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Issues Left in General Relativity

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Abstract— **From ancient Greece to modern times, philosophers and scientists have developed a history of thought processes that seek to find the cause of gravity that causes objects to fall. Today, Einstein explained the phenomenon of gravity that the curved space was gravity. General Relativity expresses the phenomenon of gravity very strictly, but its origin and generation mechanism of the force of gravity are not well explained; the explanation of reason is insufficient why the force of gravity is generated when the space curves.**

In this paper, curved space, or curvature of space, is purely mathematical geometric quantities, but with the help of continuum mechanics, it is shown that they are related to actual forces. Given a priori assumption that space as a vacuum has a physical fine structure like continuum, it enables us to apply a continuum mechanics to the so-called "vacuum" of space.

Applying the continuum mechanics of space to General Relativity, the mechanism of gravity has shown as one possibility.

Keywords— General Relativity; Curvature; Gravity; Space-time; Continuum mechanics; Acceleration field; Curved space.

1. INTRODUCTION

From ancient Greece to modern times, philosophers and scientists have developed a history of thought processes that seek to find the cause of gravity that causes objects to fall. After all, today's theory of gravity was established by Copernicus, Kepler, Galilei, Newton, and Einstein. Einstein explained the phenomenon of gravity that the curved space was gravity. Although the explanation is correct, the interpretation of "the force of gravity" that Copernicus, Kepler, Galilei, Newton and others emphasized from the days of ancient Greece was lost. He compromises in the easy concept of "resistance force of space-time", that is, gravity is only felt when you resist space-time.

In General Relativity, the phenomenology of gravity is well explained, but the origin of gravity is only the curved space, and there is no explanation as to why things move and fall when space curves, and detailed examination has not been done. There is still room for future development. It is our experimental rule that the action of force is necessary for an object to move or start moving. This is a pending problem in General Relativity.

According to Einstein's theory of General Relativity, the following Fig.1 is often seen and explained in general books, but it is an unfriendly explanation. After all, it can only be understood that a small object is drawn into the space-time depression around the Earth and falls, and lacks a clear principle of why the small object falls.

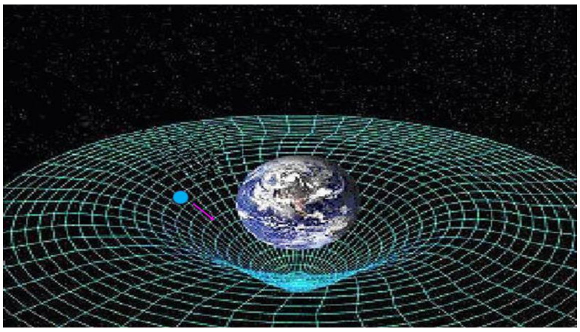


Fig. 1. Curved space around the Earth.
(https://ord.yahoo.co.jp/o/image/)

Concerning the explanation of Fig.1, an explanatory drawing depicts the state where the Earth is dropped into a two-dimensional grid pattern plane. As can be seen from the explanatory drawing, a state in which the lattice pattern is distorted can be visually recognized, and the distorted (or curved) lattice pattern itself can be interpreted as gravity. If this illustration is likened to ordinary, it is the same as a heavy object sinking on a trampoline.

In this figure and description, the flat grid-like space is depressed due to the mass of the Earth. It's just a misconception that the small object rolls toward the periphery of the dent, but it is not a consistent explanation of the relationship between the Earth, the curved space, and the falling small object.

Perhaps this figure seems to be stated where the plane of the lattice pattern drawn in two dimensions is dented and the lattice pattern is distorted, that is, the distorted lattice, like the state where the Earth sinks on the trampoline. The pattern itself is gravity. After all, it's not a convincing explanation, because we have the impression that small objects are drawn into the hollow space around the Earth and fall down.

In General Relativity, geodesic is a generalization of a "straight line" over a curved space-time. The world line of particles that do not receive any external force other than gravity is a kind of geodesic line and is important. In other words, particles in free motion or free fall move along the geodesic line. However, in general, movement requires force to move. There is no mechanism to explain force generation.

The following chapter explains “History of Trying to Find the Cause of Gravity”, next chapter explains “Remaining Problem in General Relativity” and last chapter briefly introduces the concept of “Mechanism of Gravity”.

2. History of Trying to Find the Cause of Gravity

Let's take a brief look at the process of consideration by philosophers and scientists about the phenomenon of gravity that causes all objects to fall. In the Greek era, they were interested in why objects fall, as well as considering the view of the universe. Aristarchos's view of the universe first showed the idea of the Copernican theory that the sun is at the center of the universe, and the Earth and planets orbit around it in the same way.

Although we think that the ideas of Aristarchos from 2300 years ago are natural for us today, they were ignored at that time and criticized by Aristoteles. Aristoteles established an earth-centered cosmology that all objects have weight and fall toward the Earth. It is a rationale for the Earth being the center of the universe. Aristoteles sought the reason for the fall phenomenon from the root element of matter, and established cosmology that the Earth is the center of the universe.

Later, Copernicus advocated sun-centered cosmology and the Copernican theory appeared. It is the reappearance of the Copernican theory of Aristarchos. However, it has a drawback that it is much less accurate than the Earth-centered space model of Ptolemaeos that mathematically completed the mainstream theory. Kepler discovered the three laws of Kepler's planetary motion based on the vast amount of precision astronomical observation data accumulated by astronomer Brahe. From this point, the refinement of the Copernican theory by correct orbit calculation begins.

From the experiment of the falling motion of rolling an iron ball on the slope by Galilei, the relationship between speed, acceleration and time was shown and the theory of inertia was established.

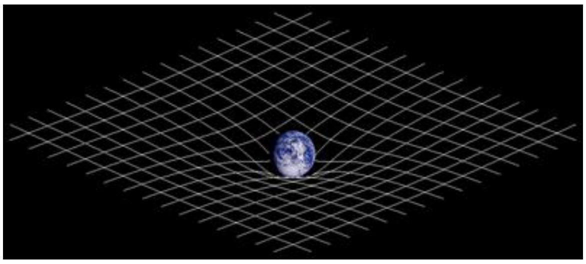
Batons for elucidating the phenomenon of gravity were handed to Copernicus, Kepler, Galilei, and Newton in that order. By comparing the falling apple and the moon around the Earth, and thinking that the moon is also falling on the Earth, Newton selects Kepler's theory that attractive force acts across the space. The three laws of Kepler's planetary motion were derived from observational data, and it was unclear why those laws hold. The result is that the mathematical consequence of the universal gravitational formula brought about three laws of Kepler's planetary motion. One law explained the falling phenomenon and the motion of the celestial body at the same time. The law of universal gravitation was positioned as a definite law explaining the force of gravity. And the new baton was handed over to Einstein from Newton.

3. Remaining Problem in General Relativity

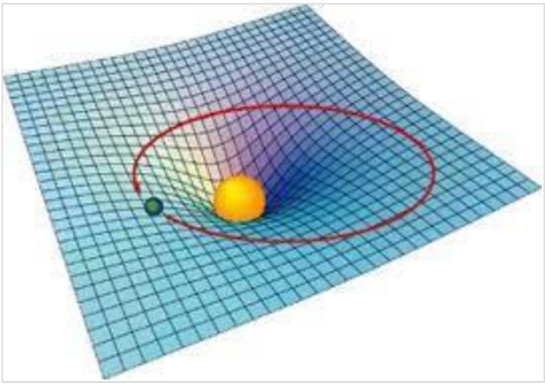
General Relativity explains the phenomenon of gravity, but at present it does not explain why gravity occurs. Unfortunately, General Relativity seems to have compromised the explanation of the phenomenon of force.

As mentioned before, geodesic is a generalization of a "straight line" over a curved space-time. The world line of particles that do not receive any external force other than gravity is a kind of geodesic line and is important. In other words, particles in free motion or free fall move along the geodesic line. However, in general, movement requires force to move. There is no mechanism to explain force generation (Fig. 2 (a)).

Furthermore, in General Relativity, gravity is thought to be a consequence of the geometry of the curved space-time, not of force, and the source of the space-time curvature is the energy momentum tensor (for example, representing matter). Thus, the orbit of a planet orbiting a star is a projection of a geodesic on a curved four-dimensional space-time into three-dimensional space (Fig. 2 (b)).



(a) A hollow space around the Earth.
(https://ja.wikipedia.org/wiki/)



(b) An object that falls to the bottom of a hollow space.
(https://ord.yahoo.co.jp/o/image/)

Fig. 2. Explanation of gravity by General Relativity.

Where did the force go? Where did the force exerted by gravity, which plagued many philosophers and scientists such as "gravity is a force", gone?

Einstein came to think of gravity as a kind of semantic illusion that can only be felt when resisting space-time. What is the relationship between curved space-time and gravity? Gravity was the resistance that appeared because the hand that was supporting the object trying to flow as it was in the space-time interfered. If you leave yourself to something like a flowing stream of curved space-time, you will not feel the force as resistance (just like as free fall). A force as gravity arises only when countering a flow.

This explanation seems to be an unconvincing compromise for the gravity.

General Relativity expresses the phenomenon of gravity very strictly, but the origin and generation mechanism of the force of gravity are insufficient. The current situation is that there is no convincing explanation of why gravity occurs when the space curves.

It is considered that there is room for future development as the remaining issues to be considered.

4. Mechanism of Gravity

Curved spaces, or curvatures of spaces, are purely mathematical geometric quantities, but with the help of continuum mechanics, it is shown that they are related to actual forces. Finally, the mechanism of gravity is mentioned. Most mathematical expressions are omitted in this article, so please refer to the references for mathematical explanations [1-9].

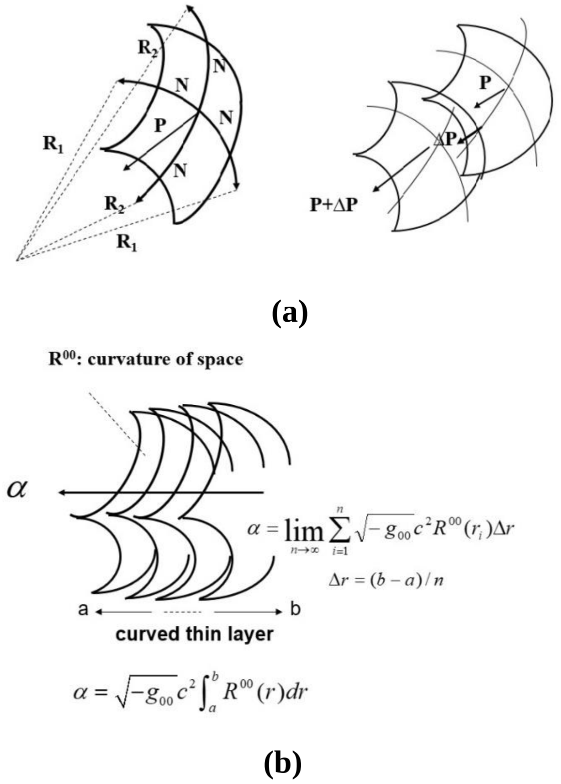
First of all, focus on one thin film layer in a curved space as shown in Fig.3.

It is now understood that the membrane force on the curved surface and each principal curvature generates the normal stress "*–P*" with its direction normal to the curved surface as a surface force. The normal stress "*–P*" acts towards the inside of the surface as shown in Fig.3 (a).

A thin-layer of curved surface will take into consideration within a spherical space having a radius of *R* and the principal radii of curvature that are equal to the radius (R_1=R_2=*R*). Since the membrane force *N* (serving as the line stress) can be assumed to have a constant value, the following equation:

$-P = N \cdot (2R^{00})^{1/2} = N \cdot (1/R_1 + 1/R_2)$ indicates that the spatial curvature R^{00} generates the inward normal stress *P* of the curved surface. The inwardly directed normal stress serves as a pressure field.

When the curved surfaces are included in a great number, some type of unidirectional pressure field is formed as shown in Fig.3 (b). A region of curved space is made of a large number of curved surfaces and they form the field as a unidirectional surface force (i.e. normal stress). Since the field of the surface force is the field of a kind of force, the force accelerates matter in the field, i.e., we can regard the field of the surface force as the acceleration field. A large number of curved thin layers form the unidirectional acceleration field (Fig.3 (b)). Accordingly, the spatial curvature R^{00} produces the acceleration field α . Therefore, the curvature of space plays a significant role to generate pressure field.



(a) curvature of space plays a significant role. If space curves, then inward stress (surface force) "P" is generated ⇒ A sort of pressure field; (b) a large number of curved thin layers form the unidirectional surface force, i.e. acceleration field α .

Fig. 3. Thin film layer in a curved space.

In Fig.3(b), the mathematical formula of

$\alpha = \sqrt{-g_{00}} c^2 \int_a^b R^{00}(r) dr$ gives the concept of gravity generation mechanism.

Here, α : acceleration (m/s²), $g_{00} (\approx -1)$: time component of metric tensor, a-b: range of curved space region(m), *c*: velocity of light, R^{00} : major component of spatial curvature (1/m²).

As shown in Fig.4, the gravitational field around the Earth is multiply covered by concentric or spherical curved spaces centered on the Earth.

Considering the case of the Earth, the curvature of space is spherically symmetric about the Earth and is fixed to the Earth, so the Earth itself cannot move due to the curvature of the space generated by the Earth.

However, as shown in Fig.5, the apples on the Earth are independently in the curved spatial region of the Earth. Since the apple exists in the curved spatial region from the curved spatial layer at the apple's position to the curved spatial layer at the distant position, the apple is pushed by the generated curved space (i.e., pressure) and falls.

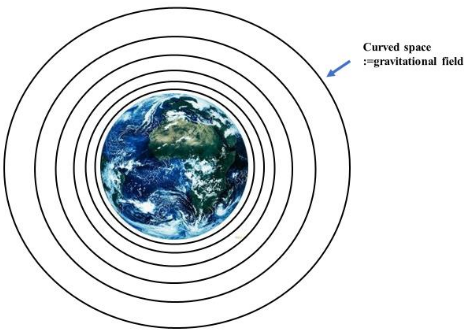


Fig. 4. Curved space.

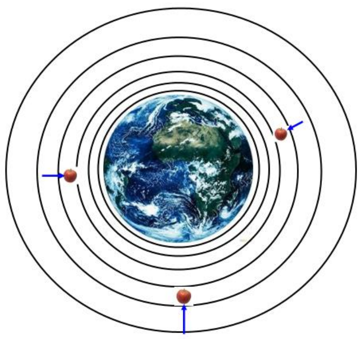


Fig. 5. Apples on the Earth.

Fig. 6. Surface force toward the center of the soap bubble.

Considering the dynamics of the soap bubble surface with Fig.3, you can see the generation of gravity. The continuum mechanics understands that the surface of the soap bubble is swollen by surface tension, but in fact, a force toward the center of the soap bubble is acting. If this is applied to the space as it is, the space curved in a spherical shape applies pressure toward the center of the sphere. This is the reality of gravity (Fig. 6).

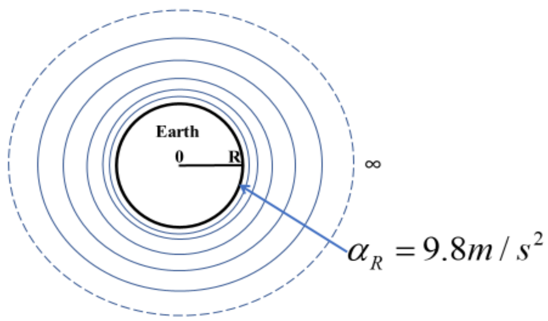
Considering this, if the space is artificially curved in a certain area, gravity will be generated there, and the material in the gravitational field should move due to the space pressure. The problem is how to curve the space. Not only the mass but also the energy there can curve the space.

The mass on the Earth will not be pulled by the Earth and fall, but will be pushed and fall in the direction of the Earth due to the pressure of the field in the curved space area around the Earth.

Fig.7 shows a concentric curved space area around the Earth. Distance of radius R from the center of the Earth is the surface of the Earth.

At a distance from the Earth to an infinite point, the space becomes flat space without being affected by the gravitation of the Earth. The point at infinity is indicated by a symbol ∞ and a dotted line.

The accumulation of surface forces in a curved area of space from the Earth's surface R to the point at infinity (∞) gives gravitational acceleration on the Earth's surface, i.e., $\alpha_R = 9.8 m/s^2$.



$$\alpha = c^2 \int_R^\infty R^{00}(r)dr = c^2 \int_R^\infty \frac{1}{2} h_{00} \frac{1}{r^2} dr = -\frac{1}{2} c^2 h_{00} \left[\frac{1}{r}\right]_R^\infty = -\frac{1}{2} c^2 h_{00} (0 - \frac{1}{R}) = \frac{1}{2} \frac{c^2 h_{00}}{R}$$

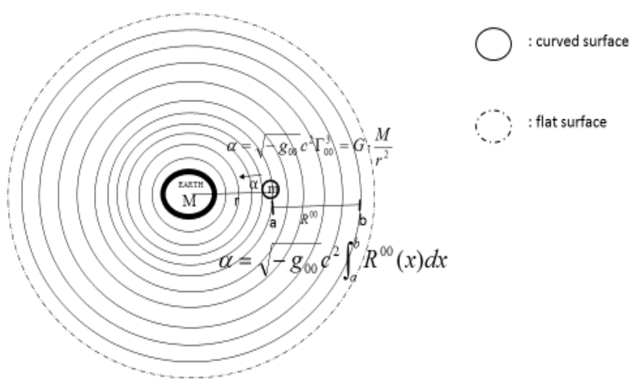


Fig. 7. Mechanism of gravitational acceleration generation on the Earth's surface.

The gravitational acceleration α is described in the following equation [3, 4, 9].

$$\alpha = c^2\int_R^\infty R^{00}(r)dr = c^2\int_R^\infty \frac{1}{2}h_{00}\frac{1}{r^2}dr = -\frac{1}{2}c^2h_{00}\left[\frac{1}{r}\right]_R^\infty = -\frac{1}{2}c^2h_{00}(0-\frac{1}{R}) = \frac{1}{2}\frac{c^2h_{00}}{R}$$

where, the deviation h_{00} of the metric tensor g_{00} from the flat space (η_{00} = -1) on the Earth's surface becomes: $h_{00} = \frac{2GM}{c^2R}$, R^{00} is the major component of spatial curvature, c is the speed of light, G is the Gravity constant, M is the Earth mass.

Substitute the values of the Earth radius R=6.378×10^{3}km, GM=3.986×10^{5}km^3/s^2, c=3×10^{5}km, we get the following values respectively:

The amount of displacement of the space on the Earth's surface: $h_{00} = 1.389\times10^{-9}$.

Curvature of space on the Earth's surface: $R^{00} = \left(\frac{1}{2}h_{00}\right)/R^2 = 1.71\times10^{-23}/m^2$.

Gravitational acceleration on the Earth's surface: $\alpha = 9.8m/s^2$.

Fig.8 shows the mechanism of gravity generation. In the upper diagram of Fig. 8, there are mass bodies A and B, and the space around each mass body is curved. As already explained, the mass B is pushed out of the curved space field generated by the mass A, and the mass A is pushed out of the curved space field generated by the mass B, so that they will move in the direction of opposition to each other. In the lower diagram of Fig.8, mass A is a giant mass of the Earth, and mass B is a light apple.

Apple is pushed from the vast curved space area of the Earth and go straight to the Earth. On the other hand, the Earth is also pushed from the narrow-curved space area of the apple and go straight to the apple. Since the mass of an apple is smaller than that of the Earth, the range of the curved space is small and the acceleration with respect to the Earth is almost zero. In effect, it looks like an apple is pulled by the Earth and falls [4, 9].

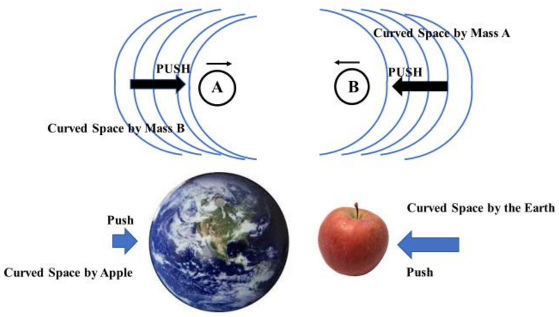


Fig. 8. Apple and the Earth are pushed out of a curved space and collide.

5. Conclusion

From ancient Greece to modern times, philosophers and scientists have developed a history of thought processes that seek to find the cause of gravity that causes objects to fall. Today, Einstein explained the phenomenon of gravity that the curved space was gravity. General Relativity expresses the phenomenon of gravity very strictly, but the origin and generation mechanism of the force of gravity are insufficient. The current situation is that there is no convincing explanation of why gravity occurs when the space curves.

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