Artificial spacetime manipulation - or how to create a spacetime tornado

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Abstract

This is a summary of notes on the concept of artificially manipulating spacetime

1 Introduction

In 1687 Isaac Newton came up with a theory of gravity which would persist for more than 200 years. The theory stipulates that gravity is an attractive force between objects of mass. Each object excerpt a force on every other object proportional to their combined masses.

If you have two objects of mass m_1 and m_2, each object excerpt forces F_1 and F_2 equal and opposite to each other.

$$F_1 = F_2 = G\frac{m_1 \cdot m_2}{r^2}$$

Isaac Newton used his theory to predict and calculate the movement of planetary objects around the sun. However, the theory is flawed in that it fails to explain a number of phenomena, observed by experiment. In particular, when a planetary orbit is elliptical, the elliptical path taken by a the planet tend to slowly rotate. This pattern is more pronounced the closer you get to a large gravitational mass such as the sun. A good example, therefore, is the planet of Mercury which revolves closely around the sun. According to Isaac Newtons theory, once an orbit has been established it never changes. It is likely that Isaac Newton himself knew of the shortcomings of his theory, but he was never able to come up with a new theory.

It would be more than 200 years before a new theory of gravity would arise. It came about with the revolutionary 1905 and 1915 papers by Albert Einstein. In them, Albert Einstein, seemingly out of thin air, conjures up a new and superior theory. A theory of space, time and gravity. Although not usable in extreme cases such as inside a black hole, and although incompatible with Quantum Physics as we know it today, Einsteins theory has largely withstood the test of time and has been used to predict a multitude of results since verified by experiment.

Einstein's theory stipulates that gravity is not a force at all. Instead space curves on itself in response to various energy sources. According to

Einstein, the sun does not excerpt a force on the Earth, instead the Sun curves space around itself. The Earth is blissfully unaware of this fact as it travels in a straight path through space. But because space itself is curved, it makes the Earth travel around the Sun. The elliptical orbit that the Earth takes around the Sun is in fact a straight line in curved space - this path is known as a Geodesic path.

The curvature of space is not uniform. As you get closer to the energy source, spacetime curvature is more pronounced. Einstein used this fact in his theory to calculate the procession of elliptical path of Mercury as it travels around the sun.

In Einsteins theory, space and time are inseparable concepts and must be considered a joined entity called spacetime. Energy in all its forms are a source of curvature in spacetime. In particular, the pressure associated with massive objects such as planets and stars are extreme sources of curvature.

Gravity, according to Einstein, is geometric curvature in spacetime and in his theory, curvature is of the most essential characteristics of gravity. Theoretically any source of energy produces curvature in spacetime, but the energy sources we consider on a daily basis are too weak to produce any measurable curvature.

If you are wondering what curved spacetime looks like, you have only to go outside and look up at the sky. Although time is invisible and space appears to be straight, you actually experience the curvature as acceleration - it is the curvature in spacetime that is responsible for you falling towards the earth. But it is not only space that is curved. Time, too, is curved. In practice this means that time itself passes slower as you get closer to an energy source. For example, time passes (ever so slightly) slower on the surface of the Earth than it does in the orbit taken by the satellites that implement the Global Positioning System (GPS). This fact has to be encoded in the software of the satellites and GPS receivers around the world. If this fact is left out of the software, the GPS system simply would not work. This need for a software correction due to the curvature in time is just one of many remarkable predictions in Einsteins theory that would later be verified by experiments.

2 Artificial Spacetime Manipulation

So in order to manipulate spacetime, all you need is a big enough energy source and the ability to direct that energy at will. On planet Earth, we have an abundance of energy sources and also the ability to direct them. So what is the problem?

The problem becomes apparent if you perform an experiment. Take a small chunk of iron and hang it from a string, then take a small magnet and place it in close proximity to the iron. The string is immediately deflected due to the forces excerpted by the magnet on the iron. Now replace the magnet with a mass of 100.000 kg of iron and place is in close proximity to the iron suspended on a string. The string is not deflected in the slightest. This is because magnetic forces are much stronger than gravitational forces. This fact is reflected in the size of Newtons constant

G which appears in Newtons original equations. Newtons constant is extremely small - approximately $6.674 \cdot 10^{-11} \frac{Nm^2}{kg^2}$.

We also know that $E = mc^2$ (at rest), so the amount of energy contained in a mass of 100.000 kg is enormous, yet not enough to make up for Newtons constant. The fact that we can both feel and measure gravity on the surface of the Earth is due to the fact that the mass of the Earth is so incredibly large. The problem, then, is that no amount of energy that can be produced on this planet is enough to manipulate spacetime. Or more precisely, the amount of energy required to manipulate spacetime cannot be produced instantaneously.

This leads us to instead consider a system of storing gravitational energy combined with a method of pumping energy over long periods of time into that system. Such a system does not depend on the instantaneous production of quantities of energy, large enough for spacetime manipulation. Instead it is a function of time in combination with available energy production.

2.1 Laser pumping

Systems that store energy in conjunction with a pumping strategy are common. As an example, consider the laser, which was also conceptualized by Albert Einstein in his 1916 paper 'Zur Quantentheorie der Strahlung'.

In his paper, Einstein laid out the foundation for a pumping system required to produce a workable laser. Essentially a laser pump is just a specific gas isolated in a glass tube with an electric circuit attached to each end. As electric current runs through the tube, some of the gas atoms are excited to a higher quantum state, and to do so must absorb energy from the electric current. After some time, the atoms will again fall down into a lower quantum state. As they do, they release energy in the form of electromagnetic radiation of a certain wave length. The exact wave length depends on the gas in question. Some gasses produce wave lengths that are visible to the human eye, those are the types of electromagnetic radiation we refer to as 'light'. Depending on the gas, the light produced has different colors as seen by the human eye. The light emitted from a pump of this sort radiates in all directions, just like a light-bulb. In fact, it IS a light bulb. Although, light bulbs had already been invented in 1880, it was Einstein who provided the theoretical explanation for it using the theories of Quantum Physics. With his explanation it also became possible to calculate the amount and color of the light produced.

So a light bulb is the instantaneous production of light through the instantaneously available amount of energy. But if you add two mirrors to the ends of the light bulb, you can capture the light emitted in an endless loop between the two mirrors. The mirrors function as a storage for the light and you can pump more an more light into the storage. However, there is a maximum capacity of any such pumping device. As energy builds up during pumping, the device heats up. The heat makes the device lose energy by radiating heat at a higher and higher rate eventually creating an equilibrium of input and output of energy. With this device fully pumped, opening up a small hole in one of the mirrors produces a strongly coherent and powerful beam of light known as a laser. The color/wavelength of the laser depends on the gas in question.

2.2 Spacetime pumping

Gravity is geometric curvature in spacetime itself. Therefore, it does not make sense to talk about a material that reflects gravity in the same way as a mirror can reflect light. Any material placed in curved spacetime would simply experience acceleration in some direction, just like we do on Earth.

So how do you go about constructing a spacetime pump when spacetime does not interact with any known material? Part of the answer is spacetime itself. The only thing that spacetime curvature interacts with is spacetime curvature itself.

This brings us to another important characteristics of spacetime. Consider an idealized and simplified scenario, with only two dimensions of space and no energy sources at all. In that case, spacetime is just a flat 2 dimensional grid. Now imagine an energy source in the form of a single point in the middle of the 2 dimensional grid. In that case, the 2-dimensional spacetime curves around the energy source. Now consider what happens if the energy source suddenly disappears in an instant. In that case, the 2-dimensional spacetime returns to its original flat state. However, that does not happen instantaneously. The curvature bounces back up to produce a smaller curvature in the opposite direction. Then it bounces back and forth until finally finding its equilibrium in a flat state. This bouncing back and forth produces gravitational waves in spacetime itself. Waves that travel from the source and outward in all directions (in this case in both of the 2 dimensions, but in the case of spacetime, in all three spacial directions).

The scenario is similar to what happens if you throw a single stone in a pond of water. Waves will travel from the source and outward. The central idea of this project is a hypothesis that the analogy of the water in a pond holds further. That spacetime behaves like a fluid and obeys the laws of fluid dynamics. In a pond, the waves can be amplified or canceled by interacting with other waves. Waves of the same direction and amplitude are constructive and works to amplify each other, while waves at opposite directions and amplitude are destructive and works to cancel each other.

This project proposes to design a system to produce gravitational waves in spacetime that work constructively. The system should be constructed to direct the waves in a circular motion to create a rotation of spacetime just like a fluid can be made to rotate. More and more rotational energy can be pumped into the system until it creates a tornado-like structure in spacetime.

Concretely, if you place a source of energy, say a strong electric charge which generates an electromagnetic field, then that produces spacetime curvature according to the field equations. The curvature will not be significant enough to measure by any instrument in existence, but it can be calculated using Einsteins field equations none the less. When the electric charge is turned off, gravitational waves will occur as spacetime goes back to its original state - again not significant enough to measure, but calculable none the less. A spacetime pump can be created by constructing a set of electrically charged sources in a circular pattern. Combined with a software system that controls the timing and amount of electric charge of each of the sources in order to produce constructive wave patterns that eventually create rotation of spacetime. This is a spacetime pump, analogous to a laserpump, where each electric charge is analogous to the electric circuit of a laserpump and the build-up of rotational energy in spacetime is analogous to the storage created by mirrors in a laserpump.

This project proposes to create a computer simulation of the sources including the control software. Then simulate the effects on spacetime using Einsteins field equations and Maxwells equations for electromagnetism. If a spacetime pump can be constructed by simulation in software, then the project can move on to create a physical prototype.

3 The problems of simulating spacetime

It is reasonable to ask, if creating a spacetime pump is so easy, why has nobody constructed a spacetime pump before. Part of the answer it that, while it looks simple conceptually, it is not easy in practice at all. In this section, we will briefly illustrate why. Another part of the answer is probably that is a bit of a quirky idea. Practically all researchers interested in general relativity think in terms of cosmological distances and cosmological objects such as black holes and neutron stars. Since we currently don't have the ability to artificially manipulate spacetime, not much effort is put into considering experiments with a localized, artificially created gravitational field and how it might be produced.

3.1 The Complexity of Einsteins field equations

The first issue we encounter is the shear complexity of Einsteins theory of general relatively. These equations are expressed in the language of differential geometry. A key characteristic of differential geometry is an entity called a metric. A metric describes the distance between two points in space - or two events in 4-dimensional spacetime. The metric is the basis of a local geometric definition, all you need is a metric at every point describing how each point is connected to its neighbors. If you have that, then you don't need anything else to know what the geometry looks like globally. This also means that differential geometry and thereby Einsteins field equations are coordinate independent.

We learned in high school how to calculate the distance s between two points in flat Euclidean space - that is Pythagoras $\Delta s^2 = \Delta x^2 + \Delta y^2$ (in two dimensions in this case). In a more general space, that allows for curvature, this distance is given by a more generalized version of Pythagoras $\Delta s^2 = \Delta A x^2 + \Delta B y^2 + C \Delta x \Delta y$ with linear combinations of Δx and Δy. But also with possible non-linear cross terms of $\Delta x \Delta y$. The generalized version of Pythagoras is collected into an entity called the metric tensor $\Delta s^2 = \Delta g_{xx} x^2 + \Delta g_{yy} y^2 + g_{xy} \Delta x \Delta y$. In four dimensions, the indices x and y range over the values 0, 1, 2 and 3 and there are 16 entries in total. As we shall see later, the generalized metric is hiding deep within Einsteins field equations.

The Einstein field equations look as follows in units where speed of light is set to 1.

$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$

In any other units, a conversion factor between Newtons constant and the speed of light is required as follows

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

The left hand side describes the geometric structure and curvature of spacetime. The right hand side describes the various forms of energy that can exists and which give rise to the geometric structure on the left hand side. The geometric structure on the left hand side and the energy distribution on the right hand side are related through a constant $\frac{8\pi G}{c^4}$.

The field equations looks deceptively simple, but when unpacked, they reveal 16 differential equations to be solved simultaneously. Let us begin by unpacking the left hand side.

The term $G_{\mu\nu}$ is called the Einstein Tensor and it is defined as follows $G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R$.

Therefore, when expanding the Einstein Tensor, the field equations look like this

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}$$

The term R is called the curvature scalar and it is defined as

$$R = g^{\mu\nu} R_{\mu\nu}$$

In this expression, the μ and ν are indices that range from 0, 1, 2 and 3, where the index 0 usually represents time[1] and the indices 1,2 and 3 represents the three dimensions of space. Notice how some indices occur as superscript and some as subscripts. These are commonly known as upstairs and downstairs indices and when associated with tensor algebra as they are in these equations, they refer to the transformation properties of the tensors. Tensors with upstairs indices transform covariantly while tensors with downstairs indices transform contravariantly. For any tensor equation to be invariant with respect to transformations in spacetime, a combination of both covariant and contravariant indices is required.

Einstein introduced a convention called the Einstein summation convention. Whenever, the same index appears twice in an equation - once upstairs and once downstairs, then that implicitly means that the index is summed over. Therefore you do not have to write all of these summation signs that would otherwise appear in abundance, you just have to remember that they are still their. So let us remember the Einstein summation convention now and put back the summation signs. There are two indices that appear twice - once upstairs and once downstairs, so there are two hidden summation signs in this equation.

[1] In some literature, the spacial dimensions are set to 0,1 and 2 while time is set to index 3. There is no fixed convention.

$$R = \sum_{\mu=0}^{3}\sum_{\nu=0}^{3} g^{\mu\nu} R_{\mu\nu}$$

Then we move on to the term $R_{\mu\nu}$. That is called the Ricci tensor and it is defined as

$$R_{\mu\nu} = \sum_{\mu=0}^{3}\sum_{\nu=0}^{3} g^{\mu\nu} R_{\sigma\mu\kappa\nu}$$

The new term $R_{\sigma\mu\kappa\nu}$ in the Ricci tensor is called the Riemann curvature tensor. It is usually expressed with one upstairs index obtained by contraction with the metric tensor as follows $R_{\sigma\mu\kappa\nu} = g_{\sigma\rho}R^{\rho}_{\mu\kappa\nu}$, but both of these are exactly equivalent.

The Riemann curvature tensor is defined as

$$R^{\rho}_{\mu\kappa\nu} = \partial\mu\Gamma^{\rho}_{\nu\sigma} - \partial\nu\Gamma^{\rho}_{\mu\sigma} + \Gamma^{\rho}_{\mu\lambda}\Gamma^{\lambda}_{\nu\sigma} - \Gamma^{\rho}_{\nu\lambda}\Gamma^{\lambda}_{\mu\sigma}$$

Each of these new symbols, Γ are called Christoffel symbols and each combination is equal to a particular combination of the metric tensor and various derivatives of it as exemplified in the expression below. Here we finally see where the generalized version of Pythagoras is hiding - or more precisely, derivatives of it with respect to 3 dimensions of space and 1 dimension of time.

$$\Gamma^{\lambda}_{\mu\sigma} = \frac{1}{2}g^{\lambda\kappa}(\frac{\partial g_{\kappa\mu}}{\partial x^{\sigma}} + \frac{\partial g_{\kappa\sigma}}{\partial x^{\mu}} - \frac{\partial g_{\mu\sigma}}{\partial x^{\kappa}})$$

This entire exercise is not to try to expand the Einstein field equations in their entirety, but merely to give an impression of just how complicated these equations are. We will not unpack the left hand side any further, but instead briefly describe the right hand side, $T_{\mu\nu}$.

The right hand side is called the Energy-stress-momentum tensor and it contains the various forms of energy that can possibly exist. There are two indices with four values ranging from 0 to 3. Thus it can be represented as a matrix with 16 values - one for each of the 16 equations of the field equations.

The energy-stress-momentum tensor is defined as follows

$$T_{\mu\nu} = \begin{bmatrix} T^{00} & T^{01} & T^{02} & T^{03} \\ T^{10} & T^{11} & T^{12} & T^{13} \\ T^{20} & T^{21} & T^{22} & T^{23} \\ T^{30} & T^{31} & T^{32} & T^{33} \end{bmatrix}$$

T^{00} is called the energy density. T^{10}, T^{20} and T^{30} are called the energy flux. T^{01}, T^{02} and T^{03} are called momentum density. The diagonal T^{11}, T^{2} and T^{33} contains the pressure. The upper triangle, T^{12}, T^{13} and T^{23} is called the shear stress. And finally the lower triangle T^{21}, T^{31} and T^{32} is called momentum flux.

Note that the original field equation, $G_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$ describes a general relationship. At each point in spacetime, there will be different types and amounts of energy and therefore the geometry will be different. Therefore, every point in spacetime has a different set of equations that describe that point. This means that the number of calculations required to simulate spacetime curvature correctly is staggering.

3.2 Non linearity and compute complexity

Let us move on to consider another complication. The non-linear nature of the Einstein field equations. Many of the most central equations in physics are linear. This applies for example to Newtons equations, the Maxwell equations of electromagnetism as well as the Schrödinger equation which is the central equation of Quantum Physics. However, Einsteins field equations are wildly non-linear. This can be seen just by looking at some of the derived equations, but there is also a physical explanation for it. In Maxwells equations, electric charge is the source of electromagnetic fields. The field propagates outward at the speed of light, carrying energy with it. In Einsteins equations, energy is the source of a gravitational field which propagates outward at the speed of light carrying energy with it, but since the energy carried along is itself a source of other gravitational fields, order quickly descents into chaos and this is the underlying physical reason why Einsteins theory must necessarily be non-linear. This also creates an exponential explosion of simulated objects to manage in any simulation and thereby an exponential requirement in terms of compute power required.

3.3 Coordinate mess due to the warping of space and time

Another complication is the fact that gravity is defined as geometric curvature. Consider a simple physics simulation, like simulating how a rocket is affected by the moon gravity using Newtons linear equations. In order to perform this simulation, you would typically construct a three dimensional coordinate system and use that as a global reference system. Then perhaps another local three dimensional coordinate system attached to the rocket. When relatively is not considered, time is fixed in steps and you simply pick an initial position and initial velocity of the rocket. Then you march forward the simulation one time step and calculate and apply the forces affecting the rocket according to the new position and according to Newtons equations. Then you march forward in time again and repeat.

With Einsteins field equations, you cannot easily construct a global reference system in four dimensions. Because whenever curvature is created in spacetime, is also affects the coordinate system and the axis of the system are bend, twisted, contracted and stretched in various ways, quickly descending into chaos. This is the very reason Einsteins field equations have to be expressed in coordinate independent terms using differential geometry in the first place.

3.4 The need for advanced mathematics and the associated learning curve

In 1905 Einstein came up with the theory of Special Relativity. It was a theory of space and time, but not yet gravity. The paper on General Relativity was published 10 years later in 1915 and that is no coincidence. The learning curve of the mathematics required for dealing with General Relativity is incredibly steep. Differential geometry, tensor calculus , covariant derivatives and Riemann curvature just to mention a few concepts.

4 Applications

Maybe you are left wondering why one would even consider creating a spacetime pump resulting in a spacetime tornado. Surely, there must be better ideas to invest your time and effort into. In addition the probability of success seem somewhat low.

But it is not an exaggeration to state that the ability to artificially manipulate spacetime will have significant ramifications on the course of human history. It also has the potential to completely transform our everyday life. This section explores just a sample of applications that are based on the manipulation spacetime.

4.1 Space exploration

Space exploration is about searching for life elsewhere in the galaxy. It is also about searching for habitable planets for our species to settle in the future. By now, we are effectively certain that no intelligent life exists anywhere in our solar system outside of planet earth (and the jury is still out on whether life on planet Earth is to be considered intelligent). We are also certain that there are no habitable planets in our solar system outside of planet Earth. So we are confined to searching for microbial lifeforms on remote moons of gas giants like Jupiter. But at the same time we know, from advanced telescopes, that there are literally thousands of potentially habitable planets in other star systems in our galaxy. So why do we not visit them? The answer is based in the rudimentary technology that is space rockets. It is all about Newtons third law: For every action there is an equal and opposite reaction.

The problem is that we use chemical rockets as propulsion for exploring space. The rocket equation states that if mass in the form of fuel is burned in one direction it propels the rocket some delta-velocity in the other direction. This simple idea puts a limit to how large the velocity can be of any one rocket. The rocket cannot accelerate to a velocity faster than the corresponding amount of fuel that can be stored on the rocket. In order to consider visiting other star systems, we would have to propel a rocket to near the speed of light and even then, it would take years or decades to reach the nearest stars. Unfortunately, the velocities we can achieve with modern rockets can not even reach anywhere near 1% the speed of light. In addition it is completely unrealistic to build a chemical rocket of the size required to reach even 10% of the speed of light. This is why we are still trying to put people on Mars - and even that task is exceedingly difficult with current day rocketry. The rocket equation and our need to conserve fuel also explains why it takes 8 months to reach Mars in a modern spacecraft.

With the ability to manipulate spacetime, acceleration can be achieved independently of Newtons third law. To see this, imagine a satellite with no fuel. It certainly cannot propel itself in keeping Newtons third law, because it has no fuel. Yet it is fully able to accelerate towards the earth none the less. This is because is not really propelling itself at all, it is just standing still in curved space - and thus experiencing acceleration. By the same token, the ability to manipulate spacetime can be used to create a method of propulsion based on the creation of curvature in front of a spacecraft. The curvature will make the spacecraft accelerate and all that is required is energy, perhaps in the form of electric charge. And electric charge can be generated by much more compact amounts of mass than the mass required by chemical reactions - for example by an onboard nuclear reactor. With this technology it is possible to propel a spacecraft to a significant fraction of the speed of light, while also having enough energy to decelerate at the destination.

4.2 A new form of transport

We are so used to the concept of transportation, that we sometimes forget the basic concepts that underlie it. If you want to move from point A to point B in a straight line, then you have to move through a series of neighboring points between A and B. You can only ever move from one neighbor to the next. So in order to reach point B, you must visit all the points on the path between A and B.

If you have the ability to manipulate spacetime, then you can create a curvature such that two previously unconnected points in space, become neighbors. The concept of transportation remains the same as always, you move one step at a time from one neighboring point to the next. It is just that two neighboring points can be hundreds of kilometers apart, but brought into proximity of each other by the creation of curvature in spacetime.

The ability to manipulate spacetime can be used to create a new form of transport. One in which you take a step in one position and instantly appear at a position hundreds of kilometers away - connected by spacetime curvature. Thus eliminating the need for traditional means of transport. The amount of energy required to curve space to the required degree is unknown, but it is bound to be higher than that required for space exploration.