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General Light Clock Visualizes General Relativity

Tao Jia

Email: *tjcoch[at]outlook.com*

Abstract: ***The concept of general light clock is proposed. A light clock is composed of two mirrors (which are mathematically abstracted as two points) and a light signal that travels between the two mirrors. From the point of view of the stationary light clock, the trajectory of the light ray 'seen' by the two mirrors of a moving light clock can be a straight line or a curved line; the shape of the light ray is a signature of the state of the motion of the light clock. The shape of the light trajectory is a straight line in inertial frames, and the shape of the light trajectory is a curved line in non-inertial frames in most cases. This means that light bending may appear in non-inertial frames. Four specific examples of light bending in four different non-inertial frames are given.***

Keywords: general light clock; trajectory; straight line; curved line; light bending; inertial frame; non-inertial frame

1. Introduction

What is time is a question that seems easy to answer at first but becomes more and more difficult to answer when digging deeper later. Many people believe that time can only be understood based on intuition; it cannot be well defined by science. According to the dictionary by Merriam-Webster, the concept of time is defined as the point or period when something occurs. Scientists always want to give a precise definition to time. In special relativity proposed by Einstein, light clock [1-2] is used to investigate time to demonstrate that time goes more slowly in a uniform moving frame. One tick of the clock corresponds to the process in which the light signal initially leaves one of the two mirrors, and then reaches the other mirror, and then returns to the mirror it initially leaves. Recently, the ergodicity of the behavior of time has been shown based on spinning light clock [3], rotational light clock [4], and oscillating light clock [5]. Time dilation can be demonstrated by conventional uniform moving light clock, and time contraction can be demonstrated by spinning light clocks, and time conservation can be demonstrated by oscillating light clocks. The connection between relativity and quantum mechanics is explained by spinning light clock [6].

For a uniform moving light clock [1-2], the relationship between the time-interval of one tick in stationary frame and the time-interval of one tick in spinning frames is determined as:

$$\Delta t_2 = \frac{\Delta t_1}{\sqrt{1 - V^2 / c^2}} \tag{1}$$

For a spinning light clock [3], the relationship is determined as:

$$\frac{(\Delta t_2)^2}{\left(\frac{k^2 + 1 + 2k\cos(\omega \cdot \Delta t_2)}{(k+1)^2}\right)} = (\Delta t_1)^2 \tag{2}$$

For a two-dimensional light clock [4], the relationship is determined as:

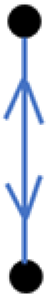
$$(\Delta t_2)^2 \cdot \frac{(k-1)^2}{k^2 + 1 - 2k \cdot \cos(\omega \cdot \Delta t_2)} = (\Delta t_1)^2 \tag{3}$$

In this paper, the concept of general light clock is proposed to give a unifying way to describe different kinds of motions. The shape of the light ray of the light clock serves as an indicator of the state of the motion of the light clock. Specific examples of light bending in the light clock are given.

2. General Light Clock

For a general light clock, the shape of the light trajectory can be arbitrary kind of curves. A general light clock can be classified into two categories: general normal light clock (shown in Fig.1) and general horizontal light clock (shown in Fig.2).

In Fig.1 and Fig.2, the light ray is marked by blue color, and the two black disks represent the two mirrors. For a normal light clock, the direction of the motion of the clock is perpendicular to the direction of the straight line passing the two points representing the two mirrors. For a tangential light clock, the direction of the motion of the clock is horizontal to the direction of the straight line passing the two points representing the two mirrors.



(a) Stationary normal light clock

(b)General normal light clock

Figure 1: Normal light clock

(a) Stationary horizontal light clock

(b)General horizontal light clock

Figure 2: Horizontal light clock

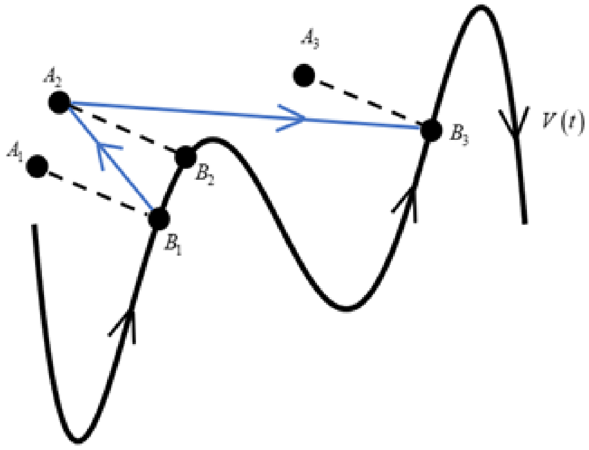


Figure 3: One tick of a normal light clock moving along a curve

In Fig.3 it shows a normal light clock moving along a curve with speed V (t). The speed can be constant or time-varying. The two points of B_i and A_i (i =1, 2, 3) represent the two mirrors of the light clock. The point B_i is always on the curve, and the direction of the line segment B_iA_i is the direction of the normal line to the curve at the point B_i. A light signal first starts from B_1, and then reaches A_2, and then reaches B_3. This constructs a tick of the normal light clock.

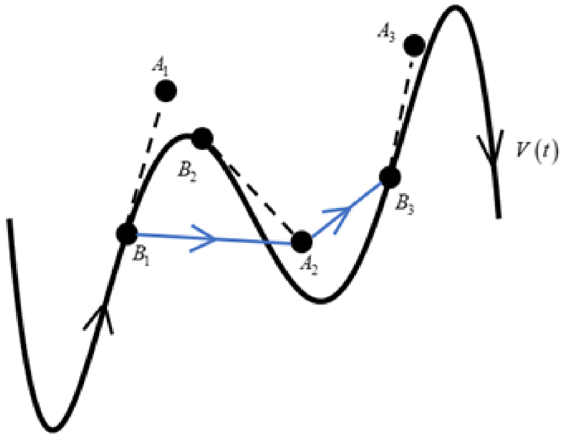


Figure 4: One tick of a horizontal light clock moving along a curve

In Fig.4 it shows a tangential light clock moving along a curve with speed V (t). The speed can be constant or time-varying. Same as the normal light clock, the two points of B_i and A_i (i =1, 2, 3) represent the two mirrors of the light clock. The point B_i is always on the curve, and the direction of the line segment B_iA_i is the direction of the tangential line to the curve at the point B_i. A light signal first starts from B_1, and then reaches A_2, and then reaches B_3. This constructs a tick of the horizontal light clock.

In Fig.5 the moving frames are shown. As the mirror represented by B_i moves along the curve, the corresponding frame moves accordingly. The visualization of the positions of the photon in the moving frames needs to be done to see what shape of the trajectory of the light ray observed by the moving light clock.

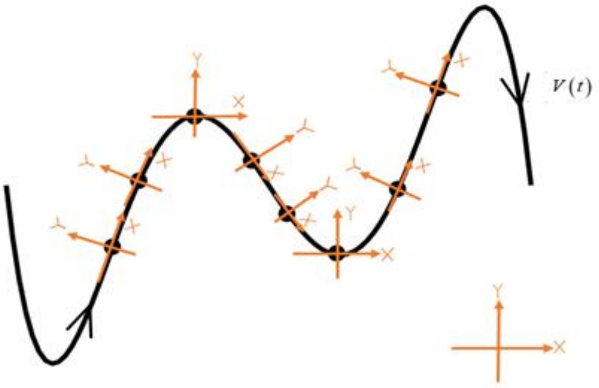


Figure 5: Moving frames along the curve

3. Visualization of light bending

As to general light clock, the word ‘general’ means that there are infinite cases. To give specific examples of light bending, numerical simulations are carried out to investigate the cases of a light clock moving along a curve shown in Fig.3 and Fig.4. In the simulation, , the light speed is set as 1, and the equation of the curve along which the light clock moves (shown in Fig.3 and Fig.4.) is the following:

$$y=-(x-1)(x-2)(x-3)(x-4)(x-5) \quad (4)$$

3.1 Cases of constant speed

In the simulations, the curve along which the light clock moves is mathematically described by Eq (4). In the simulation, the speed of the clock is set as 0.4 since the light speed is set as 1, the distances between the two mirrors in stationary state are set as 1 and 1.5 for the normal and horizontal light clocks respectively, and the starting position of the mirror (abstracted as a point, such as point B in Fig. 3) is set as (2.2, 0.9697). The number 0.9697 is obtained by plugging x = 2.2 into Eq (4) to calculate the value of y. This means y = 0.9697 when x = 2.2, regarding Eq (4). In Fig.6 there are 6 ticks for the normal light clock. In Fig.7 there are 6 ticks for the horizontal light clock.

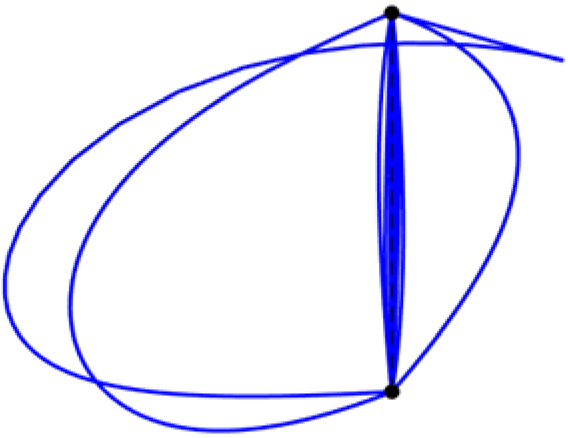


Figure 6: Light bending in the normal light clockwith a constant speed

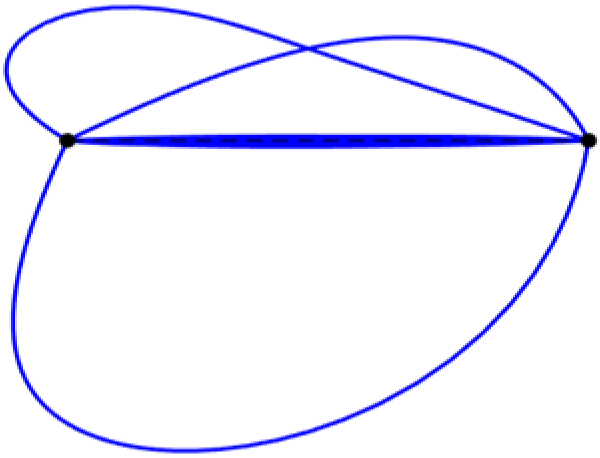


Figure 7: Light bending in the horizontal light clock with a constant speed

3.2 Cases of time-varying speed

In the simulation, the speed of the light clock moving along the curve is set as:

$$V = A \cdot \left[\sin\left(\omega t\right)\right]^2 \tag{5}$$

And the amplitude A is set as 0.4, the frequency ω is set as 0.2, the light speed is set as 1, and the distance between the two mirrors in stationary state is set as 1.

In Fig.8 there are 10 ticks for the normal light clock. In Fig.9 there are 6 ticks for the horizontall light clock. In the case of the horizontall light clock, the distance between the mirrors changes with the speed. If the speed is time-varying, and then the distance is also time-varying.

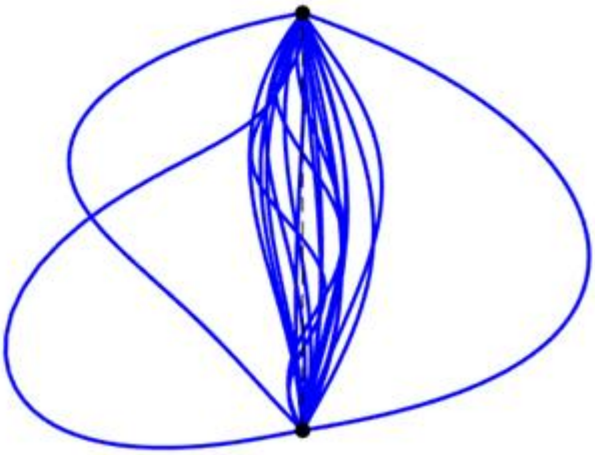


Figure 8: Light bending in the normal light clock with time-varying speed

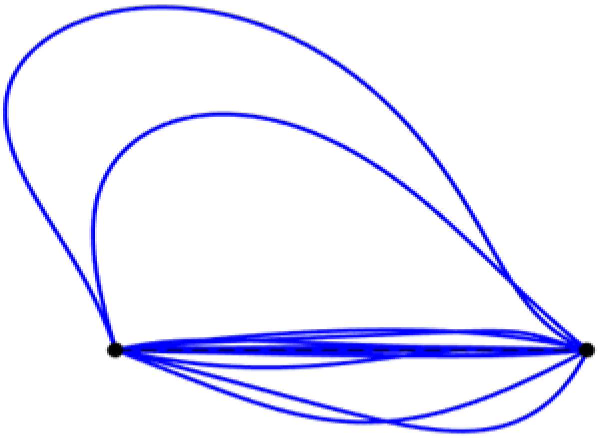


Figure 9: Light bending in the horizontal light clock with time-varying speed

4. Extension to the cases of high dimension and curved surfaces

The above method to visualize light bending is of the two dimensional. It can be extended to the cases of three dimensions and higher dimensions such as four dimensions. The fundamental point is to calculate the position of the photon in the moving reference frame. In the case of a light clock moving along a curve on a curved surface, it is represented by the moving normal and tangent vectors which represent the normal and the horizontal light clocks respectively. The two endpoints of the vector represent the two mirrors of the light clock respectively. Mathematically, if a point particle moves along a curve on a curved surface, there is a unique normal line and a unique tangent line to the surface at the pointat every moment.

5. Conclusion

A unifying framework based on the concept of general light clock to describe motion is proposed. The method of the visualization of the light bending in the moving light clock is given. This method can also be used to explain what the light clock appears to the observers in all scales. If the size of the light clock (measured by the distance between the two mirrors) is extremely large or small compared to the length of the curve line segment along which the light clock moves, there seems no light bending to the observer, and the observer assumes there is no force acting on the light clock. Only if the size of the light clock is comparable to the curve line segment, the phenomena of the light bending can be pronounced by the observer.

References

[1] G. F. R. Ellis, R. M. Williams, Flat and Curved Space Times, Oxford University Press, 2000.
[2] R. Ferraro, Einstein’s Space-Time: An Introduction to Special and General Relativity, Springer Science, 2007.
[3] T. Jia, Spinning Light Clocks Reveal Time Contraction in Spinning Noninertial Frames, International Journal of Science and Research, 10 (5), 2021.
[4] T. Jia, Rotational Light Clocks and Visualization of Spins, International Journal of Science and Research, 10 (5), 2021.
[5] T. Jia, Oscillating Light Clocks Reveal the Possibility of Time Conservation in Moving Frames, International Journal of Science and Research, 10 (8), 2021.
[6] T. Jia, Visualization of Spin 1 Divided By N Through Spinning Light Clocks, International Journal of Science and Research, 10 (9), 2021.