The speed of photons in absolute gravity

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In absolute space and time, photons rarely move at the speed of light c. Instead, photons slow down as they enter gravity wells, they speed up as they leave gravity wells, etc. This paper shows how to calculate the speed of photons in arbitrary gravitational fields. For a given unit direction vector, there are two possible speeds. The two speeds are the solutions to a quadratic equation in terms of the gravitational fields and the unit direction vector. In most places in the universe the two speeds have different magnitudes, and one speed is in the direction of the unit vector while the other is in the opposite direction. For example, consider a laboratory on Earth. In order to maintain constant speeds in all directions relative to the laboratory, photons move faster in the direction of the Earth's rotation, and slower in the opposite direction.

INTRODUCTION

In absolute space and time[2], photons rarely move at the speed of light c. Instead, photons slow down as they enter gravity wells, they speed up as they leave gravity wells, etc.

The main result of this paper is that a photon's absolute speed v in a given absolute unit direction $\hat{\mathbf{v}}$ in the fields g, $\mathbf{w}$, and $\mathbf{S}$ (see equation (9)) is:

$$\frac{v}{c} = \frac{-\mathbf{w}\cdot\hat{\mathbf{v}} \pm \sqrt{(\mathbf{w}\cdot\hat{\mathbf{v}})^2 - g(\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal))}}{\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal)}. \tag{1}$$

The $\pm$ indicates that photons can have two different speeds for a given unit direction vector. In most places in the universe the two speeds have different magnitudes, and one speed is in the direction of the unit vector while the other is in the opposite direction. For example, consider a laboratory on Earth. In order to maintain constant speeds in all directions relative to the laboratory, photons move faster in the direction of the Earth's rotation, and slower in the opposite direction[1].

DERIVATION

One way to derive equation (1) is to start from the line element from general relativity, in a metric with signature $(1,-1,-1,-1)$, and proper time measured in seconds:

$$(\mathrm{d}s)^2 = (c\,\mathrm{d}\tau)^2 = g_{\mu\nu}\,\mathrm{d}x^\mu\,\mathrm{d}x^\nu. \tag{2}$$

For a photon, the proper time τ is 0, so for a photon:

$$0 = g_{\mu\nu}\,\mathrm{d}x^\mu\,\mathrm{d}x^\nu. \tag{3}$$

Dividing both sides by $(\mathrm{d}x^0)^2$ gives:

$$0 = g_{\mu\nu}\frac{\mathrm{d}x^\mu}{\mathrm{d}x^0}\frac{\mathrm{d}x^\nu}{\mathrm{d}x^0}. \tag{4}$$

Next, we can expand the sums over μ and ν to separate the cases $\mu = 0$ or $\nu = 0$ from the cases $\mu,\nu = 1,2,3$, and then replace μ and ν by i and j for $i,j = 1,2,3$. Since $g_{\mu\nu}$ is symmetric, we can coalesce the cases $g_{i0} = g_{0i}$:

$$0 = g_{00}\frac{\mathrm{d}x^0}{\mathrm{d}x^0}\frac{\mathrm{d}x^0}{\mathrm{d}x^0} + 2g_{i0}\frac{\mathrm{d}x^i}{\mathrm{d}x^0}\frac{\mathrm{d}x^0}{\mathrm{d}x^0} + g_{ij}\frac{\mathrm{d}x^i}{\mathrm{d}x^0}\frac{\mathrm{d}x^j}{\mathrm{d}x^0}. \tag{5}$$

Noting that $\frac{\mathrm{d}x^0}{\mathrm{d}x^0} = 1$, we can eliminate the factors of $\frac{\mathrm{d}x^0}{\mathrm{d}x^0}$:

$$0 = g_{00} + 2g_{i0}\frac{\mathrm{d}x^i}{\mathrm{d}x^0} + g_{ij}\frac{\mathrm{d}x^i}{\mathrm{d}x^0}\frac{\mathrm{d}x^j}{\mathrm{d}x^0}. \tag{6}$$

Noting that $\mathrm{d}x^0 = c\,\mathrm{d}t$, we can replace occurrences of $\mathrm{d}x^0$:

$$0 = g_{00} + \frac{2}{c} g_{i0} \frac{\mathrm{d}x^i}{\mathrm{d}t} + \frac{1}{c^2} g_{ij} \frac{\mathrm{d}x^i}{\mathrm{d}t}\frac{\mathrm{d}x^j}{\mathrm{d}t}. \tag{7}$$

We now write $\frac{\mathrm{d}x^{i,j}}{\mathrm{d}t}$ as elements $\mathbf{v}_{i,j}$ of the absolute velocity three-vector $\mathbf{v}$ of a photon:

$$0 = g_{00} + \frac{2}{c} g_{i0}\mathbf{v}_i + \frac{1}{c^2} g_{ij}\mathbf{v}_i\mathbf{v}_j. \tag{8}$$

At this point, we pause to remember that in absolute gravity[2] the metric $g_{\mu\nu}$ no longer describes the curvature of space and time, but is instead a set of ten gravitational potentials at a point in absolute three-dimensional space. Following the notation of [3], we rewrite $g_{\mu\nu}$ as a scalar potential g, a three-vector potential $\mathbf{w}$ and a three-by-three matrix potential $\mathbf{S}$:

$$g_{\mu\nu} = \begin{bmatrix} g_{00} & g_{01} & g_{02} & g_{03} \\ g_{10} & g_{11} & g_{12} & g_{13} \\ g_{20} & g_{21} & g_{22} & g_{23} \\ g_{30} & g_{31} & g_{32} & g_{33} \end{bmatrix} = \begin{bmatrix} g & \mathbf{w}_1 & \mathbf{w}_2 & \mathbf{w}_3 \\ \mathbf{w}_1 & \mathbf{S}_{11} & \mathbf{S}_{12} & \mathbf{S}_{13} \\ \mathbf{w}_2 & \mathbf{S}_{21} & \mathbf{S}_{22} & \mathbf{S}_{23} \\ \mathbf{w}_3 & \mathbf{S}_{31} & \mathbf{S}_{32} & \mathbf{S}_{33} \end{bmatrix} = \begin{bmatrix} g & \mathbf{w}^\intercal \\ \mathbf{w} & \mathbf{S} \end{bmatrix}. \tag{9}$$

We can then substitute from equation (9) for the $g_{\mu\nu}$ in equation (8) to get:

$$0 = g + \frac{2}{c}\mathbf{w}_i\mathbf{v}_i + \frac{1}{c^2}\mathbf{S}_{ij}\mathbf{v}_i\mathbf{v}_j. \tag{10}$$

We can eliminate the indexes i and j by writing equation (10) in three-dimensional vector/matrix notation:

$$0 = g + \frac{2}{c}(\mathbf{w}\cdot\mathbf{v}) + \frac{1}{c^2}(\mathbf{S}\cdot(\mathbf{v}\mathbf{v}^\intercal)), \tag{11}$$

where the $\cdot$ between $\mathbf{S}$ and $(\mathbf{v}\mathbf{v}^\intercal)$ is the matrix dot product defined in [3].

Next we can write $\mathbf{v}$ as $v\,\hat{\mathbf{v}}$ and separate out v:

$$0 = g + \frac{2}{c}(\mathbf{w}\cdot\hat{\mathbf{v}})v + \frac{1}{c^2}(\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal))v^2. \tag{12}$$

Solving the quadratic equation for v gives:

$$v = \frac{-\frac{2}{c}(\mathbf{w}\cdot\hat{\mathbf{v}}) \pm \sqrt{\frac{4}{c^2}(\mathbf{w}\cdot\hat{\mathbf{v}})^2 - \frac{4g}{c^2}(\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal))}}{\frac{2}{c^2}(\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal))}. \tag{13}$$

Multiplying both sides by $\frac{1}{c}$ and then canceling out constants gives:

$$\frac{v}{c} = \frac{-\mathbf{w}\cdot\hat{\mathbf{v}} \pm \sqrt{(\mathbf{w}\cdot\hat{\mathbf{v}})^2 - g(\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal))}}{\mathbf{S}\cdot(\hat{\mathbf{v}}\hat{\mathbf{v}}^\intercal)}, \tag{14}$$

which is equation (1).

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[1] Parker, D. B., "How to explain the Michelson-Morley experiment in ordinary 3-dimensional space", 2010, https://arxiv.org/abs/1006.4596
[2] Parker, D. B., "General Relativity in Absolute Space and Time", 2022, preprint, https://pgu.org
[3] Parker, D. B., "The absolute gravity force equation as classical mechanics", 2023, preprint, https://pgu.org