Comparison of the Falling Light Experiment and the Ultracentrifuge Gamma Radiation Study

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Abstract

The discovery of the Mőssbauer effect had a great impact on experimental attempts to study basic open questions in the field of relativity. Pound et al. carried out an experiment to measure the variation of the speed of light with gravitational potential by mounting a gamma ray Mőssbauer emitter on the roof of a building and detecting the radiation at ground level. Hay et al. and others measured the dependence of the frequency of gamma radiation as a function of the speed of an absorber mounted on the rim of an ultracentrifuge/ In both cases the theoretical interpretation was based squarely on Einstein's Equivalence Principle (EP), which assumes that kinetic and gravitational acceleration are basically indistinguishable. In the present study these experimental results are analyzed on the basis of the Uniform Scaling method. It assumes that the units of physical properties vary with both the state of motion and position of the object and observer in a predictable manner. It is pointed out that the properties of light do not change as the radiation descends in a gravitational field, thereby indicating that the local acceleration due to gravity on the photons is equal to zero. This conclusion is supported by the assumption made by Schiff which successfully predicts the angle of displacement of star images observed during solar eclipses. The conclusion for the variation of the frequency of the gamma rays is that it decreases with the rotational speed of the centrifuge, thereby indicating that a blue shift is observed at the rim of the rotor for radiation emitted near the axis. It is pointed out that this result stands in contradiction to

Einstein's Symmetry Principle, which claims that two clocks in motion will both be running slower than one another at the same time.

Keywords: Mőssbauer effect, Equivalence Principle, Uniform Scaling method,

Gravitational effect on light speed, Dependence of frequency on rotational speed

I. Introduction

The discovery of the Mössbauer effect [1] made it possible for the first time to carry out quantitative tests of various predictions of Einstein's relativity theory [2-4]. One of these experiments involved studying the effects of gravity on the speed of light. To this end, a γ-radiation source was mounted on the top of a building at a height of d= 22.5 m above the absorber on the ground [5-6]. Another one had the goal of directly measuring the change in frequency of light waves that is caused by the acceleration of the light source [7-9]. In this case the gamma-radiation emitter was placed near the axis of an ultra-centrifuge rotating with high speed while the corresponding absorber was placed on the rotor's rim.

The results of both sets of experiments were interpreted on the basis of predictions of Einstein's Equivalence Principle (EP) [3,4]. It assumes that the effects of gravity on an object in free space are the same as if the laboratory in which the measurements were carried out had been uniformly accelerated from below to reach a particular speed. In the case of the Pound et al. experiments [5,6], the speed of light at the roof of the building was found to be in very good agreement with Einstein's prediction. On the other hand, it has recently been shown [7] that this claim of equivalence fails when the object of the measurement is the wavelength of the light.

It is therefore specious to use the EP as the basis for interpreting the results of the ultracentrifuge gamma-radiation studies [8-10]. Moreover, the claim by Pound et. al. [5,6] that their experiments are suggestive of the "apparent weight of photons" also needs to be critically examined, as also will be done in the discussion below,

II. Results of the Pound et al. Experiment

The Uniform Scaling method [11-13] is a concise summary of the laws of physics that pertain to both the motion of objects and the effects of gravity upon them. It serves as a good starting point for both understanding the results of Pound et al.'s falling light experiment [5,6] and also reaching new conclusions which can be deduced on this basis. To begin with, it is clear from Galileo's Relativity Principle (RP) that the observer at the location of the Mössbauer emitter must measure the standard values of both the frequency ν and wavelength λ of the gamma radiation. As a consequence, it can be concluded that the speed of light at this location in free space is equal to c (277972458 ms^{-1}), i.e. the phase velocity of light ν λ. One can go a step further and invoke Planck's radiation law to conclude that the energy E of the radiation is equal to hν, i.e. with Planck's constant h= 6.625 x 10^{-34} Js. The inertial mass m of each photon is then known to have a value of $h\nu/c^2$ = and a corresponding momentum value of p=hν/c.

After the radiation has descended to the position of the Mössbauer absorber located 22.5 m below on the ground floor, it is assumed, based on Einstein's prediction of the gravitational red shift [3], that the frequency of the radiation arriving there has the same value ν as it had above. The Uniform Scaling method is in agreement on this point and also predicts that the same value of λ will be measured since it is assumed to be independent of gravitational potential. As a result, it can be concluded that the speed of the light arriving there is still equal to c, i.e. the same value as above.

The clear indication from this result is that the radiation is not affected by gravity. There is ample supporting evidence for this conclusion. In a paper published in 1960 [14], Schiff described a theoretical calculation which is in quantitative agreement with Einstein's prediction of the angle by which the locations of stars appear to be shifted during solar eclipses. He based his calculation on the assumption that the local speed of light emanating from stars is always equal to c as it passes by the sun. He used Huygens' Principle in his derivation, as had Einstein before him. The latter only makes use of information regarding the speed of light waves in arriving at its results. Numerical calculations [15] verify Schiff's value for the displacement angle (see Fig. 1) by showing that the wave front of the light is rotated as a consequence of the fact that the speed of the waves increases as they move laterally away from the sun. Einstein's prediction [3.4] of the dependence of the light speed on gravitational potential is instrumental in arriving at this result [16-18]. Investigations by Shapiro et al. [19-20] of the "Fourth Test of General Relativity," in which measurements of time delays between the transmission of radar pulses toward Venus and Mercury and detection of their echoes were carried out, verify Einstein's prediction [3,4] for the effects of gravity on light speed.

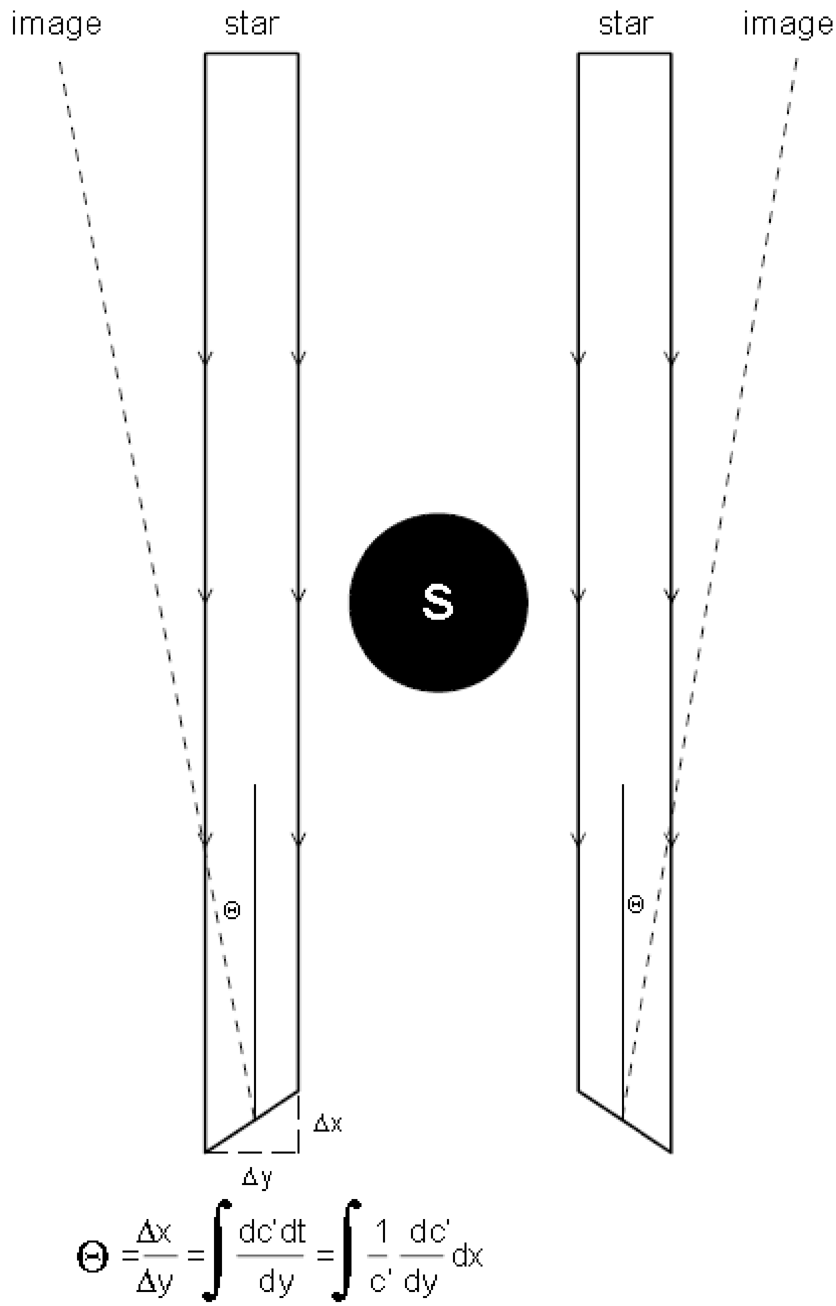

Fig. 1. Schematic diagram showing light rays emitted by stars to follow straight-line trajectories as they pass near the sun. Because of gravitational effects the speed of the light rays c′ is known to increase with gravitational potential, with the effect that the corresponding Huygens wave front gradually rotates away from the sun. As discussed in the text, the normal to a given wave front points out the direction from which the light appears to have come, causing the star images to be displaced by an angle Θ during solar eclipses.

What the above results indicate is that the gravitational acceleration constant for light has a value of g=0. This conclusion was earlier suggested by Ascoli [21-22] by virtue of his claim that the acceleration of gravity a_g for an object moving with speed v is equal to $\gamma^{-2}g= (1-v^2/c^2)g$, where g is the locally observed value of 9.8 ms^{-2}. Accordingly, if the object is light moving with speed v=c, the corresponding value for the acceleration due to gravity is zero, i.e. g(c) =0. The change in speed Δv of an object with elapsed time Δt in classical physics is proportional to a, so the conclusion on this basis is that the speed of light does not vary as it passes through a gravitational field, consistent with what has been concluded above.

The Uniform Scaling method [11-13] assumes that the conversion factor for gravitational acceleration between two rest frames is equal to Q^{-2} in general, where $Q= \gamma (v')/\gamma(v)$. Thus, it also leads to the conclusion that when the object rest frame has a speed of v'=c, no matter what the speed v of the observer is, it also follows since Q=∞ that the acceleration due to gravity acting on light waves in free space is always equal to zero.

The observer on the rooftop of the falling light experiment therefore finds no change in any of the quantities cited above. The frequency ν stays the same for the reason noted by Einstein in his original prediction of the gravitational red shift [3,4]. The speed of light remains constant because there is no acceleration due to gravity acting on the photons. Consequently, the wavelength λ of the radiation is also unaffected by the free fall. Consistent with the latter finding is the assertion of the Uniform Scaling method [11-13] that the lengths of all objects are independent of the effects of gravity. The same is true for the energy; this is consistent with both g=0 and Planck's radiation law, i.e. ΔE=hΔν=0 (note that h is invariant to gravitational potential according to the Uniform Scaling method). Because of Einstein's mass-equivalence relation Δm=0 as well, which therefore leads to the conclusion that the momentum p of the photons also does not change in free fall (this is also consistent with the general claim for the momentum of objects according to the Uniform Scaling method).

The observer on the ground floor does not obtain the same results from his measurements of the same quantities, however. This is because he uses different units to express his values; the absolute values of the two sets of measurements are nonetheless the same in each case. The conversion factors in question are all multiples of $S = 1+gdc^{-2}$. He therefore measures the frequency of the radiation to be Sν, the energy to be SE, the mass of the photons to be $S^{-1}m$, the wavelength and momentum to be λ and p, respectively, and finally the value of the light speed on the rooftop to be Sc. Note that the laws of physics are upheld at both gravitational potentials in each case.

Attempts to interpret the results of the falling light experiment [5,6] have led to a number of false conclusions that are resolved on the basis of the Uniform Scaling method [11-13]. For example, in Table 3 on p. 148 of Ref. [23] it is stated that the observer on the ground floor will measure the speed of light coming from the Mössbauer emitter above to have a value of c instead of the correct value of Sc reported above. The reason for the error is belief in Einstein's LSP, which incorrectly assumes that the speed of light is equal to c for any observer regardless of his state of motion or that of the corresponding source, has been proven to be unviable [24]. The same mistake is made in Table 4 in the same reference on p. 150. In both cases, this conclusion has led to a corresponding error in the measured value of the wavelength of the radiation ($S^{-1}\lambda$)instead of the correct value λ. Use of the LSP is also responsible for the error in Fig. 2 on p. 23 of Ref. [25], whereby the component of the light speed in the horizontal direction is assumed to be equal to $c/\gamma(v)$ instead of the correct value of c. This error in turn leads to the false conclusion that the angle of stellar aberration for light coming from the zenith is equal to $\tan^{-1}(\gamma v/c)$ instead of the correct value of $\tan^{-1}(v/c)$ [26] reported by Bradley in 1727 [27].

The question of whether the photons in the Pound et al. experiments [5.6] have weight has also led to a false conclusion on pp. 319-320 of Ref. [28]. It is claimed there that the change in energy ΔE of the radiation is equal to $h\Delta\nu = (S-1)h\nu = (gd/c^2)h\nu = (h\nu/c^2)gd = mgd$. The value of $\Delta\nu$ is zero, however, as shown above, so there is no change in energy on this basis, i.e. $\Delta E=0$. The same conclusion follows from the fact that g=0 for the falling photons, also as discussed above. Failure to recognize this fact also leads to an error in Fig, 6-6 on p. 324 of Ref. [29]. The graph for the photon path should be a straight line on this basis, as opposed to the curved path actually shown in the diagram.

As a final remark, it should be noted that the theoretical explanation for the falling light experiment [5,6] is based entirely on Einstein's EP [3,4], even though the assumed equivalence between kinetic and gravitational effects is known to be incorrect [7]. There is therefore a need to find a different explanation. The salient point in the experiment is that minimal transmission of radiation between the emitter and absorber occurs when both are stationary in the same rest frame. Since it is assumed that the speed of light is greater at the emitter than at the absorber, namely $Sc = (1+gd/c^2)\, c = (1+\Delta V)\, c$, as compared to the value of c for the absorber, it follows that maximum absorbency will be obtained when the absorber is moving downward with speed $\Delta V = gd/c$.

It needs to be recognized, however, that there is no Doppler effect for velocity, only for the wavelength and frequency of the radiation. The equalization of the speeds of light at the two locations can nevertheless be justified on the basis of the vector addition of the two velocities. The problem for conventional relativity theory, however, is that it claims that the Galilean Velocity transformation, which is just another name for the vector addition of velocities, is not applicable for light. The success of the Pound et al. interpretation can thus be looked upon as a repudiation of this aspect of Einstein's theory [2]. Moreover, it also is a verification of the prediction of the Uniform Scaling method of the conversion factor for velocity measurements of the same object carried out at different gravitational potentials.

III. Application of Uniform Scaling to the Ultracentrifuge Experiments

There are at least three reasons why the introduction of the Mössbauer effect in the context of ultracentrifuge experiments represented an important advance for investigations of Einstein's predicted transverse Doppler effect [2]. First of all, it had previously been impractical to measure the frequencies of light directly because the values for visible and ultraviolet radiation are too small to be obtained with sufficient accuracy. The Ives-Stilwell experiment [30] and the subsequent studies of greater precision [31-32] were able to obtain their results by measuring the wavelengths of the light emitted from accelerated light sources and thereby only inferring the corresponding frequency values by assuming the constancy of the speed of light in the laboratory. The frequencies of the gamma radiation emitted from a Mössbauer source are great enough to eliminate this problem.

The fact that the frequencies of the radiation could be measured directly in the transverse direction when the absorber was mounted on the rim of the rotor was also a key advantage. The Ives-Stilwell experiment [30-32] involves eliminating the angular dependence of the accelerated light waves by averaging the wavelength values for radiation measurements obtained in opposing directions. Finally, the ultracentrifuge experiments enabled the first real test of Einstein's Symmetry Principle [2], which claims that a red shift would be measured by both observers when they exchange light signals. This assertion is tantamount to saying that two identical clocks can both be running slower than each other at the same time. The Ives-Stilwell experiment only allowed for measurements from the vantage point of a stationary observer in the laboratory; mounting a diffraction grating on the accelerated light source was clearly impractical, thus ruling out this possibility.

The ultracentrifuge experiment was carried out by three different research groups [8-10]. In each case the Mössbauer emitter is mounted near the axis of the rotor while the corresponding absorber is mounted at the rim of the rotor. Just as for the Pound-Snider experiment [5,6]. the interpretation of the results was based on Einstein's EP [3] in each case. There was general agreement that a red shift was observed for the frequency of the radiation arriving at the absorber, and therefore that these results serve as a verification of Einstein's Symmetry Principle. Sherwin [33] disagreed with this conclusion, however, stating that the results showed that Einstein's theory only applies for inertial systems and therefore that the observed asymmetry was still consistent with his view. Kündig [9] stated that the absorber clock was slowed because of its acceleration on the rotor rim, which is in agreement with Sherwin's conclusion. Note, however, that as a consequence, more waves per unit time are received at the absorber than are emitted near the axis of the rotor, which is by definition a blue shift.

The Uniform Scaling method [11-13] has a different interpretation of the gamma-radiation study. From the point of view of the absorber, the conversion factor for elapsed times/periods measured at the axis of the rotor to the units employed at the rim is equal to $Q= 1/\gamma(v)= \gamma^{-1} (R\omega)$, where ω is the rotational frequency and R is the distance of the absorber clock to the location of the axis. The corresponding factor for the conversion of frequency values is thus $Q^{-1} = \gamma (R\omega)>0$. On this basis, one expects that a blue shift is observed by the absorber clock, i.e. the frequency observed there is greater than that emitted near the rotor axis. The corresponding conversion factor for wavelengths is equal to Q, which means that the wavelength of the radiation observed at the rim is $\gamma^{-1} (R\omega)$ smaller than emitted at the axis; in other words, a blue shift is also observed on this basis at the rim of the rotor. The results are therefore seen [34] to stand in contradiction to the red shift predicted on the basis of Einstein's Symmetry Principle.

In the Ives-Stilwell study [30-32], the emitter clock is moving at speed v relative to the diffraction grating located in the rest frame of the laboratory; thus, the value of Q is equal to $\gamma (v)>0$ in this case. Consequently, the value of the conversion factor for frequency is $Q^{-1}<0$, which means that a red shift is expected, in agreement with observation. The conversion factor for wavelengths is equal to Q>0, so the value of the wavelength of the radiation observed in the laboratory is γ times larger than for the emitted radiation, also as observed.

IV. Conclusion

The key objective in the falling light experiment is to equalize the values of the speed of light at the *Mössbauer* emitter and absorber, respectively, in order to minimize the amount of radiation transmission. Pound et al. rely on the EP and the concept of Einstein's Elevator in order to explain why the downward movement of the absorber by ΔV compensates for the increase in the speed of the light waves caused by the location of the emitter at a higher gravitational potential relative to the absorber's position on the ground floor. The same effect is expected on the basis of the Galilean Velocity transformation (GVT), however. This amounts to verifying that the GVT can be applied in the present case, even though conventional relativity theory insists that it cannot be.

The Uniform Scaling method also predicts the same increase in light speed at the higher gravitational potential. It does so by claiming that the unit of speed for the observer increases as he changes his position upward. As a result, the observer on the ground floor measures the value of the light speed coming from the emitter at a distance d above his position to be $S = (1+gdc^{-2})c$, i.e. the corresponding conversion factor between the two sets of units is S. In his elucidation of the gravitational red shift, Einstein stated that the conversion factor for frequencies is also S. He went further to declare that the frequency ν *does not change* during the descent of the light, i.e. it remains at a value of $S\nu$ throughout. The Uniform Scaling method claims that distances are invariant to gravitational potential, so this implies that the product of wavelength and frequency of the radiation also does not change; therefore, the ground observer finds that the light speed remains constant at a value of Sc. This implies that there is no gravitational effect on the radiation (g=0). There is ample varication for this prediction. Schiff's method for the calculation of the angle of displacement of star images assumes that the local speed of light is always equal to c as it passes by the sun (see Fig. 1). The value of the acceleration due to gravity is velocity dependent, as first claimed by Ascoli, which leads to the conclusion that g=0 for an object moving with speed c.

The application of the Uniform Scaling method to the ultracentrifuge experiment is quite straight forward. First of all, it ignores the EP. It also foregoes consideration of gravitational scaling for the simple reason that everything takes place at the same gravitational potential. The value of the fundamental kinetic scaling factor Q for the observer at the rotor rim relative to the units of the axis of the rotor is equal to γ^{-1} (Rω) <0. Hence, the observed frequency at the absorber is $Q^{-1}\nu = \gamma\nu > 0$, i.e. a blue shift is observed. For wavelengths, the conversion factor is Q, so the wavelength measured at the absorber is γ^{-1} (Rω) < 0, i.e. smaller values than at the axis, again indicative of a blue shift. In the Ives-Stillwell experiment Q>0 from the vantage point of the observer in the laboratory, proving that a red shift in frequency has occurred by virtue of the acceleration of the light source, as well as a corresponding increase in wavelength measured by the diffraction grating located in the laboratory.

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