Nat. Volatiles & Essent. Oils, 2021; 8(4): 1719-1729

Heuristic Principle in theory of General Relativity Based on the principle of Unity

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Abstract

The theory of relativity was not derived from a supernatural god, but from existing theories and observational facts. As a result, it is more of a naturalism than a supernatural one, involving aesthetic sense, a psychological factor. It is not a matter of force being applied, but of time and space being bent by mass and energy, and all objects move in response to time and space distorted by inertia. The process of integrating relativity theory can be characterized as dialectical. At the end of the day, this is a type of dialectic structure that can be used as an organizing principle for scientific theory, a dialectic method for human reasoning.

Keywords: theory of relativity, naturalism, dialectic structure.

Introduction

The natural science of the twentieth century defined holism as a concept underpinning all human reasoning. Atomism, individualism, separationism, and reductionism are examples of outdated ways of thinking in the Newtonian paradigm and need to be abandoned. An appropriate principle of explanation should target the entire complex of relationships.

It may be said that this holistic thinking must be integrated with dialectical methods. According to Newtonian mechanics, this dialectical thinking has a confrontational nature, but striving for the integration of holistic thinking can serve as a powerful motivation.

The purpose of this chapter, although completely irrelevant to Newtonian mechanics, is to understand the process of integrating it with dialectical thinking through the analogy process and to explore whether such an integrated theory can be justified based on empirical data.

Among the elements of Kuhn's paradigm, symbolic generalizations provide an introduction into which logic and mathematics can enter scientific inquiry. They serve as laws and theories. Models correspond to the metaphysical part of the disciplinary matrix, and fall into two categories. The ontological model and the heuristic model are different (Kuhn, 1970). We explore how Einstein used the metaphor or analogy of this heuristic model.

Accordingly, Einstein defined the behavior of an object in a gravitational field as a path that follows it, rather than a force that attracts it, as in Newtonian mechanics. He argued that the path these objects follow depends on the structural nature of space.

What led to the principle of equivalence, where inertia and gravity are the same?

Also, what principles have been derived from this equivalence principle?

Once Einstein realized that Newton's Second Law of Revision and the Law of Universal Gravitation both referred to the same physical quantity (mass), he started thinking about general relativity. Einstein believed that if these two laws were independent, the definition of mass in each law would be different. Newton's Second Law ($F=ma$) defines inertial mass while the Law of Universal Gravitation ($F=Gm_1m_2/r^2$) defines gravitational mass.

Inertia and gravitational mass, however, are always the same. The amount of gravity is proportional to the mass of gravity, and the size of inertia is proportional to the mass of inertia.As such, it appears that gravitational mass and inertial mass are not related, so why are they the same?

As Einstein's principle of equivalence states, it is natural. That is, because inertial force and gravity have the same essence, it is only natural that inertial mass and gravity mass are the same. As a result, the general theory of relativity extended physics in order to explain the reference coordinate system in which gravity and acceleration occur, leading to the conclusion that space is curved. In addition, the theory demonstrates that space and time are not only connected, but that space, time, and matter or energy must be combined together in order to fully explain the universe.

The similarity between gravitational force and inertial force is the most important premise for the development of general relativity.

The inertial effects inside Einstein's windowless spacecraft can be observed, for instance, if it accelerates upward in space at the acceleration of gravity. If so, inertial forces are generated in the downward direction, like gravity. However, the universe and all of the nebulae are accelerating downward with the elevator in this case. A spacecraft may be thought of as a theoretically fixed reference system, in which case the gravity field arises from the acceleration of the universe. If light traveled straight, an observer in a spaceship moving at a constant speed would see the light bending in the same direction as the inertial force, as opposed to its straight path. Gravity and inertia are viewed as the same. Based on the spaceship as the reference system, the field will be gravitational, while if the universe is considered as the reference system, the field will be inertial. Hence, inertia and gravity are two different names for the same phenomenon, since there can be no absolute motion. There is only the relative motion of the elevator and the universe (Gardner, 1962, pp. 107–108). Relativity assumes that motion, whether at constant or non-constant speeds, can only be determined by certain reference systems, and that absolute motion does not exist (Barnett, 2014, p.137).

Table 1 shows the typical stages of an analogy in philosophy.A typical argument by analogy infers that properties that occur in the base domain also occur in the target domain based on the idea that two different objects are similar at a specific point, and this has played a major role in the development of scientific theory throughout history (Oh & Jean, 2017).

Typical analogy: the principle of scientific discovery

(Premise 1) Most of those that correspond to x also correspond to y.

(Premise 2) x has A.

(Conclusion) Therefore, y also has A.

By using such an analogy in this study, let us say that x is an accelerometer and y is a gravitational field.

(Premise 1) The accelerometer (baseddomain) and the gravitational field (target domain) are equivalent because all laws of physics apply equally. < Premise 1 in Table 1>

(Premise 2) It may be said that light is bent in the accelerometer (baseddomain). These thought experiments occur only in accelerators, not inertial systems. < Premise 2 in Table 1>

(Conclusion) Therefore, light bending will naturally occur in the gravitational field (target domain).

Furthermore, light moves along geodetic lines, so time and space must remain bent by mass (formation of a new general theory of relativity). A variety of phenomena can also be predicted based on the theory that time and space are bent by this kind of gravity <Conclusion of Table 1>.

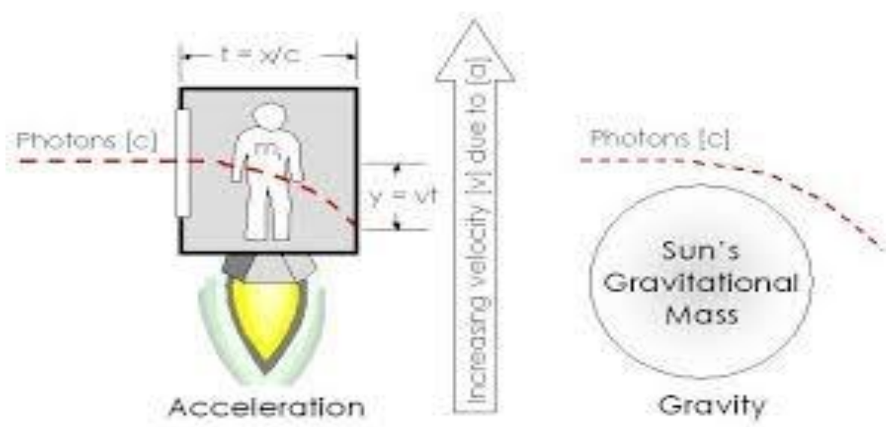
This is a logically strong analogy, and for the analogues that form the first premise to be true equivalent principles, the causal connection of scientific theories about their relationships is crucial rather than a mere example (Oh & Jean, 2017).

For example, the observer, when present in the based domain's acceleration system (initial condition), would feel inertial force; if there are meteorites stationary outside the spacecraft, the observer would feel as if they are approaching with relative acceleration (results). Additionally, the observer in the gravitational field (initial condition), which is the target domain, is aware that meteorites fall at the same gravitational acceleration in the absence of air resistance above the surface (results). Equivalence is the law of causality to which inertia and gravity both apply. Therefore, the two domains are regarded as "equivalence" beyond being analogous. By the end, it was intended to integrate in the direction of physical symmetry Newton's theory that inertial force and gravity are distinct.

According to this analogously strong equivalent principle, the observer accelerates to produce a state in which gravity applies. As shown in Figure 1, the same law applies when an observer accelerates and when gravity acts upon an object. Accordingly, a new scientific theory is formulated that space and time are bent by gravity in the case of photons since they move at the speed of light along the curved geodetic line. The result is that planets' much greater masses are therefore bound in their orbits because their mass is great enough to prevent bending due to the sun's mass escaping its gravitational grooves. As a result, expansion to a non-inertial frame was intended by including the special relativity theory that applied only to an inertial system.

It is evident that the switch that controls the rocket's thrust could be turned to simulate Earth's gravitational field. It was eventually concluded that accelerating frames of reference cannot be distinguished from stationary frames of reference related to gravity. That is, no matter what kind of physical experiment is used, the accelerated frame of reference cannot be distinguished from the non-accelerated frame of reference affected by the gravitational field.

Through analogies, we witness leaps in conceptual understanding. Cosmological unity is demonstrated by this leap.



(Based Domain)   (Target Domain)

Figure 1. The system of acceleration and the gravitational field apply the same laws of physics.

Table 1. The Principle of Equivalence through Analogical Inference, Prediction through the Equivalence Principle, and the Formation Process of New Scientific Theory

Analogues	Premise 1 <Equivalent principle, inertia and gravity are equivalents. Integrating the inertial system of Newtonian theory and the gravitational field in the direction of physical symmetry >.	Premise 2 <Thought experiment> Extend the theory of special relativity to a non-inertial frame>.	Conclusion <Predictions based on thinking experiments, real experiments, and the formation of new general relativity theories>.
A spacecraft accelerometer (based domain)	The observer in the accelerometer (spacecraft) of gravitational acceleration(initial condition).	Light (photon) is coming into the spaceship(initial condition).	
	A force equal to gravity acts (resulting phenomenon).	Light bends in the spaceship. The greater the acceleration, the more the light bends. In other words, the traveling distance of light in the spaceship is getting longer and longer (resulting phenomenon).	
	Inertia in the inertial system, Newton's Second Law (applicable theory).	It is possible only inside the acceleration systems where the special relativity theory of inertial systems is not applied (applicable theory).	

Earth's gravitational field (target domain)	Observer in the gravitational field **(initial condition)**.		Light (photon) enters the gravitational field**(initial condition)**.
	Gravity at work (resulting phenomenon).		The light will bend. (observation successful after prediction). As the mass increases, the gravitational field becomes larger and the light bends a lot. In other words, time and space stretch.
	Newton's law of universal gravitation that acts between objects (applicable theory).		Eventually, time and space are bent because of the gravitational field caused by matter (composition of the gravitational field equation in mathematical symmetry to form a new general relativity applied).

First, gravity distorts time and space. When light travels along the shortest geodetic line, it is bent by the distorted influence of time and space. <Prediction>

Furthermore, Einstein stated that it was a “distortion of space and time,” and gravity is a phenomenon that arises only when space and time are distorted.

When there is a substance, time and space are distorted. Substances have mass. In the theory of special relativity, mass and energy are equivalent. If a substance has energy, it is natural that the energy affects its surroundings. Such effects manifest themselves in the form of time and space being bent. Material does not simply sit still but bends time and space as well. As an object gets heavier, or has more energy, the more time and space it bends; as it moves farther away, it causes less bending. In the special theory of relativity, time and space are flat since acceleration is not considered. Yet, in the theory of general relativity, acceleration—that is, gravity—is implicated in the distortion of time and space. In this bent time and space, it is believed that light follows the shortest path (geometry) just as matter particles do (Hawking & Mlodinow, 2005, p.44).

A key message of general relativity is the fact that both space and time are also dynamic quantities. As opposed to Newtonian mechanics in which time and space are first given and then phenomena occurring as matter exist in that space, it is rather that time and space are bent to create the effect of gravity because matter is energy. Such time and space are, on the contrary, determinants of matter's motion. Depending on how time and space are bent, matter moves in accordance with it.

Below is Einstein's gravitational field equation, which states that matter determines the curvature of space. This gravitational field equation has complete mathematical symmetry:

(**space-time curvature) ∝ (mass-energy density).**

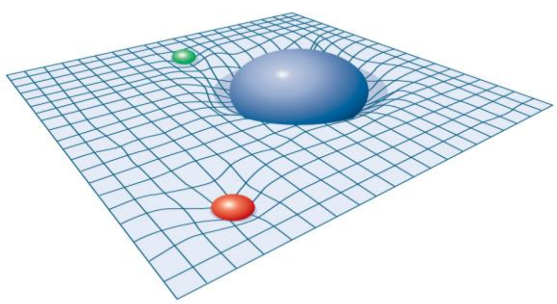


Figure 2. The greater the gravity, the larger the space-time curve. This image represents four-dimensional space-time as two-dimensional space. This basic space-time can also represent all important properties of real space-time.

Time and space are fields, and fields have energy. Energy is also a substance according to the theory of special relativity. In the end, space and time, energy, and materials are all closely connected, and they compose the essence of nature. According to general relativity, they are all connected, not separate.

If gravity did not exist in the universe, therewould be flat four-dimensional space time in which Euclidean geometry was established. But with the matter present everywhere, the gravitational field is formed, and as a result, space and time are curved, establishing non-Euclidean geometry. According to the field equation of general relativity, light does not travel straight in a gravitational field, but bends. It was recently observed that the light from a distant quasar was bent by the gravitational action of the sun, and precise information has been obtained. Gravity's bending of light's path has a similar effect to a lens, so it is called a gravity lens.

When the sun is almost straight with a distant star, the star's light is bent by the sun's gravitational field, making its apparent position different. In general, it is very difficult to observe this effect. This is because sunlight makes it difficult to observe stars in the sky near the sun. However, it can be observed during an eclipse when the moon covers the sun. In 1919, a British expedition that observed a solar eclipse in West Africa proved that light can be bent by the sun's gravity (Hawking, & Mlodinow, 2005, p.44). The theory of special relativity states that energy and mass are the same entity, and where there is energy, there must also be mass (where mass means gravity attracted by gravity). Even light has mass because light carries energy. It is therefore possible to say that the path of light is bent as it passes near the sun due to the sun's gravity pulling light (Feynman, 1995, p.200).

With the idea that gravity and acceleration are synonymous, this is a theory that indicates that if there are substances, the surrounding time and space will be distorted, which in turn allows time and space to be treated exactly as substances.

1) In an elevator accelerating upward, light passing horizontally appears to be bent.

<Thought Experiment in an Accelerometer>

2) The same physical law applies to an accelerating elevator and an elevator on which gravity acts.

<Equivalent Principle and Symmetric Principle (Covariation Principle)>

3) If the equivalent principle is applied, the light will look curved even in an elevator with gravity.<Thought Experiment with Gravimeter>

4) Since light always travels straight, it is not the light that is bent, but the space. <Mass causes space to bend>

5) Since mass and energy are equivalent and time and space are bound, mass and energy bend time and space.

Second, Mercury's orbit deviates from calculations based on Newtonian physics. Mercury's perihelion, which orbits around the sun, moves little by little. This is because the actual orbit itself moves due to the uneven distribution of the solar mass or the influence of other planets near it. The perihelion's shift can be calculated using Newtonian mechanics. Nevertheless, the perihelion of Mercury, which has the closest orbit to the sun, shows differences between the values calculated based on Newtonian mechanics and the values from actual observations. Referring to this difference in general relativity, Einstein claimed that space bends greatly around the sun, which has a large mass, and Mercury's orbit bends greatly because of this. Assuming this is a two-body problem in which the sun and Mercury exist without taking into account the effects of other planets, there should be no difference since elliptic orbits are formed according to Newtonian mechanics.On the other hand, if the movement of Mercury is calculated according to general relativity, the difference is evident because it is not a closed orbit. This is because the sun's gravitational field is considered mass, and this gravitational field created by mass is responsible for shifting Mercury's perihelion. The large gravitational field around the sun reproduces a smaller field, and this small gravitational field must be calculated to determine Mercury's perihelion. According to the phenomenon of Mercury's perihelion shift, the greater the gravity (i.e., the more that space is bent), the greater the error of the universal gravitation law.

Einstein's theory of relativity was applied to explain already known data rather than anticipated data. Nevertheless, since this was not a forecast, people had to wait until a solar eclipse occurred on May 29, 1919, when two astronomical teams led by British astrophysicist Eddington measured how much light was bent by the sun.

Third, the theory of general relativity predicts another phenomenon called gravitational redshift, where the length of a wave increases as more energy is lost when light is emitted from a gravitational field into space. In addition, the cycle of time corresponding to the wavelength of light becomes longer, so time moves more slowly in a gravitational field than in space. This is called gravitational time dilation(Hawking & Mlodinow, 2005, pp. 44–45).

Also, bending light means that space is bent.Gravity means"space is bent." Of course, it is not just space that bends, but time as well. The concept of bending time means that time changes. Consequently, in places of high gravity, time slows. Alternatively, space is stretched by a strong gravitational field, but since the speed of light cannot be increased and remains the same, it is only possible for light to cover the increased distance if time passes slowly within the stretched space. The gravitational field bends time and space, increasing the travel distance and the arrival time of light, ultimately increasing the wavelength. This can be considered as a form of Doppler effect for light. Special relativity theory can also explain the phenomenon of the wavelength of light increasing and a time delay occurring when the moving distance of light increases with the magnitude of the relative speed of a moving spacecraft. However, unlike special relativity, it is not relative, but rather, the stronger the gravity, the more space increases, making the flow of time absolutely slow.

After all, what does it mean to say that the speed of light is independent not only of the observer and light source speed, but also of the gravitational field and acceleration? Light changes its wavelength, rather than its speed. What we see are the effects of this. The property of a unique light wave is displayed in this manner. As can be seen, Einstein's theory of relativity is founded on the principle of the absolute speed of light. Einstein said there was a problem with how the theory was named relativity.

There are two reasons why gravity can slow down time:First, in general relativity, the equivalent principle that gravity cannot not be distinguished from acceleration is established. As acceleration is a number of uniform motions getting faster, it ultimately is a velocity-related physical quantity and can mean that the accelerometer is also slowing down time. Think about the example of two clocks being placed at two different heights and a free-falling elevator passing from point to point very near the clocks. Consider that the high position is A and the low position is B.

Gravitational acceleration at A will be less than that at B. Let us say these clocks are observed from a free-falling elevator. The inertial reference system exists in the elevator due to its gravity-free phase. There is no doubt that special relativity theory can be applied to this inertial reference system. The gravitational time dilation of special relativity results from the fact that time moves more slowly as the relative motion speed increases. The relative speed of the clock felt by the observer in the free-falling elevator would be much greater at point B, where acceleration is high, than at point A. The observer on the elevator will therefore feel that the clock at point B, close to the surface of the Earth, runs more slowly than at point A. This indicates that time flows more slowly in places where gravity is greater than it does in places where gravity is weaker.

Since the Lorentz transformation, which is used to determine the time (amount) that slows down, can only be applied when the velocity is constant, the special theory of relativity can only be established with constant velocity. The general theory of relativity is an equation that can be applied to accelerometers as well.

Second, it can be explained that the observation distance of light differs depending on the coordinate system described in the special theory of relativity. One can see that the observation of light paths passing through time and space bent by gravity is not the same as observation from the outside. Light that is in a strong gravitational field is observed to travel along the shortest path in three-dimensional space, which can be explained by the same principle, since the distance to observe light coming out of a long, curved path is longer from the view of an external observer.

Fourth, there exists a gravitational wave that radiates at the speed of light from the huge mass that caused the acceleration. A gravitational wave is the distortion of time and space transmitted as a wave when a celestial body with a large mass undergoes a sudden change in mass due to an explosion or collision. However, gravitational waves are extremely small, so they are difficult to detect.

Fifth, a black hole is the final stage of a giant star. Stars that are heavier than the sun lose energy by emitting light through fusion reactions, causing their own gravitational contractions. As the star contracts, its density increases infinitely. Thus, the gravity on the surface of the star becomes higher and higher and the space surrounding it becomes extremely twisted. Neither matter nor light can escape in this situation.

With the thought experiment, we discovered that when space increases by gravity, time is delayed, and the stronger the gravity, the greater the delay. That is, the object moves toward the delayed time.

If a star contracts and its density becomes higher and closer to its center, its gravitational field will grow bigger. With the passing of time, the star’s signal becomes redder or weaker as the arrival period of the floor increases in duration. Eventually, the star will become so faint that we will no longer be able to see itfrom a distance. All that will remain is a black hole in space.An event horizon is the boundary at which the escape speed becomes the speed of light, and the larger the mass of the black hole, the larger the radius. In the event of an object entering the event horizon, it appears that it falls into the event horizon indefinitely; however, since time is infinitely stretched, it appears to exist as if it were observable.

The 2020 Nobel Prize in Physics was awarded to black hole researchers, one of the most dramatic and romantic phenomena in the universe. The award recipients were physicists who predicted that black holes exist in space, and astrophysicists who proved the existence of huge black holes at the center of our galaxy through real-world observations. Black holes only existed as "concepts" up to thatpoint,and even Einstein was unsure of their existence, but these scientists proved that they do exist.

Conclusion

Einstein believed that the substance of Aristotle's "why" and Newton's "how" could be understood in different ways. Rather than starting from a supernatural god, the theory of relativity was derived from existing theories and observations. This is more natural than a kind of supernatural thing that includes the psychological factor of aesthetic sense. It is not that force is applied, but that time and space are bent by mass and energy, and all objects move in response to space and time, bent by inertia. Einstein's field-equation does not presuppose anything transcendent, and the simplicity of explaining the bending of time and space by energy density based on the absolute speed of light is aesthetically beautiful.

The process of integrating into relativity theory can be seen as a dialectical process. In the end, this dialectical structure can be said to be the principle of organizing scientific theory as a dialectical method of human reasoning.

Acknowledgements,

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017S1A5A2A01023529).

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