated by both Alcubierre and Natario themselves.(see pg 8 after eq 19 and pg 9 in [1] and pg 1 and 3 in [2])

And to make the things even worst:This negative energy density in both Alcubierre and Natario warp drive spacetimes is directly proportional to the square of the speed of the bubble which means to say that as fast as the bubble goes by then more and more amounts of negative energy are needed to sustain the bubble speed.Also this negative energy in both cases is directly proportional to the square of the light speed.[10]

But the most important point here is the fact that in both cases the negative energy is directly proportional to the square of the derivatives of the shape functions.Mathematical expressions for the negative energy in the Alcubierre case can be seen in pg 8 eq 19 in [1] and eqs 9 and 10 pg 3 in [6]. Mathematical expressions for the negative energy in the Natario case can be seen in pg 5 in [2] and eqs 23 and 24 pg 6 in [6]. The negative energy is concentrated in the regions where the derivatives of the shape functions are not 0 which means to say that the negative energy is concentrated on the walls of the warp bubble.

Now we can illustrate the difficulties generated by the negative energy problem in both Alcubierre and Natario warp drive spacetimes using a language a common reader can understand:Imagine that we want to visit the nearby star Vega at 26 light-years away in a trip of 2 months.We would need to attain a bubble velocity at least 200 times faster than light. But light speed have a value of 300.000 kilometers per second and 1 kilometer are 1000 meters.So the light speed in meters per second is 300.000.000 .A number with 8 zeros.In science there exists a way to write this number avoiding the huge number of zeros:it is called the scientific notation[11].So the value of the light speed is 3×10^8 meters/second.The square of the light speed would then be 9×10^{16} $meters^2/second^2$.A bubble speed of about 200 times faster than light(2×10^2) in scientific notation would be given by $2 \times 10^2 \times 3 \times 10^8 = 6 \times 10^{10}$ meters/second.

The square of the bubble speed would then be 36×10^{20} $meters^2/second^2$ but the number is more correctly written as $3,6 \times 10^{21}$ $meters^2/second^2$. So for a bubble speed of 200 times faster than light the negative energy density is directly proportional to a number with 21 zeros!!!.

The mass of the Earth is $5,9 \times 10^{24}$ kilograms[12] and 1 ton is 1000 kilograms.So the mass of Earth in tons is 5×10^{21} tons. So the negative energy in this case is directly proportional to a number with the same magnitude of the mass of Earth in tons!!

[9]For experienced readers:the derivatives of the original shape functions for both Alcubierre and Natario spacetimes are not zero but the values are so small that inside and outside the bubble these values can be neglected

[10]For experienced readers:we will neglect the effects of the gravitational constant in this presentation since for non-technical readers the speed of the bubble and the light speed are enough to illustrate our purposes

[11]remember that this work is being written for non-experienced readers so the scientific notation is important

[12]see Wikipedia:The Free Encyclopedia

So in order for a spaceship to attain a speed of 200 times faster than light in order to visit Vega at 26 light-years away in a journey of a couple of months the negative energy density is directly proportional to the magnitude of the mass of the Earth in tons!!!Directly proportional to the mass of an entire planet!!!!

No laboratory in the world can generate the mass of a planet[13]!!!!.
And the scenario will become even worst because the negative energy density is not only directly proportional to the square of the speed of the bubble which is a number with 21 zeros in our case of Vega but also directly proportional to the square of the speed of the light which is a number with 16 zeros!!!!.

So we must multiply the square of the speed of the bubble which is $3,6 \times 10^{21}\ meters^2/second^2$ by the square of the speed of the light $9 \times 10^{16}\ meters^2/second^2$.

Working only with the powers of 10.The total magnitude of the negative energy density in order to attain a speed of 200 times faster than light in order to reach Vega is directly proportional to 10^{21} but also directly proportional to 10^{16} so we must multiply these numbers giving a result of 10^{37} a number with 37 zeros[14]!!!!

Lets illustrate the immense magnitude of a number with 37 zeros: Our galaxy the Milky Way have 100 billion stars.[15]100 billion stars is 100.000.000.000 stars.In scientific notation is 10^{11}. Not all the stars in our galaxy have a planet with the mass of the Earth but lets imagine that every star in our galaxy have a planet like the Earth.So in our galaxy we have 10^{11} Earths(one hundred billion Earths)!!!! and each Earth with a mass of 10^{21} tons!!!.We could multiply these numbers to find the total mass of all the Earths in our galaxy in tons but the real magnitude of the negative energy density to attain a speed of 200 times faster than light is not $10^{21} \times 10^{11} = 10^{32}$ but is $10^{21} \times 10^{16} = 10^{37}$.

But since the Universe have billions of galaxies we can select a number of 100.000 galaxies(one hundred thousand galaxies) similar to our Milky Way and consider that each galaxy have a planet like the Earth around every star.So we are selecting 10^5 galaxies each one with 10^{11} Earths and each Earth weights 10^{21} tons!!!!

So we are left with $10^{21} \times 10^{11} \times 10^5 = 10^{37}$ which is equal to $10^{21} \times 10^{16} = 10^{37}$.

Then the total amount of negative energy in both Alcubierre and Natario warp drive spacetimes needed to attain a speed of 200 times faster than light in order to visit Vega at 26 light-years away in journey of a couple of months is directly proportional to the magnitude of one hundred thousand galaxies (100.000 galaxies) each galaxy with one hundred billion Earths (100.000.000.000 Earths) each Earth weighting 1.000.000.000.000.000.000.000 tons!!!!Each Earth weighting 1 sextillion tons!!!![16] The number that represents the total magnitude of the negative energy density for 200 times faster than light is: 10.000.000.000.000.000.000.000.000.000.000.000.000 in tons!!!! This number is impossible to be achieved by any present or future technology.

[13]the mass of a planet will always be heavier than the mass of the laboratory equipments that will generate the negative energy density independently of present or future technologies

[14]the scenario is even worst.we neglected deliberately the gravitational constant because this is a presentation for non-technical readers.the correct figure is 10^{48}!!.a number with 48 zeros.the correct estimates can be seen in pg 8 in [10],pg 4 in [9] and pg 3 in [6]

[15]see Wikipedia:The Free Encyclopedia

[16]billion,trillion,quatrillion(4),quintillion(5),sextillion(6)

And note that 200 times faster than light is not enough to reach Kepler-22 at 600 light-years away.At this speed we would need 3 years to complete the trip and this is not practical.[17][18][19].

In order to reach Kepler-22 in a reasonable amount of time we would need to attain speeds of about 4000 times to 6000 times faster than light but if we cannot even generate the magnitude of the energy density for 200 times faster than light then we can forget the whole story because faster then light space travel is still impossible wether in the Alcubierre or the Natario warp drive spacetimes!!!!!

Well!!:Not exactly.Unfortunately the square of the speed of the bubble and the square of the light speed are there in the negative energy density equations of both Alcubierrr and Natario warp drive spacetimes and these factors are there to stay.

But fortunately the square of the derivative of the shape function is also in the equations of the negative energy density in both Alcubierre and Natario warp drive spacetimes and the shape function is the responsible for the warp drive "magic".

In the next section we will show how to obliterate these huge numbers resulting from the bubble and light speeds using mathematically tools and techniques applied to the shape function in order to obtain "low" and "affordable" magnitudes of negative energy for both Alcubierre and Natario warp drive spacetimes and again we will use a language accessible to the general public.

The "magic" of the shape function will allow ourselves to pass both Alcubierre and Natario warp drive spacetimes from science fiction to science fact...at least in mathematics!!!!!!

[17]the human body cannot withstand more than a year in space in the absence of gravity otherwise the bones will loose the calcium.a ship can of course generate artificial gravity but then this would imply in a gravity generator and such a device would demands lots of energy too and this generator would have to work for a period of 3 years.

[18]another problem:we mentioned before the fact that long exposures effects of human tissues to low temperatures are unknown so the cryogenic hibernation is not an option.the ship must leave the Earth with all the food supplies for a journey of 3 years since as far as we know in interstellar space there are no gas stations and no highway diner's restaurants with extra-terrestrials eating cheeseburgers.

[19]assuming a future starship with the size of the Star Trek Enterprise the Enterprise is composed by a number of 400 crew members.so in this case the ship should provide food and supplies for 400 people during 3 years!!!not practical at all!!

5 Reduction of the Negative Energy Density Requirements in both Alcubierre and Natario Warp Drive Spacetimes.

In the previous section we presented the shape functions as the mathematical "magic" tool that turns possible both Alcubierre and Natario warp drive spacetimes.

Lets review the basic properties of the shape functions:

Inside the bubble and outside the bubble the value of the shape functions for both Alcubierre and Natario warp drive spacetimes is always constant the shape functions never changes its values so we dont need to worry about this situation.Both shape functions have constant or fixed values so the derivatives of the shape functions inside and outside the bubble are zero in both cases.[20]

- 1)-In the Alcubierre case the value of the shape function is always 1 inside the bubble and always 0 outside the bubble.(see eq 7 pg 4 in [1])
- 2)-In the Natario case the value of the shape function is always 0 inside the bubble and always $\frac{1}{2}$ outside the bubble(see pg 5 in [2]).

In the walls of the warp bubble in both Alcubierre and Natario cases the shape functions varies with different positions taken from different points inside the walls which means to say that the shape functions changes its values and we must analyze this situation because in this case the shape functions dont have constant or fixed values.The derivatives of the shape functions in this case are not zero.

- 1)-In the Alcubierre case the value of the shape function in the warp bubble walls is always between 1 and 0.The shape function in this case change its value between these boundaries when crossing the walls of the warp bubble.This region is known as the Alcubierre warped region.
- 2)-In the Natario case the value of the shape function in the warp bubble walls is always between 0 and $\frac{1}{2}$. The shape function in this case change its value between these boundaries when crossing the walls of the warp bubble. This region is known as the Natario warped region.

One more important thing:the original shape functions of both Alcubierre and Natario warp drive spacetimes and its derivatives are dimensionless.Both can possesses integer or fractionary values but no physical dimensions in meters or seconds etc.[21][22][23]

[20]For experienced readers:the derivatives of the original shape functions for both Alcubierre and Natario spacetimes are not zero but the values are so small that inside and outside the bubble these values can be neglected

[21]For experienced readers:the parameter @ in the original shape functions of both Alcubierre and Natario warp drive spacetimes is dimensionless.This can be seen in pg 9 in [9].

[22]Plot an Alcubierre shape function with rs varying from 0 to 150 meters for example and a bubble radius R of 100 meters and an Alcubierre dimensionless parameter @ = 400.The Alcubierre warped region will starts at $rs = 99,96$ meters and will end at $rs = 100,03$ meters.

[23]The derivatives of the Alcubierre shape function with the Alcubierre parameter @ dimensionless can be seen in eqs 18 and 19 pg 7 in [9].

It will be the non-dimensionality of the derivatives of the shape functions that will allow ourselves to overcome the negative energy density problem in both Alcubierre and Natario warp drive spacetimes.[24][25]

In order to give an explanation accessible to the general public about how the negative energy density requirements can be lowered we will use the Alcubierre warp drive spacetime as an illustrative example but this line of reason also works for the Natario warp drive spacetime[26][27][28]

We already know that the negative energy density in both Alcubierre sand Natario warp drive spacetimes is directly proportional to the square of the bubble speed and directly proportional to the square of the light speed.

And we also know from the previous section that for a speed of 200 times faster than light the negative energy density is directly proportional to 10^{37} while the mass of the Earth in "only" 10^{24} in kilograms.So the negative energy density for a speed of "only" 200 times faster than light is directly proportional to something with the magnitude of the combined masses of 10^{13} planet Earths!!!!.Or better:directly proportional to something with the magnitude of the combined masses of 10.000.000.000.000 planet Earths!!!.The negative energy density for a speed of 200 times faster than light is directly proportional to ten trillion times the mass of the planet Earth!!!!.Such amount of energy is impossible to be generated by any known(or still unknown) physical process.!!!!

And remember that such a speed is not enough to reach Kepler-22 at 600 light-years away.

But fortunately the negative energy density is also directly proportional to the square of the derivatives of the shape function.This means to say that we must multiply 10^{37} by the square of the derivative of the shape function.

What happens when we multiply 10^{37} by zero????The result is zero!!!!.

Because any number multiplied by zero will give zero as a result!!!!

So if we can use shape functions that will produce very low derivatives with values close to zero($\cong 0$) then their derivative squares will be even close to zero and multiplying 10^{37} by a number close to zero will give a negative energy density that will be close to zero and not ten trillion times the mass of the planet Earth.

$(10^{37} \times derivativesquare \cong 0)$ if and only if $(derivativesquare \cong 0)$.

[24]For experienced readers:the shape functions presented in eq 4 pg 3 in [5],eq 9 pg 5 in [7] and eq 9 pg 5 in [8] are dimensionless but their derivatives are not.These works must be re-examined.

[25]For experienced readers:we consider only analytical shape functions.see our comment on analytical functions pg 3 in [10]

[26]see pg 8 in [6].

[27]remember that [6] mentions the Alcubierre parameter @ as a dimensional parameter in meters but we actually know that the parameter @ is dimensionless.

[28]withdrawing the word "meters" from the parameter @ the conclusions of [6] are correct.

An important question must be made here:

- 1)-How can we produce (at least mathematically)shape functions with very low derivatives close to zero in order to obliterate the enormous factor 10^{37}???

We already know that the value of the Alcubierre shape function is 1 inside the bubble 0 outside the bubble and between the limits of 1 to 0 inside the Alcubierre warped region.Hence $0,5$ is a value of the shape function taken inside the warped region(warp bubble walls)

We already outlined the important fact that the shape function and its derivatives are dimensionless.[29][30][31]

So what would happen if we could raise the Alcubierre shape function to a power factor????Since we are dealing with a speed 200 times faster than light we can analyze the behavior of the Alcubierre shape function raised to a power of 200 as an integer number.The Alcubierre shape function raised to a power of 200 is a new shape function.

- 1)-Inside the bubble:the value of the old shape function is 1 so $1^{200} = 1$.the new shape function retains the same behavior when raised to a power.
- 2)-Outside the bubble:the value of the old shape function is 0 so $0^{200} = 0$.the new shape function retains the same behavior when raised to a power.
- 3)-In the warp bubble walls:the Alcubierre warped region.in this region the old shape function reaches fractionary values between 1 and 0.

A value of $0,5$ for the old shape function is a value inside the Alcubierre warped region.What happens if we raise $0,5$ to a power of 200 ???.We get the corresponding value for the new shape function inside the same point in the Alcubierre warped region.

Raising $0,5$ to a power of 200 means to raise $\frac{1}{2}$ to a power of 200 or better:

$$[\frac{1}{2}]^{200} = \frac{1^{200}}{2^{200}} = \frac{1}{2^{200}} \tag{1}$$

since $1^{200} = 1$.

The number 2^{200} is enormous:its value is $1,61 \times 10^{60}$ a number with 60 zeros!!!!The mass of the Earth is $5,9 \times 10^{24}$ in kilograms.A number with "only" 24 zeros!!!

But we are raising $\frac{1}{2}$ to a power of 200 which means to say that the result is 1 divided by 2^{200} or better:we are dividing 1 by the huge number $1,61 \times 10^{60}$ and the result of this division is a number very small.

The result of $\frac{1}{2}$ raised to a power of 200 is $6,22 \times 10^{-61}$ a number much smaller than $\frac{1}{2}$ or better:a number much smaller than 5×10^{-1}.

[29]For experienced readers:the parameter @ in the original shape functions of both Alcubierre and Natario warp drive spacetimes is dimensionless.This can be seen in pg 9 in [9].

[30]Plot an Alcubierre shape function with rs varying from 0 to 150 meters for example and a bubble radius R of 100 meters and an Alcubierre dimensionless parameter @ = 400.The Alcubierre warped region will starts at $rs = 99,96$ meters and will end at $rs = 100,03$ meters.

[31]The derivatives of the Alcubierre shape function with the Alcubierre parameter @ dimensionless can be seen in eqs 18 and 19 pg 7 in [9].

So the old shape function have in a given point inside the Alcubierre warped region[32][33][34] the value of $\frac{1}{2}$ or 5×10^{-1} which is $\frac{1}{2}$ written in scientific notation.[35]

But the new shape function in the same point in the same Alcubierre warped region have the value of $6,22 \times 10^{-61}$ which is a value much smaller than the value of the original shape function.

And why??Because we are raising fractionary numbers to powers and a fractionary number raised to a power will produce a second fractionary number much but much smaller than the first one. Also note that both Alcubierre and Natario shape functions possesses fractionary values in their respective warped regions.And at last we are raising the Alcubierre shape function to a power of the modulus of the warp bubble speed!!!

Then we took the value of the original shape function inside the Alcubierre warped region (5×10^{-1}) and we raised this value to a power of an integer number which is exactly the modulus of the warp bubble speed (200 times faster than light) and we generated(mathematically of course) a second shape function with a new value of $(6,22 \times 10^{-61})$ which is 10^{60} times smaller than the original value.

Or better:the new value is 1.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000 times smaller than the original value[36]

We already illustrated before how big is the number 10^{37} using the mass of the planet Earth in kilograms.Now we will illustrate using a simple language accessible to the general public how small is the number 10^{-61}.

$$10^{-61} = \frac{1}{10^{61}} = \frac{1}{10.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000} \quad (2)$$

$$10^{-61} = \frac{1}{10^{61}} = 0,000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.000.01 \cong 0 \quad (3)$$

Note that from above this number is exactly what we are looking for:a number very close to zero ($\cong 0$) that can be used to obliterate the huge factor 10^{37}.

The mass of the electron(subatomic particle) possesses a value of about $9,11 \times 10^{-31}$ in kilograms.[37]

This means to say that the electron is nearly 10^{31} times lighter than a kilogram.

And the value 10^{-61} is 10^{30} times smaller than the value of the magnitude of the mass of the electron.

[32] exactly the center of the Alcubierre warped region

[33] plot the Alcubierre shape function with a radius $R = 100$ meters and an Alcubierre dimensionless parameter @ = 20.the Alcubierre warped region starts at 99 meters and ends at 101 meters.in the center of the Alcubierre warped region $R = 100$ meters and the shape function have a value of $\frac{1}{2}$ because 100 lies in the middle point between 99 and 101

[34] see pg 5 in [6]

[35] remember that this is being written for introductory readers

[36] billion,trillion,quadrillion,quintillion...the second value is a "twentillion" times smaller than the original value.

[37] see Wikipedia.The Free Encyclopedia

Now its time to review some topics:

- 1)-The negative energy density in both Alcubierre sand Natario warp drive spacetimes is directly proportional to the square of the bubble speed and directly proportional to the square of the light speed.
- 2)- For a speed of 200 times faster than light the negative energy density is directly proportional to 10^{37} while the mass of the Earth in "only" 10^{24} in kilograms.So the negative energy density for a speed of "only" 200 times faster than light is directly proportional to something with the magnitude of the combined masses of 10^{13} planet Earths!!!!.Or better:directly proportional to something with the magnitude of the combined masses of 10.000.000.000.000 planet Earths!!!.The negative energy density for a speed of 200 times faster than light is directly proportional to ten trillion times the mass of the planet Earth!!!!
- 3)-We took the value of the original shape function inside the Alcubierre warped region (5×10^{-1}) and we raised this value to a power of an integer number which is exactly the modulus of the warp bubble speed (200 times faster than light) and we generated(mathematically of course) a second shape function with a new value of $(6,22 \times 10^{-61})$ which is 10^{60} times smaller than the original value.
- 4)-The value 10^{-61} is 10^{30} times smaller than the value of the magnitude of the mass of the electron.
- 5)-The negative energy density is also directly proportional to the square of the derivatives of the shape function.This means to say that we must multiply 10^{37} by the square of the derivative of the shape function.

We raised the Alcubierre shape function to a power of the modulus of the bubble speed and generated a new shape function.Now we must analyze the behavior of the derivative of the new shape function which means to say the derivative of the original Alcubierre shape function when raised to a power.

If we have in a given point inside the Alcubierre warped region the value of $0,5$ for the original shape function then the corresponding value for the new shape function is:

$$[\frac{1}{2}]^{200} = \frac{1^{200}}{2^{200}} = \frac{1}{2^{200}} = 6,22 \times 10^{-61} \cong 0 \tag{4}$$

Since this presentation is for the general public we will omit some details.The derivative of the new shape function is:

$$200([\frac{1}{2}]^{199})x = 200(\frac{1^{199}}{2^{199}})x = 200(\frac{1}{2^{199}})x \tag{5}$$

since $1^{199} = 1$.We will deliberately neglect the term x.[38] [39] [40] The derivative of the new shape function is then given by:

$$200([\frac{1}{2}]^{199}) = 200(\frac{1^{199}}{2^{199}}) = 200(\frac{1}{2^{199}}) = 2,49 \times 10^{-58} \cong 0 \tag{6}$$

[38]For experienced readers:the term x is the derivative of the original Alcubierre shape function.

[39]it can be neglected in this public presentation.do not affect the final result when multiplied by 10^{-58}

[40]For experienced readers:although this presentation is for the Alcubierre warp drive for illustrative purposes we would recommend the complete mathematical details in pg 9 to pg 12 in [6] for the Natario warp drive

We already found the derivative of the new shape function as being:

$$200([\frac{1}{2}]^{199})x = 200(\frac{1^{199}}{2^{199}})x = 200(\frac{1}{2^{199}})x \tag{7}$$

We deliberately neglected the term x.[41] [42] [43][44][45]The derivative without this term is given by:

$$200([\frac{1}{2}]^{199}) = 200(\frac{1^{199}}{2^{199}}) = 200(\frac{1}{2^{199}}) = 2,49 \times 10^{-58} \cong 0 \tag{8}$$

Note that this derivative have a very low value 10^{-58} much close to 10^{-61}.Exactly what we are looking for in order to obliterate the factor 10^{37} since like 10^{-61} 10^{-58} is a value much close to zero($\cong 0$).

But we must outline an important thing:

- 1)-The negative energy density is directly proportional to the square of the derivatives of the shape function and not proportional to the derivative of the shape function.

The square of the derivative of the new shape function omitting some details since this presentation is for the general public is given by:

$$40000([\frac{1}{2}]^{398})x^2 = 40000(\frac{1^{398}}{2^{398}})x^2 = 40000(\frac{1}{2^{398}})x^2 \tag{9}$$

In scientific notation:

$$4 \times 10^5([\frac{1}{2}]^{398})x^2 = 4 \times 10^5(\frac{1^{398}}{2^{398}})x^2 = 4 \times 10^5(\frac{1}{2^{398}})x^2 \tag{10}$$

The term in x^2 will be neglected too.The square of the derivative of the new shape function is then given by:

$$4 \times 10^5([\frac{1}{2}]^{398}) = 4 \times 10^5(\frac{1^{398}}{2^{398}}) = 4 \times 10^5(\frac{1}{2^{398}}) = 6,20 \times 10^{-116} \cong 0 \tag{11}$$

The term 2^{398} is enormous,Its value is $6,46 \times 10^{119}$.A number with 119 zeros!!!!.Dividing 1 by 2^{398} we get the following value:$1,55 \times 10^{-120}$.This number is very small and about 10^{90} times smaller than the magnitude of the electron mass.Multiplying this number by 4×10^5 we get the final value for the square of the derivative of the new shape function which is $6,20 \times 10^{-116}$.

A number very close to zero ($\cong 0$)!!!!.

[41] For experienced readers:Why???because since the Alcubierre shape function is dimensionless and the Alcubierre parameter @ is also dimensionless then the derivative is dimensionless too.

[42] Alcubierre introduced the parameter @ between eqs 6 and 7 pg 4 in [1] but he said nothing about wether the parameter @ is dimensionless or not.

[43] Plot an Alcubierre shape function with rs varying from 0 to 150 meters for example and a bubble radius R of 100 meters and an Alcubierre dimensionless parameter @ = 400.The Alcubierre warped region will starts at $rs = 99,96$ meters and will end at $rs = 100,03$ meters.

[44] in the above case @ = 400 and not @ = 400 meters.

[45] The derivatives of the Alcubierre shape function with the Alcubierre parameter @ dimensionless can be seen in eqs 18 and 19 pg 7 in [9].

So the square of the derivative of the new shape function is:

$$4 \times 10^5([\frac{1}{2}]^{398}) = 4 \times 10^5(\frac{1^{398}}{2^{398}}) = 4 \times 10^5(\frac{1}{2^{398}}) = 6,20 \times 10^{-116} \cong 0 \tag{12}$$

But remember that previously we wrote the following statements:

- 1)-The negative energy density is directly proportional to the square of the derivatives of the shape function.This means to say that we must multiply 10^{37} by the square of the derivative of the shape function.
- 2)-If we can use shape functions that will produce very low derivatives with values close to zero($\cong 0$) then their derivative squares will be even close to zero and multiplying 10^{37} by a number close to zero will give a negative energy density that will be close to zero and not ten trillion times the mass of the planet Earth

The term $6,20$ like the terms x and x^2 can be neglected.[46]

Now its time to achieve our goal in our attempt to reduce the negative energy density in the Alcubierre warp drive spacetime:

The multiplication of the term 10^{37}(about the magnitude of the combined masses of 10^{13} planet Earths or ten trillion times the mass of the planet Earth resulting from a warp bubble speed of 200 times faster than light) by the term 10^{-116}(about 10^{85} times lighter than the mass of the electron resulting from a new shape function which is the original Alcubierre shape function raised to a power of the modulus of the bubble speed.In this case the Alcubierre shape function was raised to a power of 200).

The final estimative for the negative energy density in the Alcubierre warp drive spacetime with a speed of 200 times faster than light using the new shape function is:

$$10^{37} \times 10^{-116} = \frac{10^{37}}{10^{116}} = \frac{1}{10^{79}} = 10^{-79} \cong 0 \tag{13}$$

A number close to zero($\cong 0$)and not ten trillion times the mass of the Earth!!!.We get an estimative of the negative energy density of about 10^{-79} which is 10^{48} times lighter than the mass of the electron.!!!

So a new shape function based over the original Alcubierre shape function raised to a power of the modulus of the bubble speed enable ourselves to neutralize the huge amount of negative energy needs(ten trillion times the mass of the Earth!!!) to sustain a warp bubble with a speed 200 times faster than light using only a negative energy requirements of about 10^{48} times lighter than the mass of the electron.!!! allowing ourselves to pass the warp drive from science fiction...to science fact!!!!!

At least in mathematics!!!!!

[46]because the derivative of the Alcubierre shape function or the square of the derivative of the Alcubierre shape function or the term $6,20$ will not affect the final result when multiplied by 10^{-58} or 10^{-116} because these numbers are close to zero $\cong 0$

In order to close this section we need to review some basic properties of the Alcubierre and Natario shape functions.

- 1)-In the Alcubierre case the value of the shape function is always 1 inside the bubble and always 0 outside the bubble.(see eq 7 pg 4 in [1])
- 2)-In the Natario case the value of the shape function is always 0 inside the bubble and always $\frac{1}{2}$ outside the bubble(see pg 5 in [2]).
- 3)-In the Alcubierre case the value of the shape function in the warp bubble walls is always between 1 and 0.The shape function in this case change its value between these boundaries when crossing the walls of the warp bubble.This region is known as the Alcubierre warped region.The Alcubierre shape function possesses fractionary numbers in this region.
- 4)-In the Natario case the value of the shape function in the warp bubble walls is always between 0 and $\frac{1}{2}$. The shape function in this case change its value between these boundaries when crossing the walls of the warp bubble. This region is known as the Natario warped region.The Natario shape function possesses fractionary numbers in this region.
- 5)-A fractionary number raised to a power will produce fractionary numbers much smaller than the original number.

Note that we took the value of the new shape function in a point inside the Alcubierre warped region where the value of the original shape function is $\frac{1}{2} = 0,5$ and we raised it to a power of 200.We already know what happens when $(\frac{1}{2})^{200} = 6,22 \times 10^{-61} \cong 0$.

Note that this point is exactly in the middle of the Alcubierre warped region because $\frac{1}{2}$ is the middle point between 1 and 0.

If we move ourselves to the end of the warped region we will reach the intersection point between the end of the warped region and the beginning of the region outside the bubble.In this point the original shape function have values very close to zero ($\cong 0$) because outside the bubble the value of the shape function in 0.Taking powers of 200 for a value close to zero we will produce a new value also close to zero $(\cong 0)^{200} \cong 0$ so in this region the factor 10^{37} is also obliterated.

But if we move ourselves to the beginning of the warped region we will reach the intersection point between the beginning of the warped region and the end of the region inside the bubble.In this point the original shape function have values very close to 1 ($\cong 1$) because inside the bubble the value of the shape function is 1.Taking powers of 200 for a value close to 1 we will produce a new value also close to 1 $(\cong 1)^{200} \cong 1$ so in this region the factor 10^{37} is not obliterated by the power factor.

But fortunately the term x we deliberately neglected in this public presentation have very low values close to zero able to neutralize the factor 10^{37} in the beginning of the warped region.

Although this was a public presentation for the Alcubierre warp drive the complete mathematical details can be seen from pg 8 to 13 in [6] for the Natario warp drive.[47].[48]

[47] the reason why the Natario warp drive is deeply covered in [6] will be explained later

[48] remember that the Alcubierre parameter @ is dimensionless so in [6] when appears @ = 20 meters actually we mean only @ = 20.forget the word "meters"

Although we choose the power factors to reduce the negative energy requirements in both Alcubierre and Natario warp drives using a new shape function constructed over powers of the original shape function there are other ways to reduce the negative energy requirements:

- 1)-Using the original Alcubierre or Natario shape function in a warped region very thin of microscopical thickness(for those interested see [9]).
- 2)-Using a different shape function:the Heaviside step functions also produces values between 1 and 0 and dividing these functions by 2 we will have values between 0 and $\frac{1}{2}$(for those interested see [10]).

These two approaches above have a mathematics much more complex than simply power factors and cannot be covered in a public presentation.

But the power factor is the most effective way to reduce the total energy requirements.We raised the original Alcubierre shape function to a power of 200 but this factor is an arbitrary parameter not depending on the bubble speed.The speed of the bubble of 200 times faster than light was a coincidence.Lets retain the original Alcubierre shape function raised to a power of 200 and the value of the square of the derivative of the new shape function:

$$4 \times 10^5([\frac{1}{2}]^{398}) = 4 \times 10^5(\frac{1^{398}}{2^{398}}) = 4 \times 10^5(\frac{1}{2^{398}}) = 6,20 \times 10^{-116} \cong 0 \tag{14}$$

We know that 200 times faster than light is not enough to reach Kepler-22 at 600 light-years away in a couple of months.To do so we would need to achieve a speed of 6000 times faster than light.

So here we go again[49]:

speed of the bubble: $6 \times 10^3 \times 3 \times 10^8 = 18 \times 10^{11} = 1,8 \times 10^{12}$
square of the speed of the bubble: $3,24 \times 10^{24}$
square of the light speed: 9×10^{16}
mass of the Earth: $5,9 \times 10^{24}$
mass of the electron: 9×10^{-31}

Working with power of 10 only:

$$10^{24} \times 10^{16} = 10^{40} \tag{15}$$

$$10^{40} \times 10^{-116} = \frac{10^{40}}{10^{116}} = 10^{-76} \cong 0 \tag{16}$$

In order to sustain a warp bubble speed of 6000 times faster than light able to reach Kepler-22 at 600 light-years in a couple of months we need only an amount of negative energy density 10^{45} times smaller than the magnitude of the mass of the electron.

So we can pass the warp drive from science fiction to science fact.At least in mathematics!!!!!

[49]written in MKS units but we omitted the names of the units

However travelling at 6000 times faster than light is not an easy task.Interstellar space is not empty.Its full of asteroids comets interstellar dust and debris photons ionized particles supernova remnants etc.

An impact at 6000 times faster than light between the warp bubble and a single photon of cosmic background radiation for example is extremely dangerous to the warp bubble and compromises the integrity of the ship. And think how many photons we have per cubic centimeter of space between Earth and Kepler-22????.

In order to pass the warp drive from science fiction to science fact we must learn how to deflect incoming hazardous objects that appears in front of the ship in a real interstellar spaceflight protecting the ship and the crew members.

We will do this in the next section:

6 Collision with hazardous objects that may harm the ship(asteroids or comets)in a realistic interstellar spaceflight at superluminal speeds in both Alcubierre and Natario Warp Drive Spacetimes

We have seen so far in section 3 the differences between the impulse velocity and the warp velocity.An object(a spaceship) inside a warp bubble do not moves at all and it is the spacetime geometry around the bubble that moves itself carrying the bubble from the departure point (Earth)to the destination point(Kepler-22)(Natario case) or moves away from the bubble the departure point(Earth) and moves close to the bubble the destination point(Kepler-22) while the bubble is at the rest(Alcubierre case)

Lets review the Natario example of the fish and the aquarium from section 3.The spaceship is the fish and the aquarium is the warp bubble.The stream of a river carries the aquarium with the fish inside and in the same way the spacetime stream carries the warp bubble with the spaceship inside.

So there are three positions where an observer watching this situation can be placed:

- 1)-Inside the bubble:the region where the ship(or a fish) resides completely at the rest with respect to its local neighborhoods.
- 2)-Outside the bubble:the region where a faraway external observer(the rest of the Universe or an observer in the margin of the river) resides watching the bubble(or the aquarium) passing by him at large speeds
- 3)-In the warp bubble walls:the physical boundary limits of the bubble itself.corresponds to the glass in the walls of the aquarium-As already seen in sections 4 and 5 this correspond to both Alcubierre and Natario warped regions.

Graphical or artistic presentations of the Natario warp bubble are available at pg 7 fig 1 in [2] where the interior and exterior regions of the bubble are depicted or fig 2 pg 18 in [15] where a spaceship is depicted inside the bubble.The blue ring depicts the walls of the warp bubble

An artistic presentation of the Alcubierre warp bubble depicting the regions inside and outside the bubble with a spaceship inside the bubble can be seen at fig 2 pg 4 in [12].

- 1)-Another very important presentation of the Natario warp bubble is given by fig 1 pg 15 in [15]

Compare both fig 1 pg 15 in [15] and fig 2 pg 4 in [12]:[50][51]

- 1)-In the Natario warp drive according with fig 1 pg 15 in [15] the negative energy surrounds all the warp bubble and specially the parts of the bubble directly in the front of the ship.The negative energy density layers in the front of the ship protects the ship against impacts from incoming hazardous interstellar objects. [52]

[50] we do not present figures here in order to invite the curious readers to consult the references
[51] and this also means specially experienced readers
[52] For experienced readers:look to the equations of the negative energy in the Natario warp drive spacetime pg 16 in [15]

- 2)-In the Alcubierre warp drive according with fig 2 pg 4 in [12] the negative energy is concentrated in the blue regions above and below the ship.The part of the bubble in front of the ship is empty.There are no negative energy density layers in front of the ship to protect the ship against impacts from incoming hazardous interstellar objects.The blue arrow from the white horizon in yellow depicts hazardous interstellar matter entering in the bubble compromising the ship.

Compare now both fig 2 pg 18 in [15] and fig 2 pg 4 in [12]:[53]

- 3)-In the Natario warp drive according with fig 2 pg 18 in [15] the negative energy surrounds all the warp bubble and specially the parts of the bubble directly in the front of the ship.The blue ring around the spaceship is the distribution of the negative energy density. Note that the ring covers the front of the bubble. The negative energy density layers in the front of the ship protects the ship against impacts from incoming hazardous interstellar objects.[54]

As we pointed out before interstellar space is not empty and poses a very serious threat to the ship when travelling at 6000 times light speed in order to reach Kepler-22 at 600 light-years away in a couple of months.While the negative energy density problem can be contoured by mathematical techniques the collision between the warp bubble and the hazardous interstellar matter is the most terrible and formidable obstacle against the Alcubierre warp drive.

- 1)-according with pg 11 in [13] a collision between the front of the bubble at 200 times faster than light and a single photon of cosmic background radiation will release an amount of energy equal to the photosphere of a sun.How many photons exists per cubic centimeter of space between Earth and Kepler-22 at 600 light-years away?? And note that 200 times faster than light is 30 times slower than the speed we need. In pg 12 they say that this prevents any starship from ever attaining a speed greater than that of light.Or in other words;Warp drive is impossible!!!!! [55]

- 2)-according with pg 6 and 7 in [12] these highly energetic photons(equal to the ones depicted in pg 11 in [13])will raise the temperature of the warp bubble and the temperature will reach the Hawking Temperature.See again in fig 2 pg 4 in [12] hazardous interstellar matter entering in the bubble compromising the ship.They say at pg 9 that we will have luck if we could ever travel at 99 percent of the light speed.Or in other words:Warp drive is impossible!!!!!

- 3)-According with pg 10 in [11] any ship inside the Alcubierre warp drive carrying people would need shielding to protect them from potential dangerous particles during the journey.Or in other words:Without shields warp drive is impossible!!!![56][57]

According with the refs [11],[12] and [13] presented above the Alcubierre warp drive is impossible!!!!

So it will never pass from science fiction to science fact!!!!!

And unfortunately refs [11],[12] and [13] are entirely correct!!!!!

[53] again we do not present figures here in order to invite the curious readers to consult the references
[54] again look to the equations of the negative energy in the Natario warp drive spacetime pg 16 in [15]
[55] we will deliberately neglect the Doppler Effect in this public presentation
[56] For experienced readers:we will deliberately neglect the analysis depicted in [11] except for pg 10.
[57] For those interested read [15].

Why this happens with the Alcubierre warp drive???

Remember that the Alcubierre warp drive works by an expansion of the spacetime behind the warp bubble moving away from the bubble the departure point(Earth) and a contraction of the spacetime in front of the warp bubble moving closer to the bubble the destination point(Kepler-22).

OK Fine!!!!:But remember that Earth and Kepler-22 are separated by 600 light-years of interstellar space so this means "zillions" of cubic centimeters of space between Earth and Kepler-22 each one of these cubic centimeters filled with photons of cosmic background radiation interstellar dust and debris asteroid comets supernova remnants hydrogen atoms etc etc etc.

And when we say the bubble speed is 6000 times faster than light we mean to say that the bubble is at the rest and it is the geometry of the spacetime that contracts the spacetime in front of the bubble with a speed of 6000 times faster than light bringing Kepler-22 to the front of the bubble with an approximation speed of 6000 times faster than light but also bringing all the interstellar "garbage" between Earth and Kepler-22 to the front of the bubble with the same approximation speed and this "garbage" will arrive to the front of the bubble which is empty and there is nothing to protect the ship!!!! .

See again fig 2 pg 4 in [12].The blue arrow from the white horizon in yellow depicts hazardous interstellar matter entering in the bubble compromising the ship.[58]

So for the "aficionados" of the Alcubierre warp drive geometry refs [11],[12] and [13] seals the final destiny!!!!

So once again we arrived at the conclusion that faster than light space travel is impossible because the warp drive is impossible and we must "pack our things and go home" and forget the whole story about Kepler-22???

Well not really!!!!!

Note that refs [11],[12] and [13] are indeed telling that the warp drive is impossible!!!!!

Attention because these references covers only the Alcubierre warp drive and not the Natario warp drive!!!![59]

So the analysis of the refs [11],[12] and [13] is incomplete!!!!Because these references do not cover the Natario warp drive....Fortunately !!!!!!!![60][61]

Then refs [11],[12] and [13] cannot say warp drive is impossible.At least they can say Alcubierre warp drive is impossible.[62]

[58] again we do not present figures here in order to invite the curious readers to consult the references

[59] we want to outline that these works [11],[12] and [13] telling that the warp drive is impossible covers only the Alcubierre warp drive and not the Natario warp drive.So when speaking about the possibility or the impossibility of the warp drive the situation cannot be generalized!!!

[60] otherwise we would need to "pack our things and go home"giving up from Kepler-22

[61] the Natario warp drive cannot be placed in the same foot of the Alcubierre warp drive .....really!!!!

[62] many people that read warp drive papers think that Natario = Alcubierre.Absolutely not.Definitely the correct equation is :Natario $\neq$Alcubierre

Remember that the Natario warp drive is like an aquarium in the flow of a river so the Natario warp drive go with the flow like a fish in the stream of a river and in this case the spacetime geometry do not bring to the front of the bubble all the "garbage" between Earth and Kepler-22.The Natario warp bubble slides [63] through spacetime because the expansion of spacetime behind the bubble and contraction of spacetime in front of the bubble is simply.....zero!!!!.See pg 1 in [2].

So in the Natario case the spacetime geometry creates a continuum spacetime flow between Earth and Kepler-22 that carries the bubble like the stream of a river.A river between Earth and Kepler-22.See pg 5 in [2] for a mention to Fluid Dynamics.[64]

The negative energy density in the Natario case covers the front of the bubble like the walls of the aquarium protecting the ship inside against collisions with hazardous interstellar objects.

- 1)-For a curious reader:see pg 33 and 38 in [16],pg 15 and 20 in [15]
- 2)-For a curious reader:there exists for the Natario warp drive an analysis equivalent to the one depicted in [11],[12] and [13] for the Alcubierre warp drive.See all the section 6 pg 20 in [16] and the complete work [15]

So the negative energy density in front of the Natario warp bubble means that the walls of the Natario warp bubble in the front possesses a key ingredient:Negative mass generating a negative gravitational field!!!!!!

And negative gravitational fields resulting from a negative mass are repulsive not attractive!!!!.[65]

Natario in pg 7 in [14] mentions the existence of this negative gravitational field from a negative mass density.Also see pg 15 in [10] for a comment on the repulsive forces from a negative gravitational field.

Is this negative mass outlined by Natario in front of the bubble that will deflect by repulsive gravitational field[66] all the interstellar "garbage" protecting the ship allowing the Natario warp drive to survive a trip from Earth to Kepler-22.

Due to a different geometrical distribution of the negative energy density that allows the existence of negative mass in front of the bubble deflecting incoming objects the Natario warp drive survives against collisions with interstellar hazardous objects and is a valid candidate for interstellar travel.[67]

The Natario warp drive can pass from science fiction..to science fact!!!!And maybe someday it will certainly carry humans to the stars!!!!!

However there exists another problem to be solved:The astronaut inside the ship cannot control the warp bubble from inside.We will outline this problem in the next section.

[63] look for the word "sliding" in pg 1 in [2]

[64] this is an explanation for the general public

[65] see Wikipedia the Free Encyclopedia

[66] For experienced readers:or a negative curvature of spacetime that will generate a negative gravitational bending of light to deflect photons

[67] this is the reason why in [6] we covered deeply the Natario shape function raised to power factors.

Bur before closing this section we will give a brief explanation about why the negative gravitational field can deflect objects in a language accessible to the general public.[68]

Imagine that you are in the top of a building...in the ceiling and you drop an orange....you will see the orange falling until reach the ground..or the floor.Why this happens????

This happens because both the orange and the Earth have positive masses.The gravitational force between bodies of positive mass have a positive sign and is always attractive.How can we compute the gravitational force between two bodies???

The gravitational force between two bodies is directly proportional to the product of the masses of the bodies and inversely proportional to the square of the distance between the bodies.

Lets give an example: if i have a body A with a mass of 5 kilograms and a body B of mass 12 kilograms both separated by a distance of 2 meters the gravitational force between A and B would then be:

$$F = \frac{5 \times 12}{2^2} = \frac{60}{4} = 15 \tag{17}$$

15 Newtons(the Newton is the unit of force in physics).Note that the sign of the force is positive so we can say that both A and B are attracting each other.A gravitational force with positive sign is always attractive.

Now imagine that the body A have a negative mass of -5 kilograms as the mass originated by the mass density proposed by Natario in pg 7 in [14].The force between A and B would then be:

$$F = \frac{-5 \times 12}{2^2} = \frac{-60}{4} = -15 \tag{18}$$

-15 Newtons.Note that the sign of the force is negative and we can say that A and B are repelling each other.A gravitational force with negative sign is always repulsive.

[68]For experienced readers:we will again neglect the Gravitational Constant in this public presentation.

7 Horizons:Causally disconnected portions of spacetime (the warp bubble cannot be controlled by an astronaut from inside the bubble) in the Natario warp drive spacetime

According with refs [11],[12] and [13] the Alcubierre warp drive cannot survive to an interstellar space travel and since our goal is faster than light space travel for real and not theoretical mathematics we will cease to discuss it.

However one thing must be said:the Natario warp drive owe its existence to the Alcubierre warp drive.Without the Alcubierre warp drive the Natario warp drive simply would never exists.

Natario took inspiration from the Alcubierre idea of a spacetime that expands behinds a warp bubble and contracts in front of the same warp bubble to create a warp drive spacetime with a behavior similar to the Alcubierre warp drive(a warp bubble that can moves at superluminal speed) but without expansion/contraction of spacetime.(see abs and pg 1 in [2])

Since the Natario warp drive is the best candidate for interstellar space travel because it can survive the "endurance proof" of the collisions against the hazardous objects that exists in interstellar space it seems that the Natario warp drive is the unique candidate liable to pass from science fiction..to science fact!!!

This section will be entirely devoted to the Natario warp drive.[69][70]

The last problem raised against the physical feasibility of the warp drive as a dynamical spacetime is the Horizon(causally disconnected portions of spacetime) between the astronaut in the center of the warp bubble and the front of the warp bubble.This means to say that the astronaut cannot control the front of the bubble.

But what is a Horizon???What is a causally disconnected portion of spacetime???We are about to explain these physical concepts in a language that can be easily understood by the general public.

In physics we say that two different portions of spacetime B and A are connected when one portion (B) can send signals to the other (A).So B is causally connected to A. The maximum known speed to send signals is the light speed.

Lets explain this better using an analogy with the speed of the sound:

Imagine that we have two supersonic jets A and B flying with the same speed and the jet B is flying behind the jet A. Both jets initially are flying below the speed of the sound.Imagine also that both jets have the radios turned off due to malfunction and the only way for the jets to communicate between each other is by "phonon machines".A "phonon machine" is a machine that emits phonons and these are the equivalent of the photons of light but for the speed of the sound.A phonon always travels at the speed of

[69] we omitted the Doppler Effect in this public presentation so we will not cover the Infinite Doppler Blueshift although we know that the Natario warp drive can survive to it.see entire [15] and abs and section 6 pg 20 in [16]

[70] remember that this is being written to the general public so our discussion will be given in an introductory level

the sound.[71]

If the jet B travelling behind the jet A wants to send an information to the jet A and both are below the speed of the sound ok!! no problem because the phonon travels at the speed of the sound so the phonon is moving faster than the jet A and will reach it.

Now both jets pass to supersonic speeds at the same time and both jets maintains the same speed.What will happens???

If the jet B travelling behind the jet A wants to send an information to the jet A and both are above the speed of the sound now we have a problem because the phonon travels at the speed of the sound so the phonon is moving slower than the jet A and will never reach it.

The jet B cannot contact the jet A.An Horizon is established between the jet B and the jet A.The jet B becomes causally disconnected from the jet A.

But the jet A can send signals to the jet B because if the jet A sends a phonon to the jet B that is flying behind the jet A the phonon is sent to a direction behind the jet A and the jet B moves behind the jet A but in the same direction towards the jet A so the jet B will be intercepted by the phonon sent from A.The jet A is still causally connected to the jet B.

Now lets back to our trip between Earth and Kepler-22 at 6000 times faster than light in a Natario warp drive.Inside the bubble the astronaut is at the rest with respect to his neighborhoods like the pilot of the jet B is at the rest with respect to his cockpit but both the astronaut and all the bubble are at 6000 times faster than light[72].So the astronaut is the jet B and the front of the bubble is the jet A.If the astronaut send a signal at light speed to the front of the bubble the signal will never reach it.Because the front of the bubble is moving at 6000 times faster than light and the signal will never be able to reach the front of the bubble.An Horizon a causally disconnected portion of spacetime is established between the astronaut and the front of the bubble.

- 1)-For a curious reader:the complete mathematics can be seen in the entire [15](advanced) and section 6 pg 20 in [16](basic).See also pg 6 in [2](advanced) and pg 3 in [17](advanced).

This poses a serious problem:When the bubble arrives at Kepler-22 the astronaut must send to the front of the bubble a signal to stop otherwise the journey will continue forever but if the astronaut cannot send information to the front of the bubble how will the bubble stop?? How will the bubble "know" that it must stop ???

Another problem arises from this geometrical scenario:

Imagine that we have again both jets A and B below the speed of the sound. The jet B send to the jet A the information that in 30 minutes both jets must pass to the speed of the sound.Since the information is sent by phonons at the speed of the sound no problem.The jet A is below the speed of the sound so the phonon will reach the jet A and A will receive the information. And exactly 30 minutes later both jets acquires the speed of the sound.When this happens the jet B becomes causally disconnected from the jet A!!!!

[71] a siren is an example of a phonon machine...a siren emits sound waves which means to say that a siren emits phonons

[72] For experienced readers:from the point of view of a remote frame

Why this happens???:Because now if the jet B wants to send more information to the jet A using phonons at the speed of the sound this information will never reach the jet A because the jet A is already at the speed of the sound so the phonon cannot reduce the distance between him and the jet A because both are travelling at the same speed which is the maximum speed to transmit signals(speed of the sound in this case).So the phonon sent by the jet B will never reach the jet A.

Now transposing the situation described above to an astronaut inside the Natario warp bubble. The bubble is created at very low speed and must gradually accelerates towards the speed of 6000 times faster than light.The bubble is not created instantaneously with the speed of 6000 times faster than light. Like when someone enters in a car and ignites the "spark plug" the car do not pass instantaneously to 300 km/hour.The car starts to move slowly and accelerates gradually and continuously to reach the speed of 300 km /hour.In a certain amount of time the speed of the car must reach the 100 km/hour before reaches the 300 km/hour.

So our warp bubble initially moves below the light speed and the astronaut is sending signals at the light speed to the front of the bubble to accelerate it.Since both astronaut and the front of the bubble are below the light speed no problem..the signals from the astronaut will reach the front of the bubble...like the jets B and A below the speed of the sound.

In a given time the astronaut send to the front of the bubble which is still moving below the light speed the information that the bubble must achieve the light speed using photons.Since the walls of the bubble are moving below the light speed and photons moves at the light speed this information will reach the walls of the bubble and the bubble achieves the light speed.

Again the illustrative example of the Natario warp drive as an aquarium being carried out by a river stream or a spacetime stream.The walls of the aquarium are the walls of the bubble and the astronaut is the fish inside the aquarium.

When the bubble achieves the light speed the bubble carries the astronaut at light speed just like the aquarium going with the flow of the river carries the fish inside it.

Now both astronaut and the font of the bubble(aquarium wall in front of him) are moving at light speed.The front of the bubble becomes causally disconnected from the astronaut because both are travelling at light speed and the light speed is the maximum speed allowed to signal transmissions.

Why??:If the astronaut wants to send to the front of the bubble "the order to accelerate the bubble to faster than light speed" using photons of light speed these will never reach the front of the bubble that is already moving at light speed.The photons moving at light speed will never be able to shorten the distance between them and the front of the bubble which is also moving at light speed.So the bubble will never receive the "order to accelerate to faster than light speeds"!!!!!

- 1)-This is very important:the astronaut inside the bubble cannot accelerate the bubble to faster than light speeds!!!!!!
- 2)-If the astronaut cannot accelerate the bubble to faster than light speeds then who else can????

It seems that this geometrical scenario will doom the Natario warp drive like the interstellar space dust just doomed the Alcubierre warp drive!!!

Then we are back again to the scenario of the impossibility of faster than light space travel and once again we must "pack our things and go home" forgetting the whole story of Kepler-22.

Again fortunately the scenario described by the statements above is not entirely accurate!!!

Lets back to the jets B and A with the radios turned of and both travelling at the speed of the sound.The jet B is causally disconnected from the jet A using phonons.Now suddenly by a "miracle" both radios of B and A starts to work again!!!.

Now the jet B can signal the jet A regardless of any supersonic speed because the light speed(maximum speed allowed to transmit signals) is much faster than the speed of the sound or much faster then any supersonic speed.The causal connection between B and A is now restored!!!

This means to say that the astronaut inside the bubble must restore the causal connection between him and the front part of the bubble.But how this can be done???

Simply the astronaut must send to the front of the bubble information at a faster than light speed and using a speed faster than the superluminal speed of the warp bubble in order to allow the information to intercept the front of the bubble transmitting effectively the information to the front of the warp bubble.Is this possible????

Yes...at least in mathematics!!!!![73]

Some years ago in pg 10 and 11 in [5] it was mentioned that microscopical warp bubbles carrying electrons or other particles should be possible to be created more easily than large macroscopical warp bubbles which accommodates starships.A microscopical warp bubble could in theory carry the information to the front of the large Natario warp bubble.So the astronaut moving at light speed creates a micro warp bubble and store into it the information the "order to the bubble pass the light speed" and send this micro warp bubble with a speed $1,5$ times the light speed to intercept the front of the big bubble which is still moving at light speed.[74]

The micro warp bubble at $1,5$ times faster than light will intercept the front of the large Natario bubble still at light speed and will transmit the information to pass to $1,5$ times faster than light.So the astronaut regains the control of the large Natario warp bubble.

[73]For experienced readers:note that in pg 3 in [17] it is mentioned the need of tachyonic matter to create or control the warp bubble by the spaceship crew members

[74]still from pg 3 in [17]:Note that they mention also that the creation or control of the bubble must be taken by someone who contains the entire light one of the bubble-An external observer outside the warp bubble!!!!.Note that when the astronaut inside the large Natario warp bubble creates the microscopical warp bubbles he is an external observer with respect to these micro warp bubbles so he contains the entire light cone of these micro warp bubbles

Gradually by sending micro warp bubbles in a sequence to the front of the big warp bubble with a speed slightly ahead of the big bubble speed the astronaut can accelerate the bubble.

When the big Natario bubble is moving with a speed 5999 times faster than light the astronaut send to the front of the big bubble the final micro warp bubble at 6000 times faster than light in order to place the big Natario warp bubble in the desired speed.

The reverse process is also true:when the astronaut arrives at Kepler-22 at 6000 times faster than light he can send micro warp bubbles to the front of the big bubble the first of these micro warp bubbles must be sent with a speed of 6001 times faster than light in order to intercept the big Natario bubble moving at 6000 times faster than light with the information to de-accelerate it.So sending micro warp bubbles progressive slower in a sequence the astronaut can de-accelerate the big Natario warp bubble arriving in safety at Kepler-22.

We "solved"[75] the third problem that affects the warp drive and we can say with great confidence that the Natario warp drive will someday pass from science fiction to science fact and will emerge as a "winner" against the obstacle posed by the light speed barrier and will be taken as a valid candidate for faster than light space travel.

The Natario warp drive survived against all the obstacles pointed as physical impossibilities that rules out the warp drive as a dynamical spacetime.

We will now terminate our work with a conclusion.

But first we must describe the gravitational force between two bodies of negative mass:

In our geometric scenario the astronaut sent photons to the walls of the bubble.However since the walls of the bubble are made with negative energy density which means to say negative mass according to Natario in pg 7 in [14] the photon will never reach the front of the bubble even if the bubble moves at sublight speeds due to the repulsive gravitational force of the negative mass[76] that deflects the photon.

Also from the previous section we know that bodies of positive mass cannot approach a body of negative mass because the sign of the gravitational force is negative meaning a repulsive gravitational behavior between the positive and negative masses.So positive masses cannot be used to transmit information to the walls of the bubble.Besides it was this repulsive behavior between positive and negative masses that saved the Natario warp drive against the impacts with the hazardous interstellar matter... hazardous matter with positive mass!!!!

But what happens between two bodies of negative mass if one body approaches the other????

Like in the previous section and according with Natario in pg 7 in [14] imagine that we have two bodies A and B both with negative masses.The body A have a mass of -5 kilograms and the body B have amass of -12 kilograms both separated by a distance of two meters.

[75] at least in mathematics!!!!

[76] or negative gravitational bending of ligh)

Computing the gravitational force we have:[77]

$$F = \frac{-5 \times -12}{2^2} = \frac{60}{4} = 15 \tag{19}$$

15 Newtons
Gravitational force with positive sign!!!

The gravitational force between two bodies of negative mass have a positive sign meaning that it is always attractive So the warp bubble interacts only with bodies of negative mass and the micro warp bubble of negative mass can interact with the large Natario warp bubble also with negative mass

[77] again we neglected the gravitational constant in this public presentation

8 Conclusion

In this work we covered the major developments of the warp drive theory from the scientific point of view developed by both Alcubierre and Natario however without mathematics and using a sample language in order to allow this work to be read by the general public.

After a brief Historical description about how the warp drive appeared in science for the first time coming from the speculative ideas of Roddenberry and Star Trek to the rigorous scientific formalism of both Alcubierre and Natario we covered the 3 major problems that affects the physical integrity of the warp drive as a dynamical spacetime denying the passage of the warp drive from science fiction..to science fact!!.

- 1)-Large amounts of negative energy needed to generate the warp bubble
- 2)-Collision with hazardous objects that may harm the ship(asteroids or comets) in a realistic interstellar spaceflight at superluminal speeds
- 3)-Horizons:Causally disconnected portions of spacetime(the warp bubble cannot be controlled by an astronaut from inside the bubble)

The negative energy problem:

It was the most easy to be solved.It required only sample mathematical concepts and techniques just like raising integer numbers to power factors.Both Alcubierre and Natario warp drives survived this trial.

The collision with hazardous objects in interstellar space problem:

It required the study of the geometric distribution of the negative energy in the walls of the warp bubble.Alcubierre warp drive cannot withstand collisions with the hazardous interstellar matter because there is nothing in front of the bubble to protect the ship and the crew members against lethal impacts with hazardous interstellar objects.So the Alcubierre warp drive did not survived this trial and will never pass from science fiction to science fact!!!.

On the other hand while most physicists see the negative mass as a pathology we see it as a bless because it was the presence of this negative mass in front of the Natario warp drive with negative gravitational force of repulsive behavior deflecting incoming hazardous interstellar objects protecting effectively the ship and the crew members that allowed the Natario warp drive to survive this trial making it a valid and legitimate candidate for faster than light space travel. and maybe someday it will pass from science fiction..to science fact!!!

The horizon problem: It was discussed in this work only for the Natario warp drive because it survived against the collisions with interstellar matter.Our solution was based on the possibility of micro warp bubbles that are able to carry information to the front of the large warp bubble although this is still speculative.

Lastly and in order to terminate this work:There exists a fourth problem not covered here:the fact that we still dont know how to generate the negative mass and above everything else we dont know how to generate the shape function that distorts the spacetime geometry creating the warp drive effect.So unfortunately all the discussions about warp drives are still under the domain of the mathematical conjectures.

However we are confident to affirm that the Natario warp drive will survive the passage of the Century XXI and will arrive to the Future.The Natario warp drive will arrive to the the Century $XXIV$ on-board the future starships up there in the middle of the stars helping the human race to give his first steps in the exploration of our Galaxy

Our purpose in this work was to transmit the scientific concepts of both Alcubierre and Natario warp drive spacetimes in a language that can easily be understood by the general public in order to spread interest by the warp drive theory among those interested in faster than light space travel and mainly among the large community of Star Trek fans.

This work exists due to request made by a Star Trek fan.

Live Long And Prosper!!!!

9 Epilogue

- "The only way of discovering the limits of the possible is to venture a little way past them into the impossible."-Arthur C.Clarke[78]
- "The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. There is no logical path to these laws; only intuition, resting on sympathetic understanding of experience, can reach them"-Albert Einstein[79]
- "The history of science teaches that the greatest advances in the scientific domain have been achieved by bold thinkers, who perceived new and fruitful approaches that others failed to notice. If one had taken the ideas of these scientific geniuses, who have been the promoters of modern science, and submitted them to committees of specialists, there is no doubt that the latter would have viewed them as extravagant and would have discarded them for the very reason of their originality and profundity. As a matter of fact, the battles waged, for example by Fresnel and by Pasteur suffice to prove that some of these pioneers ran into a lack of understanding from the side of eminent scholars which they had to fight with vigor before emerging as the winners. More recently, in the domain of theoretical physics, of which I can speak with knowledge, the magnificent novel conceptions of Lorentz and Planck, and particularly Einstein also clashed with the incomprehension of eminent scientists. The new ideas here triumphed; but, in proportion as the organization of research becomes more rigid, the danger increases that new and fruitful ideas will be unable to develop freely. Let us state in a few words the conclusion to be drawn from the foregoing. While, by the very force of circumstances, research and teaching are weighted down by administrative structures and financial concerns and by the heavy armature of strict regulations and planning, it becomes more indispensable than ever to preserve the freedom of scientific research and the freedom of initiative for the original investigators, because these freedoms have always been and will always remain the most fertile sources for the grand progress of science."-Louis Victor Pierre Raymond de Broglie-Nobel Prize Winner 1929 in a speech in April 25,1978[80]

[78]special thanks to Maria Matreno from Residencia de Estudantes Universitas Lisboa Portugal for providing the Second Law Of Arthur C.Clarke

[79]"Ideas And Opinions" Einstein compilation, ISBN $0-517-88440-2$, on page 226."Principles of Research" ([Ideas and Opinions],pp.224-227), described as "Address delivered in celebration of Max Planck's sixtieth birthday (1918) before the Physical Society in Berlin"

[80]From the book "Heisenberg's uncertainties and the probabilistic interpretation of quantum mechanics"

10 Remarks

All the references of this work came from scientific web-servers available to consultation by the general public(arXiv and HAL).[81]

This work was an introduction to the warp drive theory from a Historical perspective in order to be accessible by the general public.It explains using a clear and simple language the ideas behind the Alcubierre and Natario warp drive spacetimes for those interested in faster than light interstellar spaceflight.It covers not only all the major developments in the warp drive theory but also the physical problems associated with them and outlines possible solutions to overcome some of these problems. Since this work have no new scientific context but instead it is a compilation of the work already done by Alcubierre and Natario however written without mathematics in order to be read by everybody it seems that the best category properly suited for this work conceived to be a HAL submission is the category of History of Physics.

11 Legacy

This work is dedicated to all the Star Trek community.As the captain Jean-Luc Picard of the starship Enterprise-E would say:Make It So!!![82][83][84]

[81] as an example of consultation browse Google for gr-qc/0009013,gr-qc/0110086,arXiv:0710.4474 or HAL-00599640

[82] fans,actors,actresses,producers,directors,argument writers,special effects technicians,sound and camera operators etc

[83] TOS,TNG,$DS9$,VOY,$NX-01$ etc..etc....all the Star Trek movies starting with the earliest ones from Harve Bennett to the latest ones from J.J.Abrahams...inclusing the newest Into Darkness

[84] Federations,Vulcans,Klingons,Romulans...etc.. and Borgs

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