

LETTERS TO PROGRESS IN PHYSICS

Simple Explanation for why Parallel-Propagating Photons do not Gravitationally Attract

Raymond Jensen

Dept. of Mathematics and Science, Northern State University, Aberdeen SD, 57401 USA. E-mail: rwjst4@alumni.nd.edu

In this article it is shown that photons of light, when traveling in parallel, do not attract one another gravitationally. This has been shown previously using general relativity, however here it is only assumed a Newtonian approximation to the gravitational attraction between photons. The explanation for the lack of gravitational attraction is simple: as co-moving objects accelerate in parallel, the flow of time is retarded, as observed by a stationary observer, according to special relativity. Hence so is the tendency for the objects to move toward one another. As the velocity of the objects approach c , the time required for the objects to approach one another approaches infinity, and so there is no gravitational attraction between objects which move parallel at the speed of light.

1 Introduction

In 1931 Tolman, Ehrenfest and Podolsky [1] were first to publish studies on how light interacts with light gravitationally. Among other things, they found that when photons move in parallel beams, there is no gravitational attraction between them. The authors did not give a physical explanation for this peculiarity. In 1999, Faraoni and Dumse [2] studied the problem of gravitational attraction between photons and concluded that for photons moving in parallel, the reason for the lack of gravitational attraction is due to an exact cancellation of the gravitomagnetic and gravitoelectric forces between them. Both sets of authors used a linear approximation to the metric to come to their conclusions. Here, we come to the same conclusion, but it is argued that the lack of gravitation can be entirely explained in Minkowski spacetime with assumption of the Newtonian approximation for gravity. This is reasonable, since the gravitational fields between photons can be expected to be very weak.

2 No attraction between parallel photons

Consider two free particles separated by distance x initially at rest in empty space with respect to an observer. The observer will find that after a time interval t , the objects will come together due to their mutual gravitational attraction. Since the objects are regarded to be small, it is sufficient to assume Newtonian mechanics in the calculation of t , however calculation of the exact value is not necessary for the purpose of the argument here.

Next, consider what happens when the two objects are returned to a distance x apart from one another, accelerated to some terminal velocity v perpendicular to x , and then released. Upon release, the objects initially move parallel to one another, with distance x between, but as before, begin to attract, and eventually come together. However, in this instance, the time required for the two objects to come together, in accordance with special relativity, is $t' = t/\sqrt{1-v^2/c^2} > t$.

Thus, according to a stationary observer, it takes longer for the two objects to approach one another, when their center-of-mass frame is moving at some non-zero velocity. Since the factor $1/\sqrt{1-v^2/c^2} \rightarrow \infty$ as $v \rightarrow c$, the time required for the two particles to come together as $v \rightarrow c$, approaches infinity. The time required for the objects to deviate from their parallel trajectories is hence also infinite. The conclusion here is that for two particles moving at the speed of light, since time propagation in their center-of-mass frame is nonexistent, their gravitational attraction is also nonexistent. Although x was taken to be perpendicular to the direction of propagation, this condition can be relaxed without changing the conclusion of no gravitational attraction.

3 Attraction between coplanar non-parallel photons

In both of the references, the authors found that for non-parallel propagation, the gravitational attraction between photons is non-zero. This can be reasoned, for some simple cases, as follows: suppose the two particles, in this case photons, are returned to their original positions, but upon release, propagate away from one another at a relative angle $2\theta > 0$, according to a stationary observer. Then, the center of mass frame propagates at a velocity $v = c \cos \theta < c$ and so gravitational attraction between photons is retarded by a factor of $1/\sin \theta$, according to a stationary observer. For example, at $2\theta = 180^\circ$, the photons trajectories are antiparallel to one another, and there is no retardation since the center of mass frame is stationary. The same applies for photons converging at these nonzero angles.

Submitted on: September 10, 2013 / Accepted on September 15, 2013

References

1. Tolman R. C., Ehrenfest P., Podolsky B. On the gravitational field produced by light. *Physical Review*, 1931, v. 37, 602–615.
2. Faraoni V., Dumse R. M. The gravitational interaction of light: from weak to strong fields. *General Relativity and Gravitation*, 1999, v. 31 (1), 91–105.