PHOTON ENERGY IN GRAVITATIONAL INTERACTION

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1) Gravitational kinetic energy of photon

Physical object-photon have the external energy corresponding to the space outside the effective radius ($R_T < R_h < \infty$), but its internal energy in the range of $< R_T$ is not gravitational energy but only pure electric energy as known – this is typical of the photon as a "gravitaty quanta", which is formed from remnant electrical interaction mentioned in [1] and is different to the other physical object form (see the Figure 1).

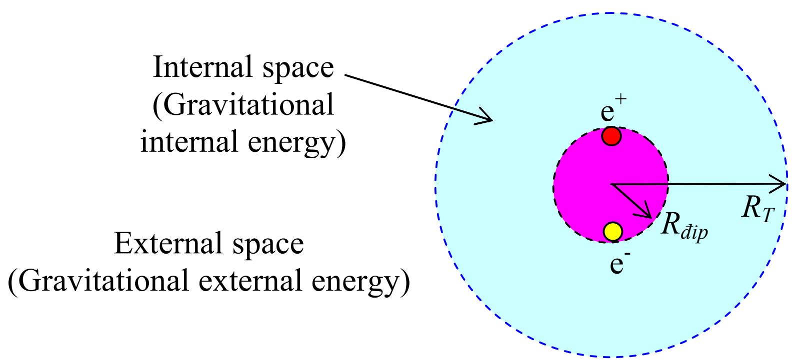
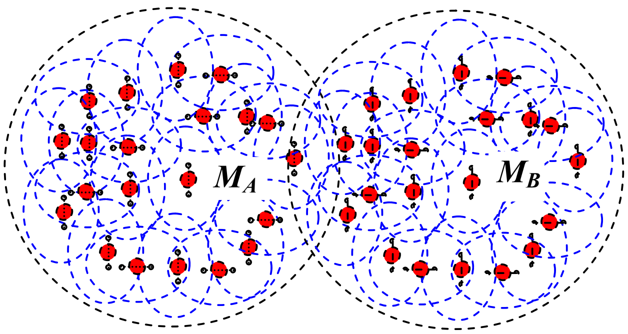


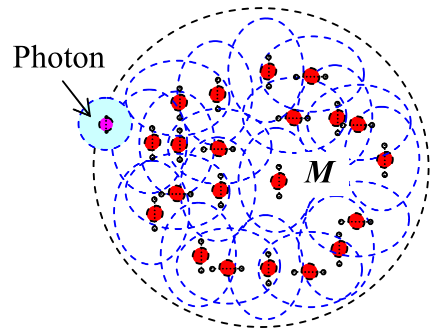
Figure 1. Photon model in gravitational interaction

This difference shows evidently in interactions: when other bodies, which are created from the atoms, collide each other, i.e there is a direct contact between the "their internal space" each other (see Figure 2a), in that internal space, there are always the gravitational energy (represented by the area outside the ellipse) and electrical energy (represented by the area inside the ellipse).

Meanwhile, the "collision" of photons only happen with electrical interactions, because in its "internal space" $< R_T$, gravitational interaction don't exist. This leads to a consequence that: gravitational kinetic energy of the photon seems not to be shown in the collision with other physical entities. But if so, where will the gravitational kinetic energy disappear? The problem is that the kinetic energy of an physical object in a force field (in this case, it is electric field) is energy of their motion in that force field; it just means when interaction may occur. When transmiting in a gravitational field, photon still has inertial mass in a gravitational field $m_T = M_T$ and still has a particularity that is preserve the direction of motion and only deflected when impacted of strong gravitational source. But when appearing conditions "collision" (see Figure 2b – blue area is the electric effective radius of the photon), i.e, when the "internal spaces" contact with each other, photon has only electric interaction with body that it collide without any "involvement" to the gravitational interaction (see Figure 2a), unlike for other bodies, which has the gravitational masses too. However, there is a question that if in the internal space of the photon no gravitational interactions, in a gravitational field, it must to have not "gravitational internal energy", i.e, it is true that its internal energy in the gravitational field must be 0?



a) Collision between two bodies



b) Collision between photon and body

Figure 2. Collision model between two physical objects

However, as we have said in [1], for whatever a physical object, there can be no external energy without the internal energy and moreover, any external energy can not be larger than internal energy, therefore, the concept of internal energy of 0 is meaningless. Moreover, the so-called "gravitational external energy" of the photon is only part of the electrical energy ("remnants" energy), which created that "internal energy" only; if that internal energy equal to 0, photon could not taken form? Here there is only problem with calling it: although called "gravitational internal energy", but it only starts from pair of opposite categories "internal-external" only; because the external energy is called "gravitation", so that oppositive side (internal energy) is also called "gravitation", while it is just pure electric energy itself. In summary, both internal and external energy of the photon (in the gravitational interaction) are from the same source – electric energy of electron-positron pairs, how to call a convention, not matter.

However, the photon reduces its speed when going from the vacuum to electric field (of the environment) makes its movement speed is reduced, but by logic, its gravitational kinetic energy also depends on the speed of movement, so it should also be reduced: at this, a part of gravitational kinetic energy automatically transforms into internal energy of the photon (in range of radius R_T) corresponds to the speed reduction of the photons from c to u that we will consider specifically in the subject "Photon with the electric interaction" later.

2) Total energy of photon

In the gravitational field, photon has the internal space (< R_T) corresponding to the "gravitational internal energy" W_{nh}, and external space (> R_T) corresponding to the remnant electric energy – is gravitational external energy W_{ngh} consisting of gravitational kinetic energy K_h and gravitational potential energy U_h (R_h):

$$K_h = \frac{m_T c^2}{2} = \text{const}, \tag{1}$$

$$U_h(R_h) = \gamma \frac{M M_T}{R_h}. \tag{2}$$

$$W_{ngh} = K_h + U_h(R_h)., \tag{3}$$

Here is $m_T = M_T$ – corresponding to inertial and gravitational mass of photon. Total energy of photon in the pure gravitational field can be written as the sum of "gravitational internal energy" W_{nh} and "gravitational external energy" W_{ngh}:

$$W_{ph} = W_{nh} + W_{ngh} = W_{nh} + K_h + U_h(R_h). \tag{4}$$

We can see the external energy of photon changes only due to the potential energy in the gravitational field, because its kinetic energy is always constant.

3) Interaction of photons with source of gravity

As photons approach to source of strong gravity with the gravitational mass M, it will be deflected the direction of motion as shown in Figure 3 – the collision between the photons with body with mass M do not happen.

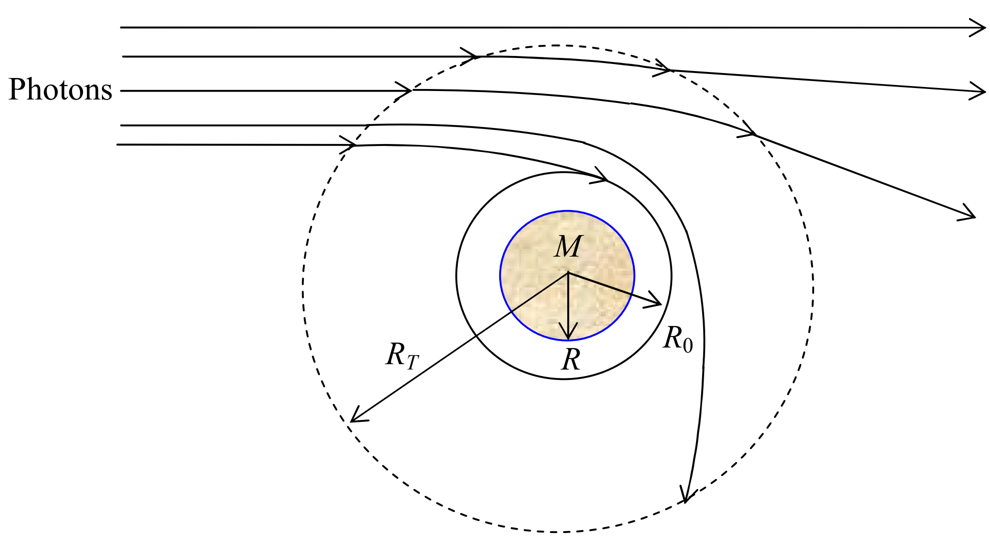


Figure 3. Deflection of photons near source of strong gravity

Just as with other bodies, it can be assumed that the first possible orbit will correspond with radius R_0 when the centripetal force of that body affect to photon equal to the centrifugal force of it:

$$\gamma \frac{MM_T}{R_0^2} = \frac{m_T c^2}{R_0}, \tag{5}$$

here is $\gamma \approx 6{,}67\text{x}10^{-11}$ Nm^2/kg^2.

After reducing the two sides of (5), we obtain:

$$\gamma \frac{M}{R_0} = c^2, \tag{6}$$

or:

$$\frac{M}{R_0} = \frac{c^2}{\gamma}. \tag{7}$$

What will happen to the photons as they collide directly with M body, whether they are as in per the direction to the center as photon A, or under any angle as photon B as shown in Figure 4?

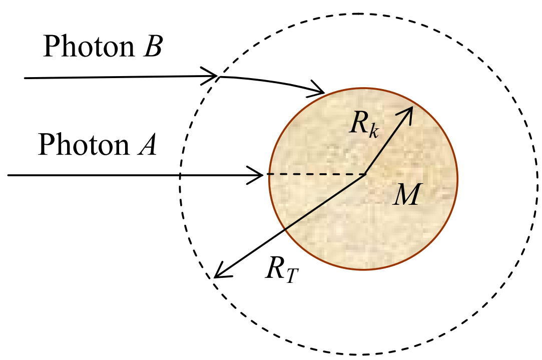


Figure 4. Photon collides with the source of strong gravity

If we assume that the radius of that body can be small in order at the collision point, photon not to be reflected back again, i.e., the gravitational potential energy U_h (R_K) is balanced with kinetic energy K_h of photon A:

$$\gamma \frac{MM_T}{R_k} = \frac{m_T c^2}{2}. \tag{8}$$

From this, we can be drawn:

$$\frac{M}{R_k} = \frac{c^2}{2\gamma} = \text{const.} \tag{9}$$

This ratio is a constant for all bodies and equal: $9\text{x}10^{16}/2\text{x}6{,}67\text{x}10^{-11} \approx 6{,}75\text{x}10^{26}$ (kg^2/N.s^2). Comparing (9) with (7) we see $R_K = 2R_0$, i.e., the critical radius of two times the radius to be formed the circular orbit of photon just above referred. This means that if no collision occurs in R_k, photon may be moved to the R_0? We will clarify this matter.

From [2], we have known that the kinetic and potential energy of a body fall freely in the gravitational field, are always equals, and expression (8) is just a special case when the body falls to reach the balanced state between its internal and external energy (Meanwhile, the radius R_k is called the critical radius):

$$W_{nd} = W_{ngh} = K_h + U_h(R_k). \tag{10}$$

Called "critical" because if it can survive the smaller radius, the photon going deep into the centre of gravitational field, its external energy will be increased over the internal energy, and the result is that photon will be "crushed" by the strong gravitational field of a body with the mass M – the photon will decay into a electron and a positron.

This is also true for photon A, due to the gravitational field of an body with mass M, it can still be considered "free fall" for two reasons: first, as mentioned above, although they are formed anywhere, the initial state of photon is both kinetic and potential energy in a gravitational field are zero, and the second, known as its kinetic energy always corresponds to the critical speed c, so, at radius "critical" R_K still corresponds to c is of course. Meanwhile, the total energy of the photon can be rewritten as:

$$W_{phh} = 2(K_h + U_h(R_k)) = 4K_h = 2m_T c^2. \tag{11}$$

From here we can calculate the internal energy of photon in gravitational field by:

$$W_{nd} = 2m_T c^2 - \frac{m_T c^2}{2} - \gamma\frac{MM_T}{R_h} = \frac{3}{2}m_T(c^2 - \gamma\frac{M}{R_h}). \tag{12}$$

We can find:

$$\gamma\frac{M}{R_h} = GR_h = V_I^2 \tag{13}$$

We can find that this formula is the square of the orbital speed (moving in circular orbits) for common bodies in gravitational field with the intensity of G. So, may be abbreviated (12) as:

$$W_{nd} = \frac{3}{2}m_T(c^2 - V_I^2). \tag{14}$$

From expression (14), it shows that from the balanced conditions between the internal and external energy of photon:

$$W_{nh} = W_{gnh} = \frac{1}{2}W_{phh} = m_T c^2, \tag{15}$$

we can write:

$$\frac{3}{2}m_T(c^2 - V_I^2) = m_T c^2 \tag{16}$$

From this, we can be drawn that maximum orbital speed for photon can only be:

$$V_I = \frac{1}{\sqrt{3}}c < c. \tag{17}$$

That means that photons can not move in circular orbits as assumed above, because before entering orbit with radius R_0, it has completely decayed to particles, which have not gravitational interaction anymore.

From the fact that for the usual celestial bodies, this orbital speed was very small compared to the speed of light: $V_I << c$, so (14) can approximate be wrote as follows:

$$W_{nd} \approx \frac{3}{2}m_T c^2. \tag{18}$$

That means that photon has always the reserves on internal energy to ensure sustainability to the effects from the outside than the critical value of 1/2 the total energy by the formula (11), as follows:

$$\frac{W_{nd}}{W_{phh}/2} \le \frac{3m_T c^2}{2m_T c^2} = 1{,}5. \tag{19}$$

That is reason why photon is a unshakeable primary particle, can not be decayed in the usual collision as other particles. As we have seen above, only when falling into the body with the radius, which reaches the critical value of R_K, are essential black holes in the universe, photon has just be decayed. Back to the expression (9), we can see, this is also the condition to form a black hole as known [3], and from here, we can be drawn the critical radius with the mass M, can become a black hole:

$$R_k = \frac{2\gamma M}{c^2}. \tag{20}$$

For photon B, although it does not fall vertically as photon A, it deflects an angle < 90° (see Figure 4), but right at the point of falling, external energy is equal as internal energy, so when collision occurs, it will be also decayed immediately, how it is reflected back? In short, when reaching the critical radius r_k, no any photons reflect back again.

The last problem is that: how the energy components of photon are changed when it moves in the gravitational field? From the total energy equation of photon in gravitational field (11), we found that its kinetic energy in (1) do not always change, so gravitational external energy can only change due to gravitational potential energy of the photon only. On the other hand, as per the above analysis, for photon, which can not move as per "circle" orbit (on inertia) as ordinary bodies, its motion should only be an unique form: non-inertial motion, i.e., energy state changes, this is the conversion of internal energy to potential energy, and vice versa, depending on each specific case. This means that when photon moves close to the gravitational field with the growth potential energy, its internal energy must be decreased, and vice versa, when photons moving away gravitational field with the smaller potential energy, its internal energy must be increase. The change of potential energy of the photon corresponds to the change of distance to the center of gravitational field R_{h1} and R_{h2}:

$$R_{h2} = R_{h1} + \Delta R_h \,. \tag{21}$$

$$\Delta U_h = U_h(R_2) - U_h(R_{h1}) = \gamma M M_T \left(\frac{1}{R_{h2}} - \frac{1}{R_{h1}} \right). \tag{22}$$

From the expressions (21) and (22), we can be drawn the change of the absolute and relative potential energy deviation of photon ΔU_h and δU_h:

$$\Delta U_h = -\gamma M M_T \frac{\Delta R_h}{R_{h1} R_{h2}}, \tag{23}$$

$$\delta U_h = \frac{\Delta U_h}{U_h(R_{h1})} = \frac{-\Delta R_h}{R_{h2}} \approx -\delta R_h \,. \tag{24}$$

On the other hand, because photon can not move as per the inertia (with a circular orbit), so in the process of moving in the gravitational field, its total energy can not be conservation, it will consume away. This is the cause that leads to the phenomenon of "red shift" observed in astronomy, which we have been mistaken that it is caused by Dopler effect, so think that “universe expands”.

Because the internal energy of photon is pure electric energy as known, so to better understand the mechanism of change in the internal energy of photon, we will consider specifically the following topics: "The energy of the photons in the electric interactions".

References

[1] Vu Huy Toan. *A new way for Physics*. Hanoi. Science and Technology Publishing House, 2007.

[2] Vu Huy Toan. *Reviewing the law of conservation of mechanical energy of the physical objects in the force field.* 2009. http://vuhuytoan.files.wordpress.com/2008/12/xet-lai-dinh-luat-bao-toan-co-nang5.pdf

[3] Новиков И.Д. *Эволюция вселенной*. Физматлит. “Наука”, Москва, 1990.