Proceedings of the 2023 International Conference on Mathematical Physics and Computational Simulation
DOI: 10.54254/2753-8818/12/20230464

The discussion about the influence of gravitational time dilation on gravity propagation speed and on light propagation speed

Xinghong Wang

Center for Theology and Philosophy Studies, Chancelada Emill Brunner World University, Miami, Florida, USA

albertwang179@gmail.com

Abstract. In this article, we will demonstrate, based upon strictly logical reasoning, thought experiment examination, and cosmic observations results, how gravitational time dilation exerts influences upon light propagation and upon gravity propagation. Neutron stars mergers have shown that the speed of gravity coincides with the speed of light (c). However, does gravitational time dilation has the same effect upon the propagation of gravity field as it has on light/electric field/magnetic field? The answer to this question can be concluded by examining such a thought experiment: according to $E=mc^2$, it is theoretically possible to transfer an enormous amount of energy to a place near a black hole and create some matter. Once created, the matter will start to generate both gravity field and light and the gravity field and light will propagate in each direction. The light it generates will NEVER enter into the black hole so it will never interact with the black hole, according to observers on the earth. But, according to current cosmic observation results, the gravity field it generates will quickly enter into the black hole and interact with the black hole, according to observers on the earth. Thus, if gravitational time dilation theory is correct, near a black hole, gravity speed is faster than light speed.

Keywords: theory of relativity, theoretical physics, time dilation, light speed, gravity speed.

1. Introduction

The fastest speed inside universe is commonly acknowledged to be the speed of light in vacuum. It is accepted by mainstream scientific views that the propagation speed of gravity (c_g) field is the same as the speed of light (c) according to the recent gravitational wave detection results. Initially, in 2016, scientists concluded the upper bound $c_g < 1.7c$[1]. If $c_g < c$, then, $c_g \div c - 1 \geq -10^{-15}$[1-2]. Then, in 2021, scientists concluded that gravity speed is identical to light speed [3-4]. Neutron stars mergers have shown, beyond any doubt, that the speed of gravity coincides with the speed of light. However, it is well-known that the speed of light is influenced by gravitational time dilation. According to distant observers, the speed of light is slowed down to be lower than 299792458 m/s near black holes, and at even horizon, the speed of light is zero according to distant observers. So, is the speed of gravity also influenced by gravitational time dilation as the speed of light? We now take this as the basis of the following discussions about the influences of gravitational time dilation.

DOI: 10.54254/2753-8818/12/20230464

2. Main text

Known to all, gravitational time dilation has an influence upon the moving speed of objects/celestial bodies [5], as well as the speed of light, according to the following formula.

$$T_{dilated} = \sqrt{1 - \frac{2Gm}{Rc^2}} \cdot T_{withoutgravity}$$

This indicates, according to observers on the earth, light speeds near a black hole are less than c (299792458 m/s). And, according to observers on the earth, when a beam of light arrives to be very near to a black hole, the speed of light is almost zero due to extremely dilated time near the black hole.

When we discuss it in terms of a photon, it is the same: when a photon approaches a black hole and is about to enter into the black hole, the speed of the photon will become slower and slower until the photon becomes completely static according to observers on the earth. As shown by the Figure 1.

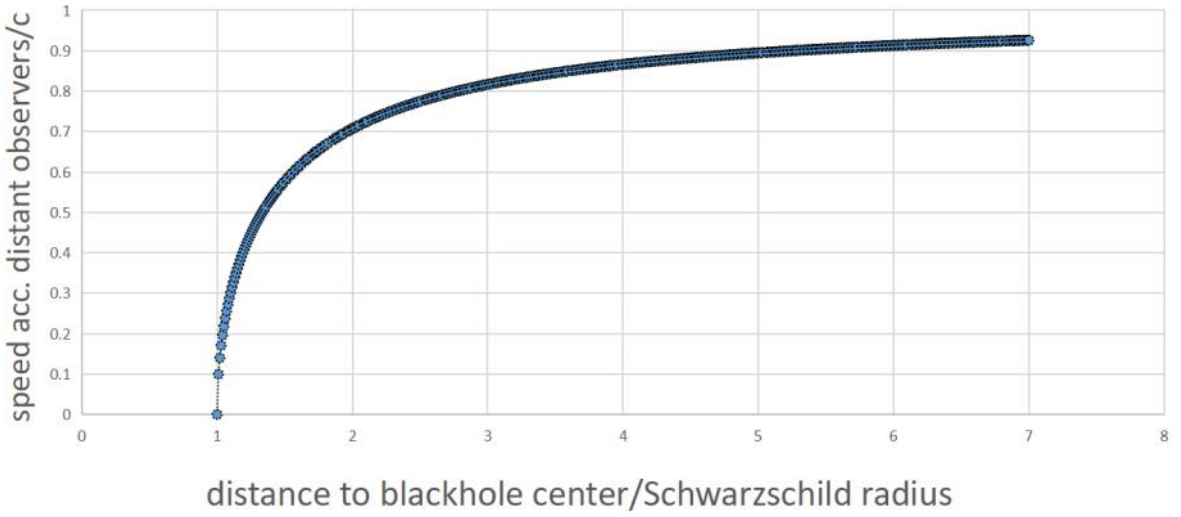

Figure 1. Light propagation speeds near a black hole.

And photons are actually electromagnetic waves which are composed of oscillating magnetic and electric fields. So, according to observers on the earth, the propagation the speed of light, the speed of magnetic field, and the speed of electric field are infinitely slowed down near black holes, as shown by the Figure 1, although they are still 299792458 m/s according to local observers.

Here, we can thus conclude that the matter and energy inside a black hole cannot have electromagnetic interaction with the electric field or the magnetic field or the electromagnetic waves generated by other celestial bodies, because it will take forever for the electric field or the magnetic field or the electromagnetic waves generated by other celestial bodies to enter into a black hole, according to observers on the earth, if gravitational time dilation theory is correct.

Then, a question can be asked: does gravitational time dilation have the same influence upon the propagation speed of gravity field? If yes, the propagation speed of the gravity fields of other celestial bodies will slow down to zero when approaching Schwarzschild radius of a black hole, as shown by the Figure 1, so the matter and energy inside the black hole cannot have gravitational interaction with the gravity field generated by other celestial bodies, according to observers on the earth.

In fact, all cosmic observations prove that, for any existing black hole, it constantly interacts with the gravitational fields generated by other celestial bodies, such as stars, neutron stars, or other black holes, according to observers on the earth. Also, needless to say, a black hole not only interacts with the gravitational fields generated by big celestial bodies but also interacts with the gravitational fields generated by any and all small particles such as each proton or each electron, even if they are tiny.

Thus, it will not take forever for the gravitational fields generated by other celestial bodies as well as by small particles in the universe to enter into a black hole, according to observers on the earth.

DOI: 10.54254/2753-8818/12/20230464

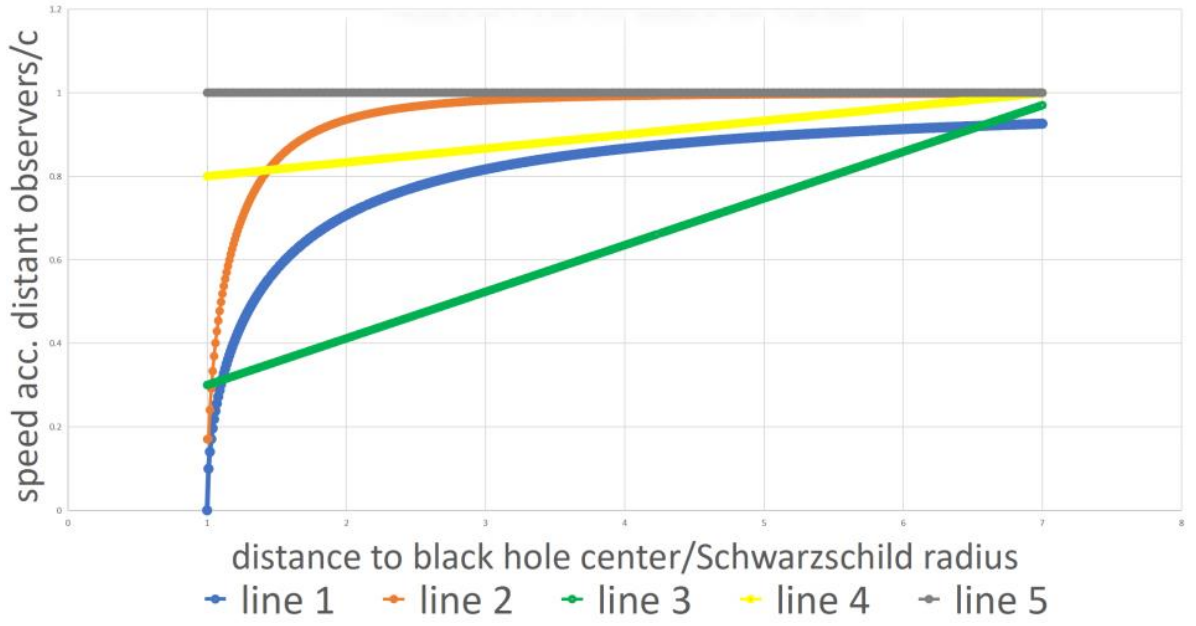

Figure 2. Exemplified possibilities of gravity propagation speeds near a black hole.

This indicates that the speed of gravity field propagation is never extremely close to zero even when approaching Schwarzschild radius of a black hole. As shown in Figure 2, according to distant observers(observers on the earth), the speed of light near a black hole is represented by line 1(blue line), at Schwarzschild radius, the speed being zero; and line 2(orange line), line 3(green line), line 4(yellow line), and line 5(grey line) each represent an exemplified possibility of gravity field propagation speeds near a black hole according to distant observers(observers on the earth), and at Schwarzschild radius, the speed being not zero. Here, if gravitational time dilation has zero influence upon gravity speed, the speed of gravity field propagation will be represented by line 5(grey line), but if gravitational time dilation has non-zero influence upon gravity speed, the speed of gravity field propagation will be represented possibly by lines such as line 2(orange line), line 3(green line), or line 4(yellow line). But anyhow, we can still logically arrive at such a conclusion: the existence of extreme gravitational time dilation causes the light propagation speed to be extremely slow (speed is infinitely close to zero) but doesn't cause the gravity propagation speed to be extremely slow (speed is not infinitely close to zero), according to observers on the earth. Thus, at least when very near the event horizon of a black hole, gravity speed is higher than light speed (the light speed is infinitely close to zero), i.e., $c_g > c$, or $b=c_g \div c > 1$.

It is thus logically inferred that, near a black hole where there is gravitational time dilation, gravity field propagates faster than electric field/magnetic field/light. If we consider the possibility represented by line 3, that is, gravity field propagation speed is sometimes lower than light speed and sometimes higher than light speed, but it is still obvious that, near a black hole, the average speed of gravity propagation is higher than light speed, according to observers on the earth.

Now, we can also use a thought experiment to examine this. For example, if we use high-energy laser to create new electrons on the earth, these newly created electrons, once created, will start to generate gravitational fields and these gravitational fields will propagate into the space in each direction to remote distance even if the intensity of the gravity fields is very low. And when these gravitational fields reach the super massive black hole located at the center of our galaxy (26k light years away from the earth), they will enter into the black hole and have gravitational interactions with matter and energy inside the black hole, and this will probably take about 26k years ($t_{gravity}$=26k years), according to observers on the earth. At the same time, these newly created electrons, once created, will also start to generate electric fields and these electric fields will also propagate into the space in each direction, although these electric fields are very weak at remote distance. And when these electric fields reach the black hole at the center

DOI: 10.54254/2753-8818/12/20230464

of our galaxy, it will take forever for these electric fields to enter into the black hole due to gravitational time dilation($t_{light}=\infty$), according to observers on the earth.

Because, apparently, $t_{gravity}$=26k years < $t_{light}=\infty$. Thus, it can be concluded that, according to observers on the earth, the propagation speed of gravitational fields is faster than the propagation speed of electric field (which is the same as the speed of light) at the places near a black hole.

Because the different locations of observers will not change observation result as long as they are in the same reference system, according to local observers near a black hole, the propagation speed of gravitational fields is also faster than the propagation speed of light. And, because, according to local observers near a black hole, the light speed is c=299792458 m/s, the speed of gravity(c_g) must be faster than c=299792458 m/s (light speed) according to local observers near a black hole.

If gravity speed is higher than light speed due to gravitational time dilation caused by the gravity field generated by black holes, it is only logical to deduce that gravity field generated by other celestial bodies can also cause the result that gravity speed is higher than light speed. Because gravity fields exist everywhere in the universe, gravity speed should be higher than light speed in all places in the universe unless gravitational time dilation is zero.

Extra evidence for this could probably be:

When gravitational waves are detected, the electromagnetic counterparts of the gravitational wave signals usually arrive at the earth later than gravitational waves, 10 ms to a few seconds [6]. For example, for GW170817, gamma ray bursts arrive about 2 seconds after the gravitational waves [7].

Although there are different explanations for this late arrival of gravitational wave signals, it is also logical to say: the ubiquitous gravitational fields in the vast space of the universe and/or the gravitational field of the celestial bodies which emit the gravitational waves and the electromagnetic counterparts caused gravitational time dilation and slowed down the speed of electromagnetic radiations which were emitted at the same time or almost at the same time when the gravitational waves are emitted.

In sum, if all of the following mainstream scientific views are correct:

(1) light speed is 299792458 m/s in vacuum anywhere in the universe locally.
(2) gravitational time dilation deduced from general relativity is correct (although many believe that general relativity theory needs to be modified [6][7]).
(3) gravity field basically propagates at a speed the same as the speed of light.
(4) black holes interact gravitationally with other big celestial bodies as well as with small particles in the universe, according to observers on the earth.
(5) near black holes, gravitational time dilation is extreme so that time stops near black holes, according to observers on the earth.

Then, we arrive at a non-mainstream conclusion:

Gravity field propagates faster than light speed in any place in the universe, i.e., the highest speed in the universe is gravitational field propagation speed but not light speed.

Now that gravity speed is higher than light speed, making it possible for information to travel faster than light:

$$c_g > c.$$

It is also practically possible to create a cosmic catastrophe alert/protection system to use gravitational wave detection result to protect human beings as well as other living creatures against such the damages as caused by gamma ray burst or supernova. Even if, hypothetically, gravity speed is not higher than light speed, it is still practical to create such a cosmic catastrophe alert/protection system, because, according to cosmic observation results, it is common that the electromagnetic counterparts (gamma ray bursts) arrive at the earth some time after the gravitational waves. In this case, the reason why there are delayed arrivals of gamma ray bursts are explained differently [8-12].

There is another result of this conclusion which will have significance: since we now use electromagnetic interaction to measure time (utilizing atomic clock), so time is measured to be dilated in gravity field because gravitational time dilation can exert influence upon electromagnetic interaction. But it is also practically possible to use gravitational interaction to measure time, so time will be measured to be not dilated in gravity field because gravitational time dilation cannot exert influence

DOI: 10.54254/2753-8818/12/20230464

upon gravitational interaction. This will change our definition of time in physics [13]. Although we will admit that it is natural for human beings to use electromagnetic interaction to measure time because we human beings as a living creature mainly depend upon electromagnetic interaction to maintain our living process, i.e. human body can function with no problem when there is no gravitational interactions going on inside our body but can't function when there is no electromagnetic interaction going on inside our body, and we human beings also depend upon electromagnetic interaction to sense the world. It is thus legitimate to call human beings, and probably all of the living creatures on the earth, as "electromagnetic life" or "electromagnetic living creature". As "electromagnetic life", or "electromagnetic living creature", we sense the time according to electromagnetic interactions, but we can also use gravitational interaction to define time in the field of scientific research of physics. Certainly, if there are other living creatures in the universe utilizing other kinds of fundamental interactions to keep their living process, it will be interesting.

3. Additional discussions

3.1. The discussion about the non-mainstream views that gravity travel instantaneously or at a speed much faster than light speed

There are also non-mainstream views that gravity travel instantaneously or at a speed much faster than light speed, for example, Tom Van Flandern stated "Laboratory, solar system, and astrophysical experiments for the 'speed of gravity' yield a lower limit of $2 \times 10^{10}c$(c=299792458 m/s)"[14].

Firstly, gravitational wave detection results already proved that gravity speed is the same or similar to light speed, so Tom Van Flandern's statement should be incorrect.

Secondly, even if 'speed of gravity' really yields a lower limit of $2 \times 10^{10}c$, then, because the detection of gravitational waves is actually detection of deformation of the earth caused by gravitational waves (disturbance of gravitational field), the gravitational waves travelling at such high speed will probably not cause any deformation on the earth because the earth doesn't have sufficient time to react to the gravitational waves. We can analyze from the micro level: when we say that the earth is deformed, it actually indicates that the enormous number of atoms of the earth interact with gravitational waves and change their positions slightly. But if the speed of gravity is faster than $2 \times 10^{10}c$, the gravity field around the entire earth is only disturbed for probably less than 10^{-11} second, and the gravity field around an atom(with a diameter of 10^{-10} meter) is only disturbed for $10^{10} \div (2 \times 10^{10} \times 299792458) = 1.7 \times 10^{-29}$ second, during such short time interval, even if gravitational waves make the atoms of the earth to move at speed of light(no atom can move faster than light speed), the atoms of the earth can only move $1.7 \times 10^{-29} \times 299792458 = 5.6 \times 10^{-21}$ meter, which is much less than the detection accuracy of LIGO which is 10^{-19}m[15], so the interaction time between the atoms of the earth and the gravitational waves are so short that the atoms will basically not move its position at all according to current detection accuracy. So, we will not be able to detect gravitational waves. But LIGO and other detection facilities have already detected gravitational waves, so the statement "the 'speed of gravity' yield a lower limit of $2 \times 10^{10}c$" must be incorrect.

Thirdly, hypothetically, even if the statement "the 'speed of gravity' yields a lower limit of $2 \times 10^{10}c$" is true, the merit of this article is still valid: the speed of gravity is different in different gravitational field intensity. The speed of gravity is lowest when gravitational field intensity is zero. And, where the gravity field intensity is extremely high, the speed of gravity is so fast as to seem to be instantaneous. And if this is true, it is more obviously possible to create a cosmic catastrophe alert/protection system as previously suggested in this article.

3.2. Discussion about the details when a particle approaches a black hole

It is also an idea that when a particle approaches a black hole, the particle will gain unlimited energy during the process, and this gained energy will have a gravitational effect on the event horizon of the black hole so that the local structure of spacetime is broken, so it will not take forever for the particle to enter into the black hole, according to observers on the earth.

DOI: 10.54254/2753-8818/12/20230464

However, firstly, as some scientist said, it is difficult to understand why in a finite system the acceleration of a freely falling particle becomes unlimited when it nears the horizon.

Also, this article used the example of photon to explain the process. Even if the photon could gain unlimited energy (or limited energy) during the process of approaching a black hole, the gravitational field of the photon (let's consider it is true that a photon has gravitational field) will also travel at the same speed of the photon, so the gravity field of the photon will have zero effect in the spacetime between the photon and the black hole, thus it will still take forever for the photon to enter into the black hole. (If it is not true that a photon has gravitational field, then it is more apparent that it will take forever for the photon to enter into the black hole.)

Therefore, the above-mentioned idea will not disprove the above-mentioned conclusion of this article.

3.3. Further deductions from the above-mentioned conclusion of the article

The reason for the fact that, near black holes, gravity speed is higher than light speed is because of gravitational time dilation, and gravitational time dilation is caused by gravity field of the black holes.

It can then be logically inferred that the existence of gravity field causes the result of gravity speed being higher than light speed:$c_g > c$, or ratio: $c_g \div c = r_{g/c} > 1$.

Then it is only logical to deduce: the higher gravity field intensity, the bigger the value of $r_{g/c} = c_g \div c$. ($r_{g/c}$ is defined as ratio of gravity speed versus light speed. And it will also be logical to deduce that $r_{g/c}$=gravitational time dilation ratio/rate).

So, the gravity speed is at least positively correlated with the rate of time dilation, and the gravity speed is positively correlated with the gravitational field intensity if we accept that c (light speed) is constant.

Also, because there are gravitational fields everywhere in the universe, the gravitational time dilation effect exists in all places inside the universe, although in most places the gravitational fields are not strong so the time dilation effect is very tiny. But at least it is correct to say, in all places inside the universe, the speed of gravity is faster than 299792458 m/s (light speed). But in most places inside the universe, speed of gravity is only very slightly higher than light speed. Only in places where gravitational field is very strong, speed of gravity is much higher than speed of light.

For example, if we assume that gravitational time dilation has no effect upon gravity speeds,

In gravitational field where gravitational time dilation ratio is 2, the local speed of gravity is $2 \times 299792458 = 599584916$ m/s.

In gravitational field where gravitational time dilation ratio is 3, the local speed of gravity is $3\times 299792458 = 899377374$ m/s.

In gravitational field where gravitational time dilation ratio is 4, the local speed of gravity is $4\times 299792458 = 1199169832$ m/s.

In gravitational field where gravitational time dilation ratio is 10^{100}, the local speed of gravity is $10^{100} \times 299792458$ m/s.

And, in places where gravitational field intensity is extremely high so that time is close to static, speed of gravity would seem to be so high as to be instantaneous according to local observers.

And, only when the gravitational field intensity is zero, speed of gravity is the same as light speed.

In sum:

- In most places inside universe, the speed of gravity is only very slightly higher than light speed, i.e., almost the same as light speed.
- In places where gravity field intensity is very high, the speed of gravity is much higher than light speed.
- $c_g = c$, where the gravity field intensity is zero.
- Where the gravity field intensity is extremely high, the speed of gravity is so fast as to seem to be instantaneous.

Now that gravity speed is higher than light speed, making it possible for information to travel faster than light, this will possibly question "Law of causation", making it necessary to reconsider about theory

DOI: 10.54254/2753-8818/12/20230464

of relativity. As said, one parameter change can collapse an ontological construction. We 'patch' old theory when new findings emerge but if we always assumed the assumptions first made may be wrong, dug out and challenge them from scratch, perhaps then we may better advance, as said by Professor Peter Jackson.

It should be noticed that there was the research conclusion that a periodic variation in gravitational constant G was measured, this could possibly be related with the different speeds of gravity in different gravitational field intensity, as studied by Professor Preston Guynn (but it can also be caused by periodical ocean tide phenomenon or/and by internal movement inside the earth).

4. Conclusion

It will take forever for the electric field or the magnetic field or the electromagnetic waves generated by other celestial bodies to enter into a black hole, according to observers on the earth, if gravitational time dilation theory is correct.

It will not take forever for the gravitational fields generated by other celestial bodies as well as by small particles in the universe to enter into a black hole, according to observers on the earth.

At the place very near the event horizon of a black hole, according to distant observers, light speed is very close to zero but gravity speed is not, so gravity speed is much higher than light speed, i.e., $c_g > c$, or $b=c_g \div c > 1$.

Generally speaking, gravity speed should be higher than light speed.

The higher the intensity of gravity field, the faster gravity field is than light speed.

It is also practically possible to create a cosmic catastrophe alert/protection system to use gravitational wave detection result to protect against such damages as caused by gamma ray burst or supernova.

We human beings, as “electromagnetic life” or “electromagnetic living creature”, use electromagnetic interaction to maintain living process, if there are other living creatures in the universe utilizing other kinds of fundamental interactions to keep their living process, it will be interesting.

Acknowledgments

The great work of Albert Einstein inspired the author to conduct the scientific research and general relativity time dilation theory is the basis for the author’s research of this topic.

The author would like to express sincere thanks to Fermilab because of the scientific information it provided on internet. Genuine gratitude and respect to Professor Don Lincoln.

Genuine thanks to Professor Preston Guynn for informative inputs.

Genuine thanks to Professor W. Belayev for informative inputs.

The research of the author is based on the detection of gravitational wave events by the Advanced LIGO Project, which is supported by the NSF, with important contributions from the United Kingdom's Science and Technology Facilities Council, the Max Planck Society of Germany, and the Australian Research Council, and the Virgo Collaboration with the international participation of scientists from several universities and research institutions with involvement and supports of more than 1000 scientists worldwide, as well as 440,000 active Einstein@Home users, and the author wish to express sincere gratitude to them all.

References

[1] Bettoni D, Ezquiaga J M, Hinterbichler K, and Zumalacarregui M 2017 Speed of gravitational waves and the fate of scalar-tensor gravity. *Physical Review D* 95, 084029. https://doi.org/10.1103/PhysRevD.95.084029

[2] Moore GD and Nelson AE 2001 Lower bound on the propagation speed of gravity from gravitational Cherenkov radiation. *JHEP* 09, 023. https://doi.org/10.1088/1126-6708/2001/09/023

DOI: 10.54254/2753-8818/12/20230464

[3] Haug E 2021 Demonstration that Newtonian gravity moves at the speed of light and not instantaneously (infinite speed) as thought! *Journal of Physics Communications* 5, 025005. https://doi.org/10.1088/2399-6528/abe4c8
[4] Lincoln D 2022 How fast is gravity? [EB/OL] https://youtu.be/Pa_hLtPIE1s
[5] Einstein A 1916 *Relativity: The Special and General Theory* (Translation 1920) H. Holt and Company, USA
[6] Srivastava M, Chen Y and Shankaranarayanan S 2021 Analytical computation of quasinormal modes of slowly rotating black holes in dynamical Chern-Simons gravity. *Physical Review D.* 104. 064034 https://doi.org/10.1103/PhysRevD.104.064034
[7] Shankaranarayanan S 2019 Strong gravity signatures in the polarization of gravitational waves. *International Journal of Modern Physics D.* Vol. 28, No. 14, 1944020 https://doi.org/10.1142/S0218271819440206
[8] Uhm Z L, Zhang B, Racusin J 2018 Toward an Understanding of GRB Prompt Emission Mechanism. II. Patterns of Peak Energy Evolution and Their Connection to Spectral Lags. *The Astrophysical Journal* 869(2) 100 https://doi.org/10.3847/1538-4357/aaeb30
[9] Geng J J, Zhang B, Kölligan A, Kuiper R, Huang Y F 2019 arXiv: 1904.02326
[10] Lin D B, Liu T, Lin J, Wang X G, Gu W M, Liang, E W 2018 First Electromagnetic Pulse Associated with a Gravitational-wave Event: Profile, Duration, and Delay. *The Astrophysical Journal* 856(2) 90 https://doi.org/10.3847/1538-4357/aab3d7
[11] Duffell P C, Quataert E, Kasen D, Klion H 2018 Jet Dynamics in Compact Object Mergers: GW170817 Likely Had a Successful Jet. *The Astrophysical Journal* 866(1) 3 https://doi.org/10.3847/1538-4357/aae084
[12] Mooley K P, Deller A T, Gottlieb O, Nakar E, Hallinan G, Bourke S, Frail D A, Horesh A, Corsi A, Hotokezaka K 2018 Superluminal motion of a relativistic jet in the neutron-star merger GW170817. *Nature* 561(7723) 355 https://doi.org/10.1038/s41586-018-0486-3
[13] Wang X 2022 A DISCUSSION ABOUT THE NATURE OF TIME. *International Journal of Scientific Research and Modern Education.* Volume 7, Issue 2 P 4. https://doi.org/10.5281/zenodo.7079721
[14] Flandern T V 1998 The speed of gravity - What the experiments say. *Physics Letters A* Volume 250, Issues 1–3 P 1. https://doi.org/10.1016/S0375-9601(98)00650-1
[15] LIGO Lab – Caltech (2017). https://www.ligo.caltech.edu/page/vibration-isolation