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On the Physical Nature of Einstein's Gravitational Lensing Effect

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Abstract

Gravitational lensing has become a powerful research tool for exploring the distribution of matter and energy in the universe nowadays, as glare phenomena around the Sun and massive galaxies are indeed observed on the Earth. What is the physical nature of gravitational lensing effect? Both Newton's law of gravitation and Einstein's theory of relativity are difficult to physically explain these glare phenomena. This study points out that the observed glare around the Sun and large galaxies is a result or product of the orthogonal interaction of high-energy particles emitted from different star light sources. It shows a new physical state associated with abnormal high mass-energy density.

Keywords

Gravitational Lensing, Newton's Law, Einstein's Theory, Perpendicular Collision

1. Introduction

Gravitational lensing is used as a research tool for exploring the distribution of matter and energy in the universe. It can show the redirection or bending of light rays traveling in the gravitational field of an object, which is predicted by the general relativity and commonly observed near massive objects like the Sun, other stars, and distant galaxies. This optical phenomenon is like the refraction of light through a lens. However, lens such as glass lens is usually made of transparent material surface for the spherical part of the optical element. There are two main differences between a glass lens and a gravitational lens. The former has a defined focal point while the latter does not necessarily have a unique focal point, but only a focal line [1]. As indicated by Lodge in 1919, who pointed out that it is "not permissible to say that the solar gravitational field acts like a lens, because it has no focal length" [2]. But, as in the Einstein's 1936 paper, his title used the phrase "lens-like" instead of "lens" [3]. Therefore, gravitational lensing is well approximated to a lens from an analogical view and widely used as an astronomical detection terminology [4] [5] [6] [7] [8].

The first one of mentions about "a massive object capable of bending the trajectory of a light ray due to its strong gravitational field" was made by Erasmus Darwin (1731-1802) who was a famous physician and a scientific popularizer [1]. Then, some others tried to estimate the effect of bending light trajectories, named the gravitational lensing (or lens) since the Einstein's 1936 paper [4] [5] [6] [7]. Obviously, this thought was originated from and influenced by Newton's gravitational law, because the deflection of light emitted by stars with its particle mass can be attracted by a massive object [9].

A hundred years ago, two British expeditions measured the deflection of starlight by the Sun's gravitational field during a total solar eclipse on May 29, 1919 and confirmed the prediction made by Einstein's general relativity (GR) [10] [11]. Before the GR proposed, Einstein had published a review on the theory of special relativity (SR) and mentioned that the light rays are bent by the gravitational field [12]. Four years late, another paper about the influence of gravitation on the propagation of light was published in 1911 [13]. From the two theories of SR and GR, he recognized that the gravitational field of the Sun would be strong enough to produce a measurable effect on the bending of light by its own field. Today, many physicists around the world are involved in studying the consequences, so that the discipline receives the generic name of gravitational lensing as a research tool in astronomy and cosmology to examine the deflection of light by gravitational field [8] [14] [15] [16] [17].

All expeditions and consequences confirmed some effects that are produced by a gravitational field on the path of a ray of light traversing a massive stellar object. For more details, if the light source is at a right distance and bright enough, and if the interposed object is sufficiently massive and close to the line of sight, the gravitational field of the interposed object acts like a lens, focusing the light and producing some effects such as magnification of sources, image distortions, replicating images of a single source, and shifting the apparent location of a light source. These four consequences of gravitational light deflection are collectively known as gravitational lensing effects [1]. Among them, the magnification of light source and shifting the apparent location of light source should have a clearly physical explanation rather than give only some optical phenomena. However, theoretical answers are currently still insufficient.

Several years ago, a review article proposed some questions about gravity such as the phenomenon of gravitational lensing as well as observed rotational velocities of stars orbiting the galactic center that are deviating from Newton's law [18]. Recently, another question asked whether the cosmological constant affects the cosmological gravitational bending of light [19]. To clarify these questions, this paper re-examines the physical nature of Einstein's gravitational lensing effect from three aspects. The first is to explain the difference between the Newton's gravity and the Einstein's gravity. The second is to explain the nature of gravity. The third is to explain the nature of Einstein's gravitational lensing effect. At the end of the paper, conclusions and discussion are given.

2. Gravity from Newton and Einstein

Shortly, gravity is mostly referred as force by the attraction between two objects or two particles based on the Newton's gravitational law. We can see that apples or other objects freely fall down to the ground and all planets move around the Sun as well as satellites move around its planet. Both of an apple and the Earth or both of a planet and a satellite can be seen as two adjacent mass objects. After summarized the many works of predecessors, Newton proposed his gravitational law in 1687, which stated that any object in the universe attracts any other with a force varying directly as the product of their masses and inversely as the square of the distance between them [20].

In symbols, the magnitude of the attractive force $\boldsymbol{F}_{A,B}^{m}$ is equal to the gravitational constant G multiplied by two masses (m_A and m_B) and divided by the square of their distance $r_{A,B}$. The formula of universal gravitation is,

$$\boldsymbol{F}_{A,B}^{m} = G\frac{m_A \cdot m_B}{r_{A,B}^2}\boldsymbol{k}, \tag{1}$$

where $\boldsymbol{k}$ indicates a vector from the small mass to the large one. The Newton's law from Equation (1) is a statistical or empirical relation because there is a statistical constant G. The term $\frac{m_A \cdot m_B}{r_{A,B}^2}$ physically expresses an area distribution of two-mass product. Thus, we have not yet known the physical meaning of gravitational constant G. During the Newton years, he described the connection by only two adjacent objects in the simplest universe. The law of universal gravitation can not only be explained by many natural phenomena, but also has been widely used in space science and daily life. In other words, Newton's gravitational law is extremely successful in its practical applications.

Newton himself, however, was not satisfied with the characteristics of his gravitational law. He was worried about why an object can act on another distant object through a vacuum without any medium to transmit action and force from one to the other. He even did not believe that anyone with full competence on philosophical issues would fall into this kind of thinking. Newton panicked at the explanation of the nature of gravity because it can be very well used in practice but it is absurdly explained in theory.

The two basic expressions in Newtonian mechanics are the second law $\boldsymbol{F}_{B}^{m} = m_B\boldsymbol{g}$ and the law of universal gravitation. Equation (2) can be obtained from these two expressions based on their equivalence between $\boldsymbol{F}_{B}^{m}$ and $\boldsymbol{F}_{A,B}^{m}$,

$$\boldsymbol{g} = G\frac{m_A}{r_{A,B}^2}\boldsymbol{k}. \tag{2}$$

In Equation (2), a coefficient G is independent of distance and mass. The magnitude of the acceleration $\boldsymbol{g}$ is determined by the mass density of a large object m_A on a square plane $r_{A,B}^2$. Equation (2) shows that it brings the same acceleration to every object or particle in the space around the large object so that $\boldsymbol{g}$ is the gravitational acceleration. There are two different masses in Newton's theory. The inertial mass determines the moving state of an object under the action of force and the gravitational mass determines the amount of gravitational force that an object or a particle feels. Newton's theory regarded the constant proportional relationship between inertial mass and gravitational mass (*i.e.*, the universality of gravitational acceleration) as an unexplained coincidence.

Gravity is not the transmission of momentum in direct contact between objects or particles, but at a distance. This distance action can only be explained by massless gravitons. Gravitons are in a different direction of action from photons. Photons point from the Sun to the planets but their acceleration is zero because they are massless. So far, however, no gravitons have been detected, and it is difficult to use gravitons to interpret the present universal structure including evolutional traces of astronomical history, the formation of the Earth-Moon system, or the mass and angular momentum distribution of the solar system, also it cannot explain the opposite rotations between two adjacent planets [21].

The person who most directly doubted the nature of gravity was Einstein. He argued that gravity is not a force in the traditional sense, but an effect derived from geometry or a representation of the curved space-time [22]. The universe he understood was not flat, but there was a bending phenomenon, and the essence of gravity was the curvature of space-time. His description of the relative motion of large and small objects is as follows: Gravity phenomena such as apples falling to the ground, the Moon revolving around the Earth are because the mass of the Earth makes the space curved near these small objects. The apple and the Moon only do inertial motion in the curved space, and light will also bend with space near a massive object if some particles constructed light have their masses. Thus, cosmic space was imagined as a thin film that can be infinitely compressed. These mass-bearing objects exert pressure on this cosmic film, creating a depression. In this way, surrounding objects will move along the curved space, showing universal gravity. Einstein described the motion of the planets relative to the Sun as the curvature of space-time in relation to the mass-energy distribution. However, Einstein did not know the physical causes of inertial motion.

The actual universe could not be only two objects as described in the Newton's law of universal gravitation. In the solar system, the movement of many planets and moons relative to the Sun requires the simultaneous consideration of the relationship between them. However, the early study of physical mechanics mostly used the isolation view, and the two-body problem could be solved by linear methods. Obviously, linear methods are difficult to characterize the space-time changes of the universe. Therefore, the accelerated motion of real-world matter, such as gravitational acceleration, requires a non-linear theory.

After Newton years, beginning in the mid-19th century, physicists gave passive "vacuums", the nothingness or void that Newton had complained about, into a component of transferring force which is a field, not massless particles, such as the geomagnetic field. This had become a new concept in the physics community. At the end of 1915, Einstein first described the gravitational field as a field equation with a curved space-time in order to describe the relationship between large numbers of objects.

The left-hand side of this field equation is called the Einstein tensor and describes the geometry of space-time, such as how the curvature of space-time changes in different places. On the right hand side of the equation is the product of some constants (such as the gravitational constant G and the speed c of light in a vacuum) and stress-mass-energy tensors that contain information about matter and energy in space-time. These things are the source of the curvature of space-time. The equation means that the geometry of space-time and the things (mass-energy distributions) in the space-time are tied together by mathematical format.

Einstein's original model of the universe was unstable [10]. If there is a small fluctuation in the universe, it will expand or contract. When he became aware of this problem in 1917, an additional term of the "cosmological constant" was added to the left of his equation, as the following form,

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} . \tag{3}$$

This equation is no longer the relationship between Newton's two adjacent particles (objects), but the matter that links all the particles (objects) in the universe. Where, $R_{\mu\nu}$ is the curvature term (the Ricci tensor) indicating how curved the space is, $g_{\mu\nu}$ is a (3 + 1) four-dimensional space-time metric tensor, R is the Ricci number of scalar curvature, $T_{\mu\nu}$ is the mass-energy metric tensor for the distribution and motion of objects, G is the gravitational constant, c is the speed of light in a vacuum, and Λ is a cosmological constant artificially introduced that is proportional to the gauge tensor. The special effect of this constant term is to create some kind of repulsion in the geometry of space to balance the collapse caused by ordinary gravity. This constant gives space-time an inherent tendency to expand. As the cosmological constant is small enough, it does not change the theory's predictions about the motion of the planets in the solar system. Einstein's equations correspond the mass-energy distribution $T_{\mu\nu}$ of matter in the universe to the curvature of space-time ($R_{\mu\nu}$ and R). Finally, Einstein drove the action away from the description of gravity, presenting as a product of the shape distortion of space-time. Therefore, general relativity can be seen an extension of Newton's gravity.

Einstein was entangled in this cosmological constant because the constant term has only mathematical validity and no physical significance. When Einstein learned of Hubble's discovery of the observational analysis of "the universe is generally expanding," he admitted that he had made the "biggest blunder" of his life with the cosmological constant he had introduced. At this time, Einstein removed the constant term again. These uncertainties suggest that general relativistic equation came from speculation rather than from mathematical and physical derivations.

The cosmological equations of general relativity give the "equivalence principle" of the mass-energy and space-time distributions of cosmic matter and do not directly reflect the existence of forces. This equivalence principle can answer the law of the current motion of celestial bodies in the solar system, which can describe the motion of planets relative to the Sun more comprehensively and accurately than the Newton's gravitational law. However, it does not explain the astronomical history of the solar system or the formation of astronomical traces. It seems that Einstein implied the "force", directly giving the equivalent relationship between the "mass-energy or momentum" in space and the object trajectory, using the space-momentum distribution to describe the curvature of matter motions.

3. The Nature of Gravity

Newton's law of universal gravitation is a purely empirical summary that reflects only the quantifiable quantitative relationship between "mass" and "force", where the force acts at a distance and does not involve the nature of gravity [22]. The tricks used by the Earth with its mass to "seduce" the apples on the trees do not indicate any physically causality. Newton's law of gravity simply describes a fragment in the life cycle of an apple, in which the apple falls naturally from a tree branch. The growth of apples on branches is the result or consequence of photosynthesis [21]. Sunlight is the fundamental driving force behind the seasonal cycle of apple trees. The process of conversion between energy and force can be described that light energy acts on the apple tree, through photosynthesis (force) and the capillary of apple tree to extract nutrient particles from the ground root system to the apple, forming the potential energy and biological energy of the mature apple. Apple stores energy, water tower stores energy, animal muscle stores energy, and spring stores energy, where the storage of these energies requires a powerful role (force) to overcome inherent inertia. The release of artificial satellites is to overcome the inherent mass inertia so that the freely moving of artificial satellites exhibits that it has potential energy. After that, the prescribed motion of artificial satellites and natural satellites around the Earth no longer has the action of other forces including gravity and centripetal forces.

Einstein's GR expresses the same effect of gravity as like the force of inertia, that is, such an equivalence principle expresses the result of gravitational action and does not involve the "cause" of gravity. The "short-range line" is derived from the effect (the result) of gravity, and is also the motion route (trajectory) of objects under the action of gravity. The course of motion of an object itself is also the result of gravity rather than gravity. Therefore, general relativity, in fact, from "result" to "result", reflects only the computable quantitative relationship between "mass" and "trajectory", and has never involved the mechanism or nature of gravity.

Newton's gravity is different from Einstein's theory of general relativity. The law of universal gravitation directly shows the relationship between "mass" and "force", and the "trajectory" of the object is obtained through the force. General relativity is the implication of "force" in the field equation, which is the gravitational theory of "no gravity". Therefore, "mass" and the object's motion "trajectory" are directly linked, where the mass tells the "motion route" how to bend. General relativity completely replaces the effect of gravity with a metric approach, and then calculates the trajectory of objects, so that the space-time tells objects how to move. Therefore, what the two can show is only the result of gravitational action, and the calculation of the quantity is completed, but neither of them involves the cause, essence and mechanism of gravitational action.

The "curvature of space-time" proposed in general relativity, like "gravity", is also a difficult concept to understand. Mass tells space-time how to bend. The universe must consist of at least two mass objects. In the universe of a very large mass object and a very small mass object, there are a large space-time bending around the large object and a small space-time bending around the small object, so that the space-time bending of a large object has obviously an effect on the space-time bending of the small object. Such a space-time curvature has two mass fields. Then, a cosmic system composed of multiple objects has multiple mass fields, of which the mass field of the largest object (space-time bending) plays a leading role. The universe is space-time, so that space-time and matter are one. The concept of space-time bending, then, is equivalent to the bending of the universe, which is difficult to understand.

Forces are only reflected in the process of interaction. The interaction is related to the mass and change in the motion of objects (particles). Relative stationary or apart objects will not produce any interaction due to no force, no matter space-time is curved or not. If an object is not subjected to force, it will not move or bend. Interactions and forces can occur only between substances that undergo relative motion. The most natural way is "collision", in which the relative motion of objects (particles) is produced by interaction or forces.

Now we consider the collision of two objects or two particles interacting with each other and examine their consequences. We can pick up a chopstick at home, or pick up a branch over a riverbank and then break the chopstick or the branch into two pieces with the forces of two hands. In turn, we can also knock two chopsticks or two branches combining them together by the forces of two hands. Chopsticks and branches are separated or combined under the influence of the forces of two hands, which will change in the form and energy of the universe. The origin of this universe is so simple and surprising.

The forces of two hands are expressed as $\boldsymbol{F}_A$ and $\boldsymbol{F}_B$, *i.e.*,

$$\boldsymbol{F}_A = \frac{m_A}{r_A} v_A^2 \boldsymbol{n}_A + m_A a_A \boldsymbol{k}_A, \tag{4}$$

$$\boldsymbol{F}_B = \frac{m_B}{r_B} v_B^2 \boldsymbol{n}_B + m_B a_B \boldsymbol{k}_B . \quad (5)$$

where the term $\frac{m}{r} v^2 \boldsymbol{n}$ is a mass centripetal force with mass m and velocity v at the $\boldsymbol{n}$ direction and the term $ma\boldsymbol{k}$ is a force of mass acceleration ma at the $\boldsymbol{k}$ direction. Two terms ($\frac{m}{r} v^2 \boldsymbol{n}$ and $ma\boldsymbol{k}$) are components of the force $\boldsymbol{F}$. In addition to having mass, all objects (particles) have motion and physical characteristics related to energy, including charges (electric charge and color charge) and spin or momentum. All objects (satellites and planets) and particles or photons have their rotations and orbits, so that every particle in the universe has a radius related its moving center.

The interaction of two forces on a chopstick (or branch) is mathematically a cross-multiplication representing as,

$$\boldsymbol{\tau}_X^{+i,-j} = \left(q_A^+ \frac{m_A}{r_A} v_A^2 \boldsymbol{n}_A + q_A^+ m_A a_A \boldsymbol{k}_A \right) \times \left(q_B^- \frac{m_B}{r_B} v_B^2 \boldsymbol{n}_B + q_B^- m_B a_B \boldsymbol{k}_B \right). \quad (6)$$

where the stress $\boldsymbol{\tau}_X^{+i,-j}$ is a result of two external forces acting, the letter X represents types of result or product, the letters i and j denote different kinds of object (particle), and the signs + and − indicate different charges of object (or particle) in different macroscopic (or microscopic) worlds.

This stress in Equation (6) is like a description of mass-energy metric tensor and the evolutional tendency of object (or particle) motions with space and time because the term $ma\boldsymbol{k} = m \frac{\mathrm{d}v_k}{\mathrm{d}t} \boldsymbol{k}$ spatially shows expansion and contraction of objects (or particles) with time. It can be expanded into four terms [23],

$$\begin{aligned} \boldsymbol{\tau}_X^{+i,-j} = & \left(q_A^+ \frac{m_A}{r_A} v_A^2 \right) \cdot \left(q_B^- \frac{m_B}{r_B} v_B^2 \right) \cdot \left(\boldsymbol{n}_A \times \boldsymbol{n}_B \right) && \text{(a)} \\ & + \left(q_A^+ \frac{m_A}{r_A} v_A^2 \right) \cdot \left(q_B^- m_B a_B \right) \cdot \left(\boldsymbol{n}_A \times \boldsymbol{k}_B \right) && \text{(b)} \\ & + \left(q_B^- \frac{m_B}{r_B} v_B^2 \right) \cdot \left(q_A^+ m_A a_A \right) \cdot \left(\boldsymbol{n}_B \times \boldsymbol{k}_A \right) && \text{(c)} \\ & + \left(q_A^+ m_A a_A \right) \cdot \left(q_B^- m_B a_B \right) \cdot \left(\boldsymbol{k}_A \times \boldsymbol{k}_B \right). && \text{(d)} \end{aligned} . \quad (7)$$

The physical meaning of the stress will be given in later. Among the four terms (a, b, c, and d), the last three terms contain the acceleration $\boldsymbol{a}$. Thus, the role of the terms $\left(q_A^+ m_A a_A \right) \boldsymbol{k}_A$ and $\left(q_B^- m_B a_B \right) \boldsymbol{k}_B$ is to make the universe expand or contract at an accelerating rate, which does not exist in Equation (3) of the general relativity and in Equation (1) of the gravity.

Removing the terms of expansion and contraction of the universe from Equation (7), the remaining term (the 1st term) is like Einstein's cosmological equations. The difference between them is simply the vector form versus the tensor form, when they describe the universe. Einstein was also involuntarily involuntary in the inhibition of the contraction and expansion of the universe in the course. Therefore, the previous theories from Newton's gravity to Einstein's general relativity were all groping or testing the real world.

Physically, gravity is a quantitative description of the mass inertial motion or mass-energy distribution of all objects (particles) preserved since the beginning of astronomical evolution, rather than the interaction between them through forces. This property can be extracted from Equation (7) and physically described from the first term (a).

$$\boldsymbol{\tau}_G^{A,B} = \left(\frac{m_A}{r_A}v_A^2\right)\cdot\left(\frac{m_B}{r_B}v_B^2\right)\cdot\left(\boldsymbol{n}_A \times \boldsymbol{n}_B\right). \tag{8}$$

where the term $\boldsymbol{\tau}_G^{A,B}$ indicates the stress acted by the two external forces or the two mass centripetal forces ($\boldsymbol{F}_{CA} = \frac{m_A}{r_A}v_A^2\boldsymbol{n}_A$ and $\boldsymbol{F}_{CB} = \frac{m_B}{r_B}v_B^2\boldsymbol{n}_B$) on two objects ($A$ and B). The stress's vector is perpendicular to the plane of the two mass centripetal forces. At this moment, unlike charges ($q_A^+ \cdot q_B^- = 0$) and mass accelerations ($a_A = a_B = 0$) are not considered in Equation (8).

If the two external forces are perpendicular to each other, the modulus of stress reaches its maximum, *i.e.*,

$$\tau_G^{A,B} = \left(\frac{m_A v_A^2}{r_A}\right)\cdot\left(\frac{m_B v_B^2}{r_B}\right) = \left(v_A^2 \cdot v_B^2\right)\frac{\left(m_A \cdot m_B\right)}{\left(r_A \cdot r_B\right)}. \tag{9}$$

It represents the distribution of mass-energy density per unit area. Up to now, we can explain the stress physically. Two objects (A and B) interact with each other by forces. To resist the action of object B, the internal structure (mass-energy distribution) of object A will immediately change, forming an abnormal mass-energy density. When two objects collide, they locally form a common mass-energy density. We only know that the mass-energy density is $\left(v_A^2 \cdot v_B^2\right)\frac{\left(m_A \cdot m_B\right)}{\left(r_A \cdot r_B\right)}$ at the area $\left(r_A \cdot r_B\right)$ before they perpendicularly collide. At the moment of collision, the same mass-energy $\left(v_A^2 \cdot v_B^2\right)\left(m_A \cdot m_B\right)$ will concentrate at a very small space. Under abnormal mass-energy density, a new form of matter will appear in local space. Therefore, the modulus of stress is not a force in physics, but a mass-energy density. During this process, nuclear fusion may occur, *i.e.*, mass is converted into huge amounts of energy even a strong light can locally be produced.

Making a slight change to Equation (9) it is connected to Newton's gravity

$$\tau_G^{A,B} = \left(v_A^2 \cdot v_B^2 / G\right)\left[G\frac{m_A m_B}{\left(r_A \cdot r_B\right)}\right] = \left(v_A^2 \cdot v_B^2 / G\right)\cdot F_{A,B}^{m} \tag{10}$$

It can be seen from here that the nature of gravity is not a force, nor is it the curvature of space-time, but the distribution of mass-energy density in space. If a planet orbits a fixed point (such as the Sun with its mass m_A) following the law of inverse distance square, then its orbit must be elliptical. This is a strictly mathematical fact because the formation of elliptical trajectories needs to be satisfied, *i.e.*, a planet covers the same area of space in the same amount of time no matter where it is in its orbit, as described by one of Kepler's laws. It implies from Equation (9) where the ratio $m_B v_B^2 / r_{A,B}^2$ or the mass-energy density relative to the Sun is a constant when the planet B moves around its elliptical trajectory with variable velocity v and distance $r_{A,B}$. The manifestation of mass-energy density is associated with mass inertia including potential energy or momentum (angular momentum) [21] [23]. Equation (9) shows that at the weak field approximation, the distribution of mass-energy density can be seen as a simplified Einstein equation.

4. The Nature of Einstein's Gravitational Lensing

Equation (6) or Equation (7) should have a wide range of applications from macro to micro physics, even in astronomy [23]. Here, we only use Equation (8) to describe some new physical phenomena near the Sun and massive stars. Einstein proposed the special relativity in 1905 with two limitations. It only involves a system of uniform speed motion, without considering accelerated motion like as in Equation (7) and it does not consider the forces that change the direction of the object's motion, such as centripetal forces. In fact, the motion of the Moon in a fixed orbit around the Earth and the orbit of planets around the Sun, are not related to the centripetal force or gravity, but to the mass inertia originated from the formation of the solar system [21].

After the special relativity was proposed, Einstein began to look for a theory that could eliminate the above two limitations. Finally, he proposed the general relativity in 1915 and published his paper in 1916 [10]. This theory holds that gravity is not a force as described in Newton's theory, but a relative feature of space-time [24]. In his new theory, space and time are merged into "space-time", such that space-time participates in the physical processes of a matter motion. According to the general relativity, objects with larger masses in the universe, such as planets and stars, bend the space-time around them and determine the motion of relatively small objects. Thus, objects and light in the universe are moving in curved space-time. This concept is difficult to explain in an easy-to-understand way, because the curved motion of objects and light is not directly related to forces.

Such a GR theory would be difficult for physicists who study astronomy to understand the bending of space-time. Space-time bending is a geometric concept, so such a geometric concept of space-time is best described in mathematical language. Einstein used the method of space-time geometry developed by mathematicians in the 19th century. Thus, he discovered the equation that describes the motion of mass in the framework of space-time, which is Einstein's equation of the general relativity.

Although the general relativity's description of gravity differs from Newton's statistical relationship of particle mechanics, the results of the action of particles on other particles are the same. Newton may never have considered the problem of a light beam from an alien star being bended by the Sun's gravity. But Einstein knew before the publication of his new theory that beams of light would be bent near the Sun, although he had calculated how little the beams would bend. He wrote to an astronomer in 1913 asking if there was a way to observe stars near the Sun in sight during daytime. The answer is that the only chance to observe these stars is at the time of a total solar eclipse (the Sun-Moon-Earth in a straight line). The opportunity for daytime sunlight to be blocked by the Moon is rare. If weather is nice when the eclipse, you will see the brightness of stars which appear around the Sun just like nighttime.

Einstein proposed the inference of whether the light of a star can be bent by the gravitational pull of the Sun and hoped to compare with observations. In comparison, with photographs of stars taken during eclipses (the Sun and the Moon were located between the Earth and a distant star) and identical stellar photographs taken at night (the Sun and the Moon were not located between the Earth and the star), positions of stars should appear to be skewed. If the position of a star in the two pictures drifts, it means that the Sun's gravitational field is bending the light emitted from the star in **Figure 1**.

The outbreak of World War I prevented a German astronomical expedition from observing a total solar eclipse in Russia's Crimea region on August 21, 1914. Then a total solar eclipse occurred in 1918, but the sky was covered with dark clouds, which frustrated the observation plan of the U.S. Naval Observatory.

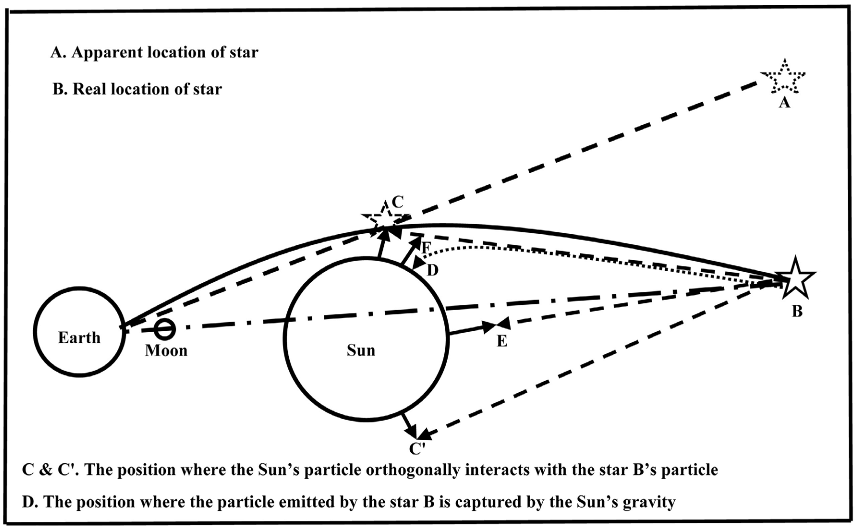

Figure 1. The Earth, the Moon, the Sun, and a real star B are along a dash-dotted straightline during a total solar eclipse while point A is the apparent position of the star observed from the Earth. The point C or C' is the position where the Sun's particle interacts orthogonally with the star B's particle. The solid-black line is the bending path of a stellar particle as determined by Einstein's GR theory. The solid-line arrow indicates the particles emitted by the Sun. The dashed-line arrow indicates the particles emitted by the real star B. The dotted-line arrows indicate the particle path emitted by the real star B but curved and captured by the Sun's gravity at the point D. The point E indicates the head-on (180-degree) collision of two particles emitted by the Sun and the star B respectively while at the point F the collision angle of two particles is larger than 90 degrees.

British researchers had another opportunity on May 29, 1919 [25]. By then, Einstein had completed the creation of general relativity and predicted that the degree of bending light was twice as large as the result of his previous hypothesis. Two sets of British observations came from Sobral in South America and Principe in Africa [11]. The analysis of the observational data is shown like the path of starlight in **Figure 1** radiating from the real location of star B. Thus, astronomers declared that observations from both places show almost no doubt that the Sun's gravity does bend the surrounding light, and that its curvature is consistent with the results given by Einstein's theory of relativity. This prediction of general relativity, confirmed by independent measurements of two very distant locations, greatly persuaded the scientific community to believe in the correctness of this theory.

In Newton's theory and Einstein's theory, the gravitational field exists in every corner of space so that all matters cannot escape the shackle of gravity. As light travels through the powerful gravitational field of the Sun, the path is deflected toward the Sun as shown in **Figure 1** by the dotted-line arrow. As the intensity of the gravitational field is known, the optical path deflection can be calculated or predicted. According to Newton's theory, the magnitude of gravity is proportional to the two-mass product of the Sun and a stellar particle. Under a strong solar gravitational field, a stellar particle that reaches the front side of the Sun should be captured by the Sun's gravity and cannot be observed by Earthlings.

Chandrasekhar cast doubt on Einstein's gravity of the Sun altering the curvature of stellar light [26]. He argued that it is only a corollary and not any precise prediction based on the theory so that it relies solely on the empirical fact that the stellar light is affected by gravity. He further noted that so far there has been no verification of any precise features of general relativity in observations, nor for some time to be expected in the future.

In **Figure 1**, we compare the results of Newton's gravitational attraction, Einstein's theory of relativity, and the collision from multiple-angle interactions between a Sun's particle and a stellar particle during a total solar eclipse. If a particle emitted from the star B reaches the Sun's Newtonian gravitational field, its path follows the dotted-line arrow. The particle velocity of radiating from the star B to the Sun is accelerated when it enters the Sun's gravitational field. It finally falls into the Sun at the point D along the path of curved dotted-line arrow. The particle of star B does not focus near the point C, so that the people on the Earth cannot observe any light spot emitted from the star B based on the Newton's gravity.

The mass and velocity of particles emitted by the star B are certain. According to the GR theory, the curvature of space-time caused by the Sun's mass is also certain. When a distant star particle reaches the curved space-time near the Sun, the particle path is certain. Particles of distant stars will not form a focus due to the action of the Sun's gravitational lensing along the bending path, so there will be no concentrated particles to form high mass-energy density at the point C.

However, bright spots were really observed at the point C. So, what is the real reason for forming the highlights? The Sun is also a luminous star. Both the Sun and the distant star B emit their particles in the surrounding space, respectively. Of these, a portion of the particles emitted by the star B reaches the Sun directly. In the periphery of the Sun, the interaction happens between particles emitted respectively by the star B and by the Sun. According to Equation (8), changes in the angle of collision between particles form changes in energy density. Only when a particle of the star B collides orthogonally with a particle of the Sun, such as at the point C or at the point C', the mass-energy density of the collision can be described by Equation (9), in where the mass-energy density reaches the maximum. The mass-energy $\left(m_S c_S^2\right)\cdot\left(m_B c_B^2\right)$ with the mass m_S and speed c_S of Sun's particle as well as the mass m_B and speed c_B of star B's particle is originally distributed on an area ($r_A \cdot r_B$) so that the original mass-energy density is $\left(m_S c_S^2\right)\cdot\left(m_B c_B^2\right)\big/\left(r_A \cdot r_B\right)$. But, after the perpendicular (or 90-degree) collision the same mass-energy $\left(m_S c_S^2\right)\cdot\left(m_B c_B^2\right)$ is concentrated in a very small three-dimensional space point C (or C') so that its mass-energy density

$$E_r = \left(m_S c_S^2\right)\cdot\left(m_B c_B^2\right)\big/ r^3 \tag{11}$$

is extreme high because the length r of the space point C (or C') is very small.

For the situation, a Sun's particle is collided with the particle emitted from the star B at the point E in opposite directions along the same straight line. The total mass-energy of head-on (180-degree) collision at the point E is the sum of their respective mass-energy [27], *i.e.*,

$$E_E = m_S c_S^2 + m_B c_B^2 . \tag{12}$$

If the collision angle is larger than 90 degrees at the point F or the collision angle is less than 90 degrees for those points located between the point C and the Earth, the mass-energy density should be

$$E_{r\alpha} = \frac{\left(m_S c_S^2\right)\cdot\left(m_B c_B^2\right)}{r^3}\cdot\sin\alpha . \tag{13}$$

where, the letter α is the collision angle between two particles emitted from the star B and the Sun. Thus, at any place of the Sun's section such as at the point F, the mass-energy density is less than that at the points C and C', namely $E_{r\alpha} < E_r$.

During a total solar eclipse, people on the Earth can observe the strongest light at the point C or the point C'. It is the position of the maximum mass-energy density generated by the orthogonal collision of particles. This bright spot (high mass-energy density) location is related not only to the particles emitted by the star B, but also to the particles emitted by the Sun. The position of the distant star was seen as at the point A by people on the Earth is an illusion. Two basic features of the gravitational lensing effects including the magnification of light source and shifting the apparent location of the light source are really the consequence of perpendicular collision or 90-degree interaction between particles emitted respectively from a distant star and the Sun. This is the physical nature of Einstein's gravitational lensing effect. People can observe a strong light ring passing the point C and surrounding the Sun, which is also named the Einstein's ring, during a total solar eclipse.

5. Conclusions and Discussion

During a total solar eclipse, it is a fact that the apparent light around the Sun observed on the Earth in the early 20th century is related to light effect of particles emitted by distant stars behind the Sun [11]. Similarly, it is also true that the Einstein ring around massive galaxies detected by astronomical instruments in recent decades is also related to the particles emitted by distant objects behind them [28] [29]. These optical phenomena observed from astronomical space should work on the same physical principle, but they are difficult to verify in a laboratory.

In astronomy, there are two major theories that are the Newton's law of universal gravitation and the Einstein's theory of relativity. If photons have no mass, neither the Newton's law of universal gravitation nor the Einstein's theory of relativity can be used to explain the enhanced bright spots that appear around the Sun. The Newton's expression of gravity must include a massive star of the Sun and an alien particle with its mass. In the Einstein's theory of general relativity, massless photons emitted from a distant star and only entered the curved space-time of the Sun cannot exhibit the gravitational lensing effect.

In the early days after the advent of the Newton's law of universal gravitation, there were some speculations about the influence of the Sun's gravity on the light path from distant stars. But the gravitational field always causes particles from distant stars to fall into the Sun, so that enhanced bright spots cannot be created around the Sun based on the Newton's law. Since the introduction of Einstein's theory of relativity, the gravitational lensing effect has been observed in two periods. One is the early observation of the gravitational lensing effect showed that light spots occurred around the curved space-time of the Sun. Another is a recent observation that the light rings appeared around massive galaxies [30]. In principle, the gravitational lensing is different from glass lenses. The gravitational lensing does not form the focal point of a light beam. It can only guess that distant lights will potentially curve around a massive galaxy but cannot physically explain the formation of a brightening ring with high mass- energy density.

The theoretical study in this paper differs from the actual situation in two ways. The first way is that, in the above theoretical study, we only considered the interaction between two particles from two different sources. The reality is that the particles from star B and the Sun are abundant. But the result of the interaction of the two particles can be fully applied to the latter case for the lots of particles. The second way is that the theoretical derivation uses low-velocity particle interactions within the non-relativistic limit. The actual particle velocity is the speed of sunlight and the speed of stellar light. Therefore, the momentum and energy in the actual situation should be considered as relativistic momentum and relativistic energy [27].

We can apply the orthogonal interaction of solar particles with the particles of distant stars to explain the enhanced light around the Sun during a total solar eclipse. The principle of enhanced light is that particles from distant stars collide orthogonally (90-degree) with solar particles at a defined position, while at other points around the Sun both collide at an angle of less than or larger than 90 degrees. The orthogonal (90-degree) collision of particles from different sources creates a distribution of high mass-energy density in space. This is clearly observed at the point C or the point C' where particles produced the orthogonal collision are emitted from the Sun and the star B. Similarly, brightness light rings that appear around massive galaxies are also the result (or consequence) of the orthogonal collision of particle beams from different light sources. Two important effects of gravitational lensing including the magnification of light source and shifting the apparent location of the light source can be explained theoretically in this paper.

The artificial construction of the heavy ion collider and the large hadron collider requires a huge cost, and their goal is to produce high abnormal mass-energy density by the collision of different particles [31] [32]. The emergence of this abnormal mass-energy density is in the hope that new physical phenomena (extreme strong light) and new substances will emerge. To obtain a high mass-energy density, a device for the orthogonal collision of two beams of particles should be used to instead of the conventional device of collisions along a straight line, namely the head-on collision. In fact, during a total solar eclipse, the enhanced bright spots around the Sun are an excellent experiment for particle collisions naturally or a natural orthogonal collider [33]. For another optical phenomenon, the Earth's aurora is formed from the orthogonal collision of solar charged particles with geomagnetic ions at the upper atmosphere near the two poles [34].

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Cervantes-Cota, J.L., Galindo-Uribarri, S. and Smoot, G.F. (2020) The Legacy of Einstein's Eclipse, Gravitational Lensing. *Universe*, **6**, Article No. 9. https://doi.org/10.3390/universe6010009

[2] Lodge, O.J. (1919) Gravitation and Light. *Nature*, **104**, 354. https://doi.org/10.1038/104354a0

[3] Einstein, A.A. (1936) Lens-Like Action of a Star by the Deviation of Light in the Gravitational Field. *Science*, **84**, 506-507. https://doi.org/10.1126/science.84.2188.506

[4] Zwicky, F. (1937) Nebulae as Gravitational Lenses. *Physical Review*, **51**, 290. https://doi.org/10.1103/PhysRev.51.290

[5] Liebes, S. (1964) Gravitational Lenses. *Physical Review*, **133**, B835. https://doi.org/10.1103/PhysRev.133.B835

[6] Renn, J., Sauer, T. and Stachel, J. (1997) The Origin of Gravitational Lensing: A Postscript to Einstein's 1936 Science Paper. *Science*, **275**, 184-186. https://doi.org/10.1126/science.275.5297.184

[7] Fu, C.P. and Shu, C.G. (2005) Gravitational Lensing and Its Applications. *Progress in Astronomy*, **23**, 56-69.

[8] Treu, T., Marshall, P.J. and Clowe, D. (2012) Resource Letter GL-1: Gravitational Lensing. *American Journal of Physics*, **80**, 753-763. https://doi.org/10.1119/1.4726204

[9] Will, C.M. (1988) Henry Cavendish, Johann von Soldner, and the Deflection of Light. *American Journal of Physics*, **56**, 413-415. https://doi.org/10.1119/1.15622

[10] Einstein, A.A. (1916) The Foundation of the General Theory of Relativity. *Annalen der Physik*, **49**, 769-822. https://doi.org/10.1002/andp.19163540702

[11] Lemos, J.P.S. (2019) Shadow of the Moon and General Relativity: Einstein, Dyson, Eddington and the 1919 Light Deflection. *Revista Brasileira de Ensino de Física*, **41**, e20190260. https://doi.org/10.1590/1806-9126-rbef-2019-0260

[12] Schwartz, H.M. (1977) Einstein's Comprehensive 1907 Essay on Relativity, Part I. *American Journal of Physics*, **45**, 512. https://doi.org/10.1119/1.10949

[13] Einstein, A.A. (1911) On the Influence of Gravitation on the Propagation of Light. *Annalen der Physik*, **35**, 898-901. https://doi.org/10.1002/andp.19113401005

[14] Bartelmann, M. (2010) Gravitational Lensing. *Classical and Quantum Gravity*, **27**, Article ID: 233001. https://doi.org/10.1088/0264-9381/27/23/233001

[15] Enander, J. and Mörtsell, E. (2013) Strong Lensing Constraints on Bimetric Massive Gravity. *Journal of High Energy Physics*, **2013**, Article No. 31. https://doi.org/10.1007/JHEP10(2013)031

[16] McHardy, J.I., Merle, A., Morris, T.R. and Ulbricht, H. (2015) On the Existence of Low-Mass Dark Matter and Its Direct Detection. *Scientific Reports*, **5**, Article No. 8058. https://doi.org/10.1038/srep08058

[17] Kamada, A., Shirasaki, M. and Yoshida, N. (2014) Weighing the Light Gravitino Mass with Weak Lensing Surveys. *Journal of High Energy Physics*, **2014**, Article No. 162. https://doi.org/10.1007/JHEP06(2014)162

[18] Hauser, J. and Droscher, W. (2017) Gravity beyond Einstein? Part I: Physics and the Trouble with Experiments. *Zeitschrift für Naturforschung*, **72**, 493-525. https://doi.org/10.1515/zna-2016-0479

[19] Hu, L.Y., Heavens, A. and Bacon, D. (2022) Light Bending by the Cosmological Constant. *Journal of Cosmology and Astroparticle Physics* **JCAP02**, Article No. 009. https://doi.org/10.1088/1475-7516/2022/02/009

[20] Newton, I. (1999) Mathematical Principles of Natural Philosophy. University of California Press, Berkeley.

[21] Qian, W.H. (2022) Star Mass Inertia Dictates the Speed of Light. *Journal of High Energy Physics*, *Gravitation and Cosmology*, **8**, 184-194. https://www.scirp.org/journal/jhepgc https://doi.org/10.4236/jhepgc.2022.81014

[22] Qin, C.G., Shao, C.G. and Tu, L.C. (2017) What Is the Nature of Gravity? *Chinese Science Bulletin*, **62**, 1555-1558. https://doi.org/10.1360/N972016-00948

[23] Qian, W.H. (2022) Four Kinds of Potential Mass-Energy Space-Time Distribution Unified by a Dynamical Approach. *Journal of High Energy Physics*, *Gravitation and Cosmology*, **8**, 417-431. https://www.scirp.org/journal/jhepgc https://doi.org/10.4236/jhepgc.2022.82032

[24] Feynman, R.P. (1970) The Feynman Lectures on Physics. Addison Wesley Longman, Boston.

[25] Dyson, F. (1917) On the Opportunity Afforded by the Eclipse of 1919 May 29 of Verifying Einstein's Theory of Gravitation. *Monthly Notices of the Royal Astronomical Society*, **77**, 445-447. https://doi.org/10.1093/mnras/77.5.445

[26] Chandrasekhar, S. (1990) Truth and Beauty. Aesthetics and Motivations in Science. University of Chicago Press, Chicago.

[27] Workman, *et al.* (Particl Data Group) (2022) Review of Particle Physics. *Progress of Theoretical and Experimental Physics*, **2022**, 083C01. https://doi.org/10.1093/ptep/ptac097

[28] Hewitt, J.N., Turner, E.L., Schneider, D.P., Burke, B.F., Langston, G.I. and Lawrence, C.R. (1988) Unusual Radio Source MG1131+04566: A Possible Einstein Ring. *Nature*, **333**, 537-540. https://doi.org/10.1038/333537a0

[29] Langston, G.I., Connert, S.R., Lehart, J., Burket, B.F. and Weiler, K.W. (1990) Galaxy Mass Deduced from the Structure of Einstein Ring MG1654+ 1346. *Nature*, **344**, 43-45. https://doi.org/10.1038/344043a0

[30] Jauncey, D.L., Reynolds, J.E., Tzioumis, A.K., *et al.* (1991) An Unusually Strong Einstein Ring in the Radio Source PKS1830-211. *Nature*, **352**, 132-134. https://doi.org/10.1038/352132a0

[31] Litvinenko, A.G. (2007) Some Results Obtained at the Relativistic Heavy Ion Collider. *Physics of Particles and Nuclei*, **38**, 204-231. https://doi.org/10.1134/S1063779607020037

[32] Bruning, O., Burkhardt, H. and Myers, S. (2012) The Large Hadron Collider. *Progress in Particle and Nuclear Physics*, **67**, 705-735. https://doi.org/10.1016/j.ppnp.2012.03.001

[33] Qian, W.H. (2022) Orthogonal Collision of Particles Produces New Physical State. *Journal of Modern Physics*, **13**, 1440-1451. https://doi.org/10.4236/jmp.2022.1311089

[34] Qian, W.H. (2023) A Physical Explanation for the Formation of Auroras. *Journal of Modern Physics*, **14**, 271-286. https://doi.org/10.4236/jmp.2023.143018