Gravitational Fields and Gravitational Waves

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Abstract: For any object with finite velocity, the relative velocity between them will affect the effect between them. This effect can be called the chasing effect (general Doppler effect). LIGO discovered gravitational waves and measured the speed of gravitational waves equal to the speed of light c. Gravitational waves are generated due to the disturbance of the gravitational field, and the gravitational waves will affect the gravitational force on the object. We know that light waves have the Doppler effect, and gravitational waves also have this characteristic. The article studies the following questions around gravitational waves: What is the spatial distribution of gravitational waves? Can the speed of the gravitational wave represent the speed of the gravitational field (the speed of the action of the gravitational field on the object)? What is the speed of the gravitational field? Will gravitational waves caused by the revolution of the sun affect planetary precession? Can we modify Newton's gravitational equation through the influence of gravitational waves?

Keywords: the law of gravitation[1] ; Doppler effect[6][7] ; gravitational wave[4][8] ; gravitational field; LIGO[3] ; gravitational constant[5] ; chasing effect

In order to demonstrate these conjectures, we first make some assumptions, and then based on these assumptions, see if we can deduce the correct results.

Hypothesis 1: The speed of the gravitational field is equal to the speed of light. For the convenience of analysis, we use x to represent the velocity of the gravitational field;

Hypothesis 2: When the velocity of the object is equal to the velocity of the gravitational field, the gravitational field no longer acts on the object;

Let's start the analysis.

1 Introduction

Newtonian gravity is an acting force at a distance. No matter how fast the object is, gravity will act on the object instantaneously. Gravity is only related to the mass and distance of the object, equal to $\frac{G_0Mm}{r^2}$, of which the universal gravitational constant $G_0 = 6.6725910Nm^2/kg^2$. And now we assume that the velocity of the gravitational field is x, assuming that when the velocity of the object is equal to x, the gravitational field no longer acts on the object, then how will the Newtonian equation of gravity change?

2 Derive the Relationship between Gravity and Velocity based on Newton's Gravity Equation

In a very short time slice dt, we can assume that m is stationary and the gravity received is constant, and then accumulate the impulse generated by the gravity on each time slice, and average it to the entire time period to get an effective constant gravitation, so as to see the relationship between equivalent gravitation and velocity.

Let us study the influence of velocity on gravity when the moving velocity of object m relative to M is not 0.

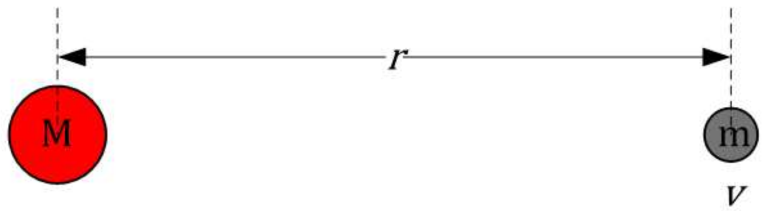

Figure 1: Gravity model

As shown in Figure 1 above, there are two objects with masses M and m, the distance between them is r, m has a moving velocity **v** relative to M, and the direction of the velocity is on the straight line connecting them. We use $F(t) = \frac{G_0 Mm}{(r+vt)^2}$ to represent the gravity on m at time t. Obviously, the Newtonian equation of gravity is used here. In any small time dt, m can be regarded as stationary. Accumulate the impulse dp obtained by multiplying the gravity and time in these small time slices, and then the sum of the gravitational impulse received by m within a certain period of time can be obtained. Suppose that the gravitational impulse obtained by m is p after the time T has passed, so we integrate the gravity in the time domain:

$$p = \int_0^T F(t) \times dt = \int_0^T \frac{G_0 Mm}{(r+vt)^2} \times dt = \frac{G_0 Mm}{r^2} \times \int_0^T \frac{1}{(1+vt/r)^2} \times dt, \tag{1}$$

$p = \frac{G_0 Mm}{r^2} \times \frac{-r/v}{1+vt/r}\Big|_0^T$,

$p = \frac{G_0 Mm}{r^2} \times \frac{T}{1+vT/r}$.

For an object m with a velocity of **v**, the accumulated impulse p during the time T can be expressed by an equivalent constant force multiplied by the time T. For the convenience of description, we use $F(v)$ to express this equivalent force. Suppose there is the following scenario now: m has two different velocity v_1, v_2, and their equivalent forces in time T are:

$F(v_1) = p_1/T = \frac{G_0Mm}{r^2}/(1 + \frac{v_1T}{r})$,

$F(v_2) = p_2/T = \frac{G_0Mm}{r^2}/(1 + \frac{v_2T}{r})$,

$\frac{F(v_1)}{F(v_2)} = \frac{(1+v_2T/r)}{(1+v_1T/r)} = \frac{r+v_2T}{r+v_1T}$.

Suppose:

$F(v_1) = K(r + v_2T)$,

$F(v_2) = K(r + v_1T)$,

so reach:

$F(v_1) - F(v_2) = K(v_2 - v_1)T$.

It can be seen that the difference of equal potency $F(v_1) - F(v_2)$ is proportional to the difference of velocity $v_2 - v_1$, and $F(v)$ and v are a linear relationship.

Next, we use the boundary conditions of the object velocity $v = 0$ and $v = x$ to obtain the expression about K, and thus obtain the gravitational equation with v as a parameter.

Velocity boundary condition 1: when $v_2 = 0, F(v_1) - F(0) = K(0 - v_1)T = -Kv_1T$, here $F(0) = \frac{G_0Mm}{r^2}$, so reach:

$$F(v_1) = \frac{G_0Mm}{r^2} - Kv_1T, \tag{2}$$

Velocity boundary condition 2: when $v_2 = x$, gravitational field no longer affects objects, so $F(x) = 0$,

then $F(v_1) - F(x) = K(x - v_1)T$,

then,

$$F(v_1) = K(x - v_1)T, \tag{3}$$

From equations (2),(3), we get:

$$F(v_1) = \frac{G_0Mm}{r^2} - Kv_1T = K(x - v_1)T \tag{4}$$

sorted out:

$KxT = \frac{G_0Mm}{r^2}, K = \frac{G_0Mm/r^2}{xT}$,

Substituting K into (4), we get:

$F(v_1) = K(x - v_1)T = \frac{G_0Mm/r^2}{xT} \times (x - v_1)T$

sorted out:

$F(v_1) = \frac{G_0 Mm}{r^2} \times \frac{x - v_1}{x}$.

use v instead of v_1 to get:

$$F(v) = \frac{G_0 Mm}{r^2} \times \frac{x - v}{x}, \tag{5}$$

What it embodies is the relationship between gravity and mass, distance, and velocity. From the formal point of view, it is the chasing effect.

We can also analyze in another way. After knowing that $F(v)$ and v are a linear relationship, as shown in Figure 2 below, use the boundary conditions

$F(0) = \frac{G_0 Mm}{r^2}$ and $F(x) = 0$,it can be easily calculated:

$F(v) = F(0) + v \times \frac{F(x) - F(0)}{x} = F(0) \times \frac{x - v}{x} = \frac{G_0 Mm}{r^2} \times \frac{x - v}{x}$.

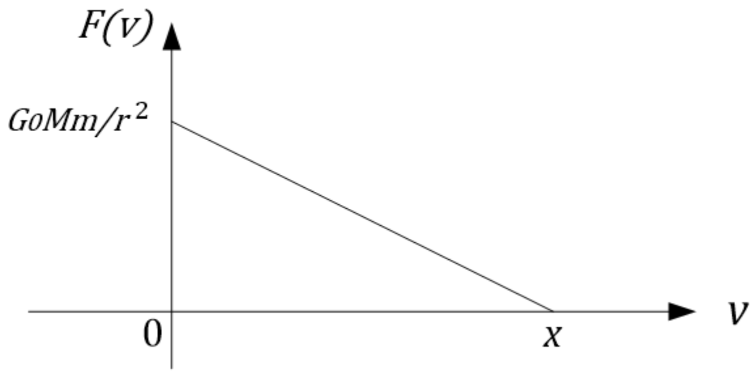

Figure 2: Linear relationship between gravity and velocity

Based on the above analysis, we write the formula of universal gravitation with velocity parameter v:

$$F(v) = \frac{G_0 Mm}{r^2} \times f(v), f(v) = \frac{x - v}{x}, \tag{6}$$

What $f(v)$ reflects is the chasing effect. If we need to preserve the form of Newton's gravity equation, we can write it like this:

$$F(v) = G(v) \times \frac{Mm}{r^2}, G(v) = G_0 \times \frac{x - v}{x}, \tag{7}$$

That is, the gravitational constant becomes a function of v, $G(v)$. In this way, you can understand that when the gravitational field has different velocity relative to m, the gravitational constant is different. Next, we will apply the new gravitational equation to the planetary orbit calculation to see if it is consistent with actual observations.

3 Calculate the Influence of the New Gravitational Equation on the Earth's Orbit

From the above derivation, we get the gravity formula with velocity v as a parameter:

$F(v) = \frac{G_0 Mm}{r^2} \times \frac{x-v}{x}$,

Considering that the velocity direction of the object m may have an angle with the gravitational field, we define v_r as the component of v in the direction of the gravitational field, and then obtain the general formula:

$F(v_r) = \frac{G_0 Mm}{r^2} \times \frac{x-v_r}{x}$,

It can be seen from the equation that when an object has a velocity component in the direction of the gravitational field, that is, there is a movement effect in the same direction between the gravitational field and the object, the gravitational force received will decrease. When the object has a velocity component that is opposite to the direction of the gravitational field, that is, the two have the effect of moving towards each other, the gravitational force received will increase. So under this chasing effect, what impact will it have on the planet's orbit? Can planets maintain the conservation of mechanical energy in their orbits?

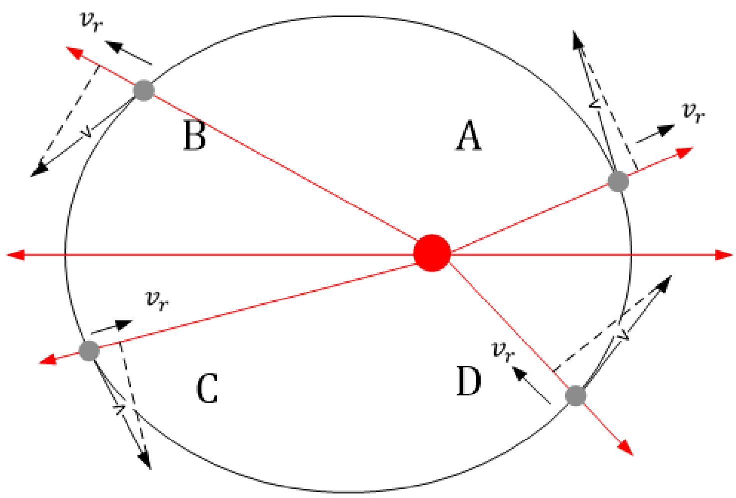

Figure 3: The velocity component of the planet's gravitational field direction

As shown in Figure 3 above, under the new gravitational equation, because the planetary velocity v has the same direction component v_r in the direction of the gravitational field in the orbits A and B, the gravity will decrease, which is equivalent to that the planet will gain extra force in the direction of the gravitational field. This force is in the same direction as v_r. According to the power calculation formula $P = F \times v_r > 0$, the planetary mechanical energy will increase.

Let's look at regions C and D. Because the planetary velocity v has a reverse component v_r in the direction of the gravitational field, the gravitational force will increase, which is equivalent to the extra force that the planet will gain in the opposite direction of the gravitational field. This force is also in the same direction as v_r. According to the power calculation formula $P = F \times v_r > 0$, the planetary mechanical energy will increase.

Therefore, under the new gravitational equation, the mechanical energy of the planet in the entire orbit will continue to increase, and the mechanical energy will become larger and larger, which will cause the planet to gradually move away from the sun and eventually fly away from the solar system. So taking the earth as an example, under the new gravitational equation, how many revolution cycles will let our earth fly away from the solar system? Below we will conduct theoretical analysis and calculations.

3.1 Introduce Polar Coordinates

Let the Sun, mass M, lie at the origin. Consider a planet, mass m, in orbit around the Sun. Let the planetary orbit lie in the $x - y$ plane. Let $\mathbf{r}(t)$ be the planet's position vector with respect to the Sun. The planet's equation of motion is

$$m\ddot{\mathbf{r}} = -\frac{G_0 M m}{r^2} \times \frac{x - v}{x} \times e_r, \tag{8}$$

where $e_r = \mathbf{r}/r$ and $v_r = e_r.\dot{\mathbf{r}}$.Let $r = |\mathbf{r}|$and $\theta = \tan^{-1}(y/x)$ be plane polar coordinates. The radial and tangential components of (8) are

$$\ddot{r} - r\dot{\theta}^2 = -\frac{G_0 M}{r^2}(1 - \frac{\dot{r}}{x}) \tag{9}$$

$$r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0 \tag{10}$$

(10) can be integrated to give

$$r^2\dot{\theta} = h \tag{11}$$

where h is the conserved angular momentum per unit mass. (9),(11) can be combined to give

$$\ddot{r} - \frac{h^2}{r^3} = -\frac{G_0 M}{r^2}(1 - \frac{\dot{r}}{x}) \tag{12}$$

3.2 Energy Conservation

Let us multiply (12) by $\dot{r}$. We obtain

$$\frac{d}{dt}(\frac{\dot{r}^2}{2} + \frac{h^2}{2r^2} - \frac{G_0 M}{r}) = \frac{G_0 M \dot{r}^2}{r^2 x} \tag{13}$$

or

$$\frac{d\epsilon}{dt} = \frac{G_0 M \dot{r}^2}{r^2 x} \geq 0 \tag{14}$$

where

$$\epsilon = \frac{1}{2}(\dot{r}^2 + r^2\dot{\theta}^2) - \frac{G_0 M}{r} \tag{15}$$

is the energy per unit mass. (14) demonstrates that the Doppler shift correction to the law of force causes the system to no longer conserve energy. In fact, the orbital energy grows without limit. This means that the planet will eventually escape from the Sun (when its orbital energy becomes positive).

3.3 Solution of Equations of Motion

Let $1/r = u[\theta(t)]$. It follows that

$$\dot{r} = -h\frac{du}{d\theta}, \tag{16}$$

$$\ddot{r} = -u^2 h^2 \frac{d^2 u}{d\theta^2}, \tag{17}$$

Thus, Eq. (12) becomes

$$\frac{d^2 u}{d\theta^2} - \gamma\frac{du}{d\theta} + u = \frac{G_0 M}{h^2}, \tag{18}$$

where

$$\gamma = \frac{G_0 M}{hx}, \tag{19}$$

is a small dimensionless constant. To first order in γ, an appropriate solution of (18) is

$$u \approx \frac{G_0 M}{h^2}(1 + eexp(r\theta)cos\theta), \tag{20}$$

where e is the initial eccentricity of the orbit. Thus

$$r(\theta) = \frac{r_c}{1 + eexp(\gamma\theta)cos\theta}, \tag{21}$$

where

$$r_c = \frac{h^2}{G_0 M}, \tag{22}$$

It can be seen that the orbital eccentricity grows without limit as the planet orbits the Sun. Eventually, when the eccentricity becomes unity, the planet will escape from the Sun.

3.4 Estimate of Escape Time

The planet escapes when its orbital eccentricity becomes unity. The number of orbital revolutions, n, required for this to happen is

$$eexp(\gamma n 2\pi) = 1, \tag{23}$$

where e is the initial eccentricity. Thus, $n = \frac{1}{2\pi\gamma} ln(\frac{1}{e})$,

but,

$$\gamma = \frac{2\pi a}{Tx(1 - e^2)^{\frac{1}{2}}}, \tag{24}$$

where a is the initial orbital major radius, and T is the initial period. Hence,

$$n = \frac{Tx(1 - e^2)^{\frac{1}{2}} ln(\frac{1}{e})}{4\pi^2 a}. \tag{25}$$

For the Earth, $T = 3.156 \times 10^7 s, x = c = 2.998 \times 10^8 m/s, a = 1.496 \times 10^{11} m$, and $e = 0.0167$. Hence, the Earth would escape from the Sun's gravitational influence

after

$$n = \frac{(3.156 \times 10^7)(2.998 \times 10^8 m/s)(1 - 0.0167^2)^{\frac{1}{2}} ln(\frac{1}{0.0167})}{4\pi^2 (1.496 \times 10^{11})} \approx 6.6 \times 10^3, \tag{26}$$

revolutions. If each revolution takes about a year then the escape time is a few thousand years. However, the age of the Solar System is 4.6×10^9 years. The escape time is smaller than this by a factor of about a million. Therefore, the previous two assumptions are invalid. The speed of gravitational waves cannot represent the speed of the gravitational field. From equation (26), the speed of gravitational field x must be much greater than the speed of light c, this is more in line with Newton's argument that gravity is an acting force at a distance.

We can make an unsuitable analogy: we use a rope to pull a kite. When we shake it hard, the rope will fluctuate and pass to the kite at a certain wave speed, but when we loosen the rope, the kite will Lost control instantly. Obviously, it is inappropriate to use the wave speed of the rope to represent the speed of the force of the rope on the kite. So how do gravitational waves affect gravity? Since the revolution speed of the sun will cause gravitational waves, how are gravitational waves distributed around the sun?

4 The Influence of Gravitational Waves Produced by the Sun on the Surrounding Gravity

The gravitational waves caused by the movement of the sun are like water waves caused by ships sailing in the water. For the convenience of explanation, we have turned the three-dimensional space problem into a two-dimensional problem. The gravitational influence caused by gravitational waves is different in the direction of the sun's velocity and the vertical direction, as shown in Figure 4.

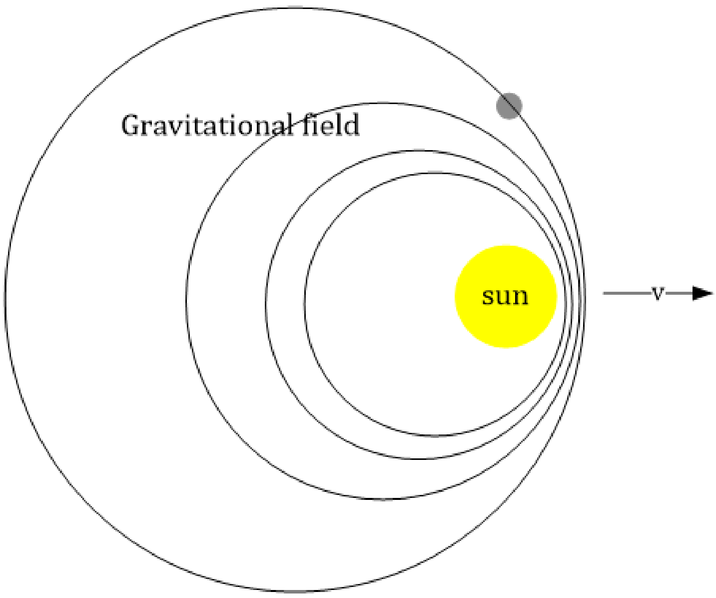

Figure 4: Gravitational wave model generated by the sun's movement

Assuming that without considering the chasing effect, the ratio of the gravitational increase caused by gravitational waves to Newtonian gravitation is r_w, we introduce a gravitational wave influence factor f_w, and $f_w = 1.0$ without considering the chasing effect. It can be seen from the above figure that due to the chasing effect of gravitational waves, the energy of gravitational waves is the largest in the direction of the sun's velocity, and the impact on gravity is the greatest. The planet's orbital surface is perpendicular to the direction of the sun's velocity, and the gravitational wave is relatively small. As shown below:

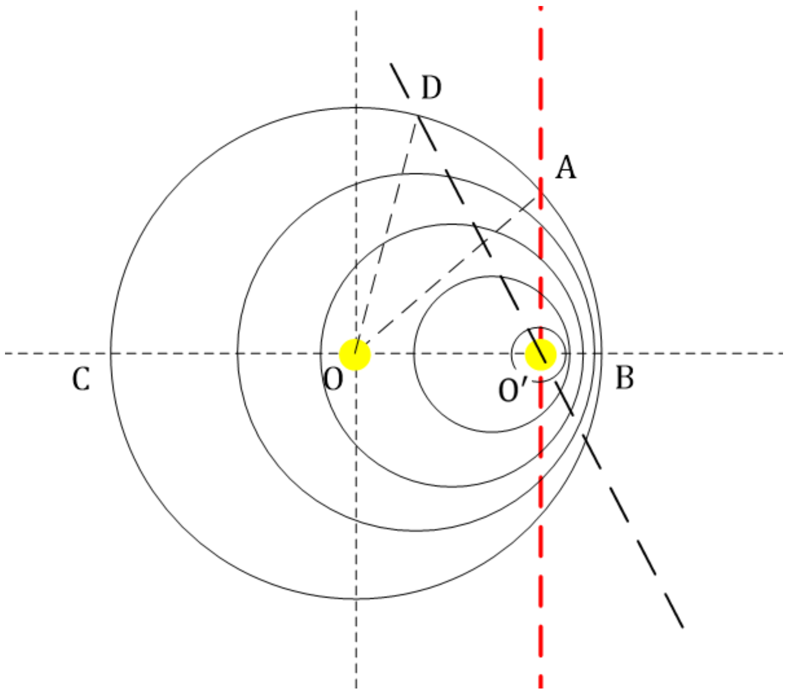

Figure 5: The solar gravitational wave calculation model

4.1 Calculation of the Influence Factor of Gravitational Waves in the Direction of the Sun's Velocity

It is known that the revolution velocity of the sun is v_s. Assuming that the sun moves from position O to position O' after time T, the gravitational waves generated in the direction of the sun's velocity during this period are all located between O'B. According to the chasing effect of gravitational waves, the influence factor of gravitational waves in this direction is:

$$f_w = \frac{c + v_s}{c} > 1.0. \tag{27}$$

4.2 Calculation of the Influence Factor of Gravitational Waves in the Vertical Direction of the Sun's Velocity

The gravitational waves in the direction perpendicular to the sun's velocity are located between O'A, we only need to calculate the ratio between O'B and O'A to get the gravitational wave density relationship in the two directions

$$O'B = cT - v_s T, \tag{28}$$

$$O'A = [(cT)^2 - (v_s T)^2]^{\frac{1}{2}}, \tag{29}$$

sorted out:

$$f_w \approx (\frac{c + v_s}{c}) \times (\frac{c - v_s}{c + v_s})^{\frac{1}{2}} = (\frac{c^2 - v_s^2}{c^2})^{\frac{1}{2}}, \tag{30}$$

Substituting the solar revolution speed $v_s = 240 \times 10^3 m/s$, and the gravitational wave speed $c = 2.998 \times 10^8 m/s$, we get $\frac{O'B}{O'A} = (\frac{c-v_s}{c+v_s})^{\frac{1}{2}} \approx 0.9992$. It also can be seen from Figure 4 above that the density of gravitational waves in the vertical direction is smaller than that in the direction of the sun's velocity. The density of gravitational waves gradually decreases from the direction of the sun's velocity to the vertical direction. If the gravitational wave density is equivalent to the level of the depression in the plane, then this gravitational wave density model is somewhat similar to the space-time depression model described by general relativity GR. As shown in Figure 6 below, the gravitational wave density presents a non-uniform distribution, and gravitational waves have the highest density at the bottom and gradually decrease upwards.

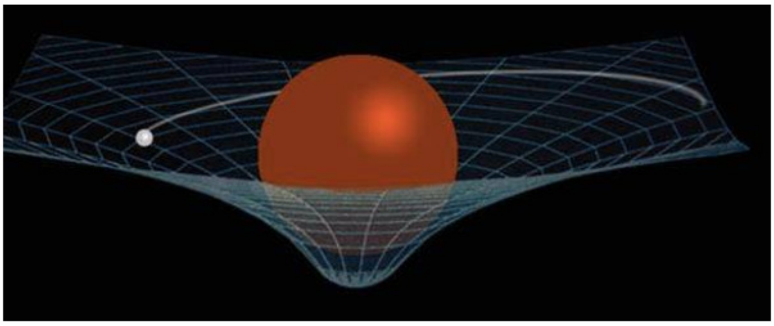

Figure 6: GR space-time depression model

4.3 Calculation of Influence Factor of Gravitational Waves on Planetary Orbital Surface

We know that the planet's orbital plane is approximately perpendicular to the direction of the sun's motion, so the red line in Figure 5 represents the planet's orbital plane. According to formula (30), we can calculate the influence factor of gravitational waves on the orbital surface, and we can see that this value will be less than 1.0.

4.4 Calculation of the Influence Factor of Gravitational Waves on the Reverse of the Sun's Velocity

Behind the vertical plane (to the left of the red line), we can see from Figure 5 that the density of gravitational waves will continue to decrease and reach a minimum in the opposite direction of the sun's velocity, at this time $\frac{O'B}{O'C} = \frac{c-v_s}{c+v_s}$, the gravitational wave influence factor is:

$$f_w \approx (\frac{c+v_s}{c}) \times \frac{c-v_s}{c+v_s} = \frac{c-v_s}{c}. \tag{31}$$

Substituting $v_s = c$ into (30) and (31), it can be seen that when the speed of the sun reaches c, the orbital surface of the planet perpendicular to the sun's velocity (the position of the red line) and the position behind it (the left side of the red line) will no longer be affected by gravitational waves.

4.5 Calculation of the Influence Factor of Gravitational Waves at any Position

As shown in Figure 5, assuming that the angle between O'D and the red line is θ, D is any position, then

$$OD^2 = O'D^2 + OO'^2 - 2O'D \times OO'cos(\frac{\pi}{2} - \theta), \tag{32}$$

get:

$O'D = \frac{2OO'cos(\frac{\pi}{2}-\theta)+[4(OO'cos(\frac{\pi}{2}-\theta))^2-4(OO'^2-OD^2)]^{\frac{1}{2}}}{2}$,

then,

$$\frac{O'B}{O'D} = \frac{2O'B}{2OO'cos(\frac{\pi}{2}-\theta)+[4(OO'cos(\frac{\pi}{2}-\theta))^2-4(OO'^2-OD^2)]^{\frac{1}{2}}}, \tag{33}$$

sorted out:

$$f_w \approx (\frac{c+v_s}{c}) \times \frac{c-v_s}{v_s cos(\frac{\pi}{2}-\theta)+[(v_s cos(\frac{\pi}{2}-\theta))^2-(v_s^2-c^2)]^{\frac{1}{2}}}. \tag{34}$$

4.6 The Influence of Gravitational Waves on Gravity

Assuming that the gravitational force of an object under the influence of gravitational waves is F_w, F_w can be regarded as two parts:

Part1: Newtonian gravity $F = \frac{G_0 Mm}{r^2}$.

Part2: The gravity contributed by the gravitational wave $r_w f_w F$.(r_w is the ratio of the gravitational increase caused by gravitational waves to Newtonian gravitation)

So we get:

$$F_w = F + r_w \times f_w \times F. \tag{35}$$

Let us take the orbital position as an example to illustrate the calculation of gravity under the influence of gravitational waves:

$$F_w = F + r_w \times f_w \times F = F \times (1 + r_w \times (\frac{c^2 - v_s^2}{c^2})^{\frac{1}{2}}), \tag{36}$$

Because there is also a chasing effect between planets and gravitational waves, it is also necessary to add the influence of this part of the factor. Assuming that the velocity of the planet is v_p, and the velocity of the planet in the direction of the gravitational wave is v_{pw}, then the chase factor $\frac{c-v_{pw}}{c}$ between the planet and the gravitational wave is obtained, and this factor is put into (36) to obtain:

$$F_w = F \times (1 + r_w \times (\frac{c^2 - v_s^2}{c^2})^{\frac{1}{2}} \times \frac{c - v_{pw}}{c}), \tag{37}$$

substituting F, get:

$$F_w = \frac{G_0 M m}{r^2} \times (1 + r_w \times (\frac{c^2 - v_s^2}{c^2})^{\frac{1}{2}} \times \frac{c - v_{pw}}{c}). \tag{38}$$

here $r_w \approx 0.00042$, this value comes from program simulation.

In the same way, the gravity of other positions can be calculated. We write the gravity equation of any position:

$$F_w = \frac{G_0 M m}{r^2} \times (1 + r_w \times \frac{c + v_s}{c} \times (\frac{c - v_s}{v_s cos(\frac{\pi}{2} - \theta) + [(v_s cos(\frac{\pi}{2} - \theta))^2 - (v_s^2 - c^2)]^{\frac{1}{2}}} \times \frac{c - v_{pw}}{c})) \tag{39}$$

5 Analysis of the Influence of Gravitational Waves on Planetary Orbits

If the planet's orbital surface is not completely perpendicular to the velocity of the sun, and part of the orbit is on the left side of the red line and part on the right side of the red line, then the impact of gravitational waves on planets is also uneven, which affects the orbit and contributes part of the force to planetary precession. The closer the planet's orbit is to the sun, the greater the gravitational wave density gradient, and the more obvious the effect of precession; the farther the distance, the less obvious.

Based on formula (39), we have briefly simulated the contribution of gravitational waves to the planet's precession per century. The data are as follows:

Mercury 43”

Venus 240”

Earth 3”

Mars 1”

Jupiter 0.8”

Saturn 0.1”

Let’s look at the calculation formula of GR,

$$\delta\dot{\varphi} \simeq \frac{0.0383}{RT} \tag{40}$$

From the formula, GR does not consider the angle between the planet’s orbital plane and the sun’s vertical plane (the red line in Figure 5) and also does not consider the eccentricity of the orbit when calculating the planetary precession. However, we need to consider them in the data calculated by formula (39), and it is considered as the main factor. This may be the biggest difference between the two. Below we substitute the R and T values of each planet (See Figure 7) for GR calculation.

The calculated precession data of each planet per century is as follows: [9]

Mercury 41.06”

Venus 8.6”

Earth 3.83”

Mars 1.34”

Jupiter 0.062”

Saturn 0.0136”

Uranus 0.00238”

We can see that except for Venus’s precession data of 240” vs 8.6”, the data of other planets are relatively close to GR.

First, let’s look at the characteristics of Venus: Venus’s eccentricity is abnormally low (e = 0.0068), which makes its perihelion extremely sensitive to small disturbances [7]. But the angle between its orbit and the vertical plane of the sun is very large 3.39°, so we have reason to believe that gravitational waves will have a great influence on the orbital precession of Venus.

So why is the data of Venus (240” vs 8.6”) so different? From formula (40) we can see that GR does not consider the eccentricity and the angle between the orbital surface and the vertical surface of the sun. Under different eccentricity and angles, the precession

Planet	M/M_0	T(yr)	R(au)
Mercury	1.66×10^{-7}	0.241	0.387
Venus	2.45×10^{-6}	0.615	0.723
Earth	3.04×10^{-6}	1.000	1.00
Mars	3.23×10^{-7}	1.881	1.52
Jupiter	9.55×10^{-4}	11.86	5.20
Saturn	2.86×10^{-4}	29.46	9.54
Uranus	4.36×10^{-5}	84.01	19.19
Neptune	5.18×10^{-5}	164.8	30.07

Figure 7: Data for the major planets in the Solar System, giving the planetary mass relative to that of the Sun, the orbital period in years, and the mean orbital radius relative to that of the Earth.

data calculated by GR is still the same. These may be the reason for the large difference between the two.

In addition to causing planetary precession, gravitational waves also cause planets to move away from the sun. We know there is also a chasing effect between the planet's revolution velocity and the gravitational waves caused by the sun. The previous 3.2 "Energy Conservation" has analyzed the influence of the chasing effect on the orbital energy. Gravitational waves will also cause the planetary orbital mechanical energy to continue to increase, which will make the planets gradually move away from the sun.

6 Conclusion

The discovery of gravitational waves provides a new way for us to reveal the universe, but the speed of gravitational waves cannot represent the speed of gravitational fields. The speed of action of gravitational fields will be much greater than the speed of gravitational waves. Just like Newton said: Gravitation is acting force at a distance. Gravitational waves caused by the revolution of the sun will affect the orbits of planets and provide some planetary precession data. The chasing effect of gravitational waves will also cause the planetary orbital mechanical energy to continue to increase slowly until the planet escapes from the solar system. Gravitational waves are real, and the gravitational model under the influence of gravitational waves we constructed is a physical model. Through the calculation of planetary orbital precession, the correctness of the gravitational equation under the influence of gravitational waves is verified, which shows that the gravitational physical model has certain research value, and it will also be a strong evidence and supplement to GR. GR provides ideas for the correction of Newton's gravitational equation.

Finally, we also asked the following questions:

Does the acceleration of planetary orbits caused by the gravitational wave chasing effect have anything to do with the accelerated expansion of the universe?

Is there a connection between the action at a distance of the gravitational field and the action at a distance in quantum mechanics?

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