Gravitational Redshift Reimagined

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Abstract

Gravitational redshift is conventionally believed to be the result of the loss of energy of photons as they emerge from a strong gravitational field into a field of lesser strength. Conversely, gravitational blueshift is believed to be the result of an increase in energy of photons as they move into a stronger gravitational field from a field of lesser strength.

I will argue that gravitational redshift is caused by time dilation of the source of radiation at the gravitational body. The redshift of the photons emitted by the source accounts in full for the measurement of redshift of those photons in a lesser gravitational field. The obverse works for the measurement of gravitational blueshift. The frequency of the photons received in a stronger gravitational field is measured to be greater than the emitted frequency because of time dilation of the receiver. The measured blueshift is illusory and is a measurement artifact. The frequency of a photon is not changed as the photon moves within a gravitational field to either a weaker or a stronger field.

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1.0 First Matters

> ‘Once it became accepted that light was an electromagnetic wave, it was clear that the frequency of light should not change from place to place, since waves from a source with a fixed frequency keep the same frequency everywhere. One way around this conclusion would be if time itself were altered—if clocks at different points had different rates.’ [3]

1.1 Objectives of this Study

This paper is adapted in large part from reference [6]. While the reference covered gravitational redshift and blueshift and cosmological redshift, its thrust was directed toward the immutability of the frequency of the photon. The current study has more to say about gravitational redshift and gravitational blueshift.

Table 1.1 Objectives of this Study
Show that gravitational redshift is caused by time dilation of the source of radiation at the gravitational body.
Show that the frequency of a photon does not change as the photon moves from a strong gravitational field to a weaker field or from a weak gravitational field to a stronger one.
Show that gravitational blueshift is caused by time dilation of the receiver within a gravitational field. The measured blueshift is illusory and is an artifact of the measurement itself.
Show that photons are not directly subject to gravity.

1.2 Definition of a Process

A process is any sequence of events that takes time. A process can be subatomic, molecular, chemical, mechanical or biological.

> 'All processes—chemical, biological, measuring apparatus functioning, human perception involving the eye and brain, the communication of force—everything, is constrained by the speed of light. There is a clock functioning at every level, dependent on light speed and the inherent delay at even the atomic level. Biological aging, therefore, is in no way different from clock time-keeping.'
>
> Taylor and Wheeler [11]

1.3 Measurements of Redshift and Blueshift [1]

The emission of light from a star or galaxy is compared with a known source using a spectroscope. The emission/absorption spectrum from a star or galaxy comprises the sum of spectra from the excited atoms radiating or absorbing light from the star's surface and atmosphere. The known source comprises the spectra of one or more species of excited atoms obtained in the gravitational field of the Earth. The spectra of the known source provide benchmarks that enable any differences in frequency of the stellar spectra from their values in the gravitational environment of the Earth to be determined.

The frequency distribution of the pattern of emission/absorption lines in the stellar spectra identifies the atoms generating the emissions and absorptions. If the frequencies of the pattern of lines are lower than those of the known pattern of given elements the frequencies are redshifted; if higher, the frequencies are blueshifted.

2.0 The Temporal Inertial (TI) Field Model of Gravity and Inertia

See Appendix A for a brief list of the properties of the TI field. Three of those properties are of particular importance to this study:

- The TI field is a field of particles that participates in the inertial and gravitational interactions.
- Particles of the TI field are accelerated by gravity in accord with Eq (B-1) in Appendix B directly toward the center of mass of each gravitational body (GB) just as test particles would be and reach the escape velocity of such particles at the distance of those particles from the gravitational center of the GB.
- The one and only cause of time dilation of a process is the velocity of the process relative to the TI field.

Two measurements are of concern in this study:

- Measurement of the redshift of photons by spectrographic comparison of photons from a source within a strong gravitational field with those from a known source within a weaker gravitational field.
- Measurement of the blueshift of photons by spectrographic comparison of photons from a source within a weak gravitational field with those from a known source within a stronger gravitational field.

I term the frequency of a photon at emission as the inherent frequency of the photon. One thesis of this paper is that the frequency of a photon is immutable; its inherent frequency does not change regardless of its motion through a gravitational gradient. This thesis is ***apparently*** contradicted by measurements of gravitational redshift and blueshift. I'll show that the gravitational effects are caused by differences in the time dilation of the emitter and/or receiver, not by changes in the inherent frequency or frequencies of the measured photons.

3.0 Gravitational Redshift

> 'In the theory of general relativity, there is time dilation within a gravitational well. This is known as the gravitational redshift or *Einstein Shift*.' [10]

We will examine how time dilation within a gravitational field affects the following measurements of gravitational redshift and blueshift:

1. Measurement of the gravitational redshift of photons from a stellar source (Section 3.1)
2. Measurement of the gravitational redshift when both source and receiver are on or near the Earth (Section 3.2 and Section B.7 in Appendix B)
3. Measurement of the gravitational blueshift when both source and receiver are on or near the Earth (Section 4.0 and Section B.8 in Appendix B)

3.1 Measurement of the Gravitational Redshift of Photons from a Stellar Source

Table 3.1 Measurement of the Gravitational Redshift of Photons from a Stellar Source
The Source of Radiation
The source of radiation in measurements of redshift from a stellar source is, of course, light from the star or stars comprising the stellar source. This light is characterized by the emission spectrum from the stellar source, the absorption spectrum from the stellar source or a combination of both.
The emission spectrum from the stellar source comprises the sum of spectra from the excited atoms radiating light from the stellar source's surface and atmosphere.
The absorption spectrum from the stellar source results from the absorption of photons by the atmosphere of the stellar source. The spectrum consists of dark lines that, like an emission spectrum, identify the atom or molecule responsible for the absorption.
Time Dilation Effect at the Source of Radiation
Time dilation in the gravitational field of the stellar source slows all processes in the field and produces redshift of the light emanating from the stellar source.
The redshift of photons caused by time dilation occurs and is fixed at the point of emission and does not increase as the photons propagate away from the stellar source.

We know that a process within a gravitational field is slowed by time dilation relative to a process in a weaker gravitational field. Accordingly, the emission of photons is redshifted at the source within a strong gravitational field compared with that of an equivalent emitter in a weaker gravitational field. The frequency of photons emitted in a strong gravitational field relative to those emitted from a hypothetical source beyond any gravitational field is given by Eq (3-1) in Table 3.2.

The frequency f_{source} in Eq (3-1) is a proxy for the entire spectrum emanating from the stellar source, as stars are not monochromatic. The change in frequency throughout a given spectrum is proportional to the frequency of each component in the spectrum.

The frequency f_{source} of the photons emitted at the source is the same value that would be measured at a receiver located beyond any gravitational source. The value of the frequency in Eq (3-1) accounts in full for the redshift of photons from the star. (This conclusion is borne out by the calculation of redshift from the white dwarf star Sirius B shown in Appendix C and Table C.1.) The frequency of photons propagating away from the star does not increase as the photons climb out of the gravitational well of the star.

At any distance from their source at the star the frequency of photons is constant as given in Eq (3-1).

Table 3.2

Table 3.2 The Redshift of Photons Emitted from a Stellar Source
$f_{source} / f_{00} = [1 - 2 GM / (r_{source} c^2)]^{1/2}$ (3-1)
f_{source} is the frequency of photons at the point of emission from a star.
f_{00} is the frequency of photons emitted from an equivalent source beyond any gravitational field. As the emitter does not experience time dilation, there is no shift in frequency of the photons from the emitter.
G is the universal gravitational constant.
M is the active gravitational mass of the star. [5]
r_{source} is the radius from the gravitational center of the star at which the photons are emitted.
c is the velocity of light.

The term $2 GM / (r_{source} c^2)$ in Eq (3-1) is the contribution of time dilation to the redshift of photons emitted by the star. (See Appendix B.) No other factor contributes to the redshift of photons emitted by the star.

The left side of Eq (3-1) appears to be inverted for those accustomed to the belief that gravitational redshift occurs as the photons radiate away from the GB toward the point of measurement. As I stated in Table 3.1, gravitational redshift originates and is fixed at the time dilated source of radiation, not on the journey out of the gravitational well of the GB.

3.2 Measurement of the Gravitational Redshift When Both Source and Receiver are on or Near the Earth

Gravitational redshift has been defined as the decrease in the frequency and the decrease in energy of photons as the photons propagate from a strong gravitational field to a weaker field. I have argued that this redshift of photons occurs at the emitter and not as the photons propagate toward a weaker gravitational field.

We have seen in Section 3.1 that gravitational redshift is caused by the time dilation of the emitter within a gravitational field. Gravitational redshift is established and fixed at the source emitter and does not increase as the photons propagate from their source to a weaker gravitational field.

Table 3.3 describes the measurement of gravitational redshift when both the source of radiation and the receiver are on or near the Earth. See Section B.7 in Appendix B for the derivation of this measurement.

Table 3.3 Measurement of the Gravitational Redshift When Both Source and Receiver are on or Near the Earth
The Source of Radiation
The source of radiation in this measurement is located nearer the center of the Earth than the receiver; hence the gravitational field is stronger at the source than at the receiver.
The source of radiation in this measurement is a manufactured device that emits photons of light or some other electromagnetic frequency.
Time Dilation Effect at the Source of Radiation
Time dilation in the gravitational field of the Earth slows all processes in the field producing redshift of the radiation emanating from the source.
The redshift of photons caused by time dilation occurs and is fixed at the point of emission and does not increase as the photons propagate away from the source toward a weaker gravitational field.
Time Dilation Effect at the Receiver
The receiver is located in a weaker gravitational field than the source, so the time dilation of the receiver is less than that of the source. The effect of time dilation of the receiver must be taken into account. This means adding a term in the equation for the measurement of redshift of the photons from the source. See Appendix B.

3.3 Stunning Conclusions About the Gravitational Redshift

As argued above, we know that any and all processes within a gravitational field are slowed by time dilation. Consequently the internal clock of an emitter of photons in a strong gravitational field runs more slowly than its equivalent emitter in a weaker gravitational field. The photons emitted by the time dilated source are redshifted by the factor expressed by Eq (3-1). The cause of the redshift is the time dilation of the source and none other. If photons are not redshifted when traversing a gravity gradient, then they cannot be directly subject to gravity at all. The arguments presented force the following conclusions:

- ***The gravitational redshift of photons emitted from a GB occurs and is fixed at the emitter.***
- ***The cause of gravitational redshift is the time dilation of the source of photons, the emitter itself.***
- ***Gravitational redshift of photons does not increase as photons climb out of the gravitational well of a GB.***
- ***Photons are not directly subject to gravity.***

The usual form in which gravitational redshift is expressed asserts that the emitted frequency of photons decreases (the photons are redshifted) as the photons move from a strong gravitational field to a weaker one. In contradiction, I express gravitational redshift to show its origin in the time dilation of the emitter. Gravitational redshift is established and fixed at the source emitter and does not increase with distance from the gravitational body.

4.0 Gravitational Blueshift

Gravitational blueshift has been defined as the opposite of redshift, where the frequencies of photons are increased and energy is increased as the photons propagate from a weak gravitational field to a stronger field. I will argue that this apparent change in frequency of photons does not occur and is an artifact of the measurement.

Table 4.1 describes the measurement of gravitational blueshift when both the source of radiation and the receiver are on or near the Earth. See Section B.8 in Appendix B for the derivation of this measurement.

Table 4.1 Measurement of the Gravitational Blueshift When Both Source and Receiver are on or Near the Earth
The Source of Radiation
The source of radiation in this measurement is located farther from the center of the Earth than the receiver; hence the gravitational field is weaker at the source than at the receiver.
The source of radiation in this measurement is a manufactured device that emits photons of light or some other electromagnetic frequency.
Time Dilation Effect at the Source of Radiation
Time dilation in the gravitational field of the Earth slows all processes in the field producing ***redshift*** of the radiation emanating from the source.
The frequency of photons is fixed at the point of emission and does not increase as the photons propagate away from the source and toward a stronger gravitational field.
Time Dilation Effect at the Receiver
The receiver is located in a stronger gravitational field than the source, so the time dilation of the receiver is greater than that of the source.
Time dilation in the stronger gravitational field at the receiver causes the receiver to run more slowly than the source. The frequency of photons from the emitter are compared with those of an equivalent emitter at the receiver. The frequency of photons emitted at the receiver is lower than that of photons from the source, so the photons from the source are measured to be blueshifted. The measured increase in frequency of the photons from source to receiver is illusory, not real, because the measured change in frequency is an artifact of the measurement, not a real change in frequency of the photons.

5.0 Conclusions

Table 5.1 Conclusions
Conclusions from the Properties of Photons
Photons are not directly subject to gravity.
Conclusions from Gravitational Redshift
Gravitational redshift is caused by time dilation of the source of radiation at the gravitational body. This real redshift is measured by the receiver.
Photon energy does not decrease as a photon propagates away from a gravitational body.
Gravitational redshift is not caused directly by gravity.
Conclusions from Gravitational Blueshift
Gravitational blueshift is caused by time dilation of the receiver within a gravitational field. The measured blueshift is an artifact of the measurement itself.
Photon energy does not increase as a photon propagates toward a gravitational body.
Gravitational blueshift does not change the inherent frequency of photons.
Gravitational blueshift is not caused directly by gravity.
Summary of Conclusions
Gravitational redshift is caused by time dilation of the source of radiation at the gravitational body. This real redshift originates and is fixed at the source. This redshift is measured by the receiver.
Gravitational redshift and gravitational blueshift are both caused by time dilation of either the emitter of photons or the receiver.
Neither gravitational redshift nor gravitational blueshift results from changes in photon frequency. The frequency of a photon is not changed as the photon moves within a gravitational field to either a weaker or a stronger field.
Photons are not directly subject to gravity.

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Appendix A

Properties of the Temporal Inertial (TI) Field in Brief

Previous studies have described the effects of gravity on the TI field. [7] [9] These effects are summarized in Table A.1.

Table A.1 Effects of Gravity on the TI Field and Time Dilation
The TI field is a field of particles that participates in the inertial and gravitational interactions.
The TI field supports the propagation of nature's force particles.
The velocity of a photon is c relative to the TI field.
The TI field is subject to gravity.
Photons are not directly subject to gravity.
Particles of the TI field are accelerated by gravity (in accord with Eq (B-1) directly toward the center of mass of each gravitational body (GB) just as test particles would be and reach the escape velocity of such particles at the distance of those particles from the gravitational center of the GB.
The one and only cause of time dilation of a process is the velocity of the process relative to the TI field.
A gravitational field affects the time dilation of a process within the field only through the mediation of the TI field. A gravitational body accelerates the TI field toward the body. The velocity of the TI field relative to a process within the gravitational field is the direct cause of time dilation of the process in accord with Eq (B-4).
An example of time dilation of a process is the emission of photons by an atom within a gravitational field. Time dilation slows the internal clock of the atom and decreases the frequencies of the emission spectrum of the atom.
The emission spectrum emitted by an atom within a gravitational field is redshifted relative to the spectrum emitted by that atom within a weaker gravitational field.

Appendix B

Effects of Time Dilation on the Measurement of Gravitational Redshift and Blueshift [10] [12]

B.1 The Acceleration Profile About a Gravitational Body [8]

The acceleration profile about a gravitational body (GB) is given by Eq (B-1). The acceleration profile expresses the acceleration that a small test object or particle would experience if placed at a distance r from the GB.

$$a = GM / r^2 \tag{B-1}$$

where

a is the acceleration of a test object toward the GB at a distance r from the GB.

G is the universal gravitational constant.

M is the active gravitational mass of the GB.

r is the distance between the gravitational center of the GB and the point at which the acceleration is measured.

B.2 Escape Velocity [2]

The escape velocity from a gravitational body is given by Eq (B-2).

$$v_{escape} = (2 GM / r)^{1/2} \tag{B-2}$$

where

v_{escape} is the escape velocity from the GB at a distance r from the gravitational center of the GB.

G is the universal gravitational constant.

M is the active gravitational mass of the GB.

r is the distance of the point of measurement from the gravitational center of the GB.

B.3 Infall Velocity of the TI Field

The infall velocity of the TI field relative to the GB is the negative of the escape velocity given by Eq (B-2).

$$v_{infall} = - (2 GM / r)^{1/2} \qquad \text{(B-3)}$$

where

v_{infall} is the infall velocity toward the GB at a distance r from the gravitational center of the GB.

G is the universal gravitational constant.

M is the active gravitational mass of the GB.

r is the distance of the point of measurement from the gravitational center of the GB.

B.4 Time Dilation of a Process is a Function of the Velocity of the Process Relative to the TI Field

Equation (B-4) shows the function that relates the period of a clock (example of a process) to the square of the difference in velocity between the clock and the TI field. The greater this difference in velocity the greater is the period of the clock.

$$t_{test} / t_{00} = 1 / (1 - v_{test}^2 / c^2)^{1/2} \qquad \text{(B-4)}$$

where

t_{test} is the period of the test clock moving at a velocity of v_{test} relative to the TI field.

t_{00} is the period of a reference clock that is stationary relative to the TI field.

v_{test} is the velocity of the test clock relative to the TI field. The reference clock is stationary relative to the TI field.

c is the velocity of light relative to the TI field.

What if both clocks are moving relative to the TI field? We must, of course, consider that likelihood. The time dilation of the reference clock is then shown by Eq (B-5).

$$t_{ref} / t_{00} = 1 / (1 - v_{ref}^2 / c^2)^{1/2} \qquad \text{(B-5)}$$

where

t_{ref} is the period of the reference clock moving at a velocity of v_{ref} relative to the TI field.

t_{00} is the period of a (second) reference clock that is stationary relative to the TI field.

v_{ref} is the velocity of the reference clock relative to the TI field.

The ratio of the period of the moving test clock relative to the moving reference clock is obtained by dividing Eq (B-4) by Eq (B-5).

$$t_{test} / t_{ref} = (1 - v_{ref}^2 / c^2)^{1/2} / (1 - v_{test}^2 / c^2)^{1/2} \qquad \text{(B-6)}$$

B.5 Gravitational Time Dilation [4]

Equation (B-7) shows that the period of a clock (example of a process) within a gravitational field is greater (the clock ticks more slowly) than an identical clock beyond any gravitational field.

$$t_{test} / t_{00} = 1 / [1 - 2 GM / (r c^2)]^{1/2} \qquad \text{(B-7)}$$

where

t_{test} is the period of the test clock within the gravitational field of a gravitational body (GB). In this equation the test clock is stationary relative to the GB.

t_{00} is the period of the reference clock beyond any gravitational field. The reference clock is stationary relative to the TI field.

G is the universal gravitational constant.

M is the active gravitational mass of the GB.

r is the distance of the test clock from the gravitational center of the GB.

B.6 The Infall Velocity of the TI Field is the Direct Cause of Gravitational Time Dilation

Consideration of the function of the Global Positioning System in a previous study [8] showed that the one and only cause of time dilation of a clock is the velocity of that clock relative to the TI field. I must extend the cause of time dilation of a clock to include the time dilation of any process. This assertion belies the theory that gravity causes time dilation directly. I'll now address this contradiction.

The infall velocity of the TI field is given by Eq (B-3) repeated below as Eq (B-8)

$$v_{infall} = - (2 GM / r)^{1/2} \tag{B-8}$$

Time dilation of a process is shown to be a function of the velocity of the process relative to the TI field as shown in Eq (B-4), repeated below as Eq (B-9)

$$t_{test} / t_{00} = 1 / (1 - v_{test}^2 / c^2)^{1/2} \tag{B-9}$$

Gravitational time dilation is shown to be a function of gravity in Eq (B-7), repeated below as Eq (B-10).

$$t_{test} / t_{00} = 1 / [1 - 2 GM / (r c^2)]^{1/2} \tag{B-10}$$

A process at rest relative to a gravitational body (GB), as on the surface of the Earth, for example, is not at rest relative to the TI field. The TI field is falling toward the center of mass of the GB at the infall velocity of the TI field at that radius from the center of mass of the GB. Accordingly, the process experiences time dilation in accord with Eq (B-9), where the velocity of the process relative to the TI field is the infall velocity of the TI field itself.

Substitute the expression for the infall velocity v_{infall} of the TI field from Eq (B-8) for v_{test} in Eq (B-9) and you get Eq (B-10) which suggests that the time dilation of the process is attributable directly and solely to the infall velocity of the TI field at the process and not directly to gravity, If, in addition, gravity contributed directly to the time dilation of the process, the total time dilation of the process would be the square of the value given in Eq (B-10). Of course gravity is the ultimate cause of time dilation of a process within a gravitational field, but gravity acts ***indirectly*** through the acceleration of the TI field.

B.7 Measurement of the Gravitational Redshift When Both Source and Receiver are Within the Gravitational Field of the Earth

The objective of this test is to measure the difference in frequency of photons moving between two points at different distances from the gravitational center of the Earth. To simplify the analysis, assume a monochromatic source emitter and an equivalent reference emitter at the receiver.

Due to time dilation the process (or frequencies) of both the emitter and receiver are less than that of a hypothetical, equivalent source located beyond any gravitational field. Equations (B-11) and (B-12) quantify these relationships.

$$f_{source} / f_{00} = [\ 1 - 2\ GM / (\ r_{source}\ c^2\ )\ ]^{\ 1/2} \qquad \text{(B-11)}$$

$$f_{rcvr} / f_{00} = [\ 1 - 2\ GM / (\ r_{rcvr}\ c^2\ )\ ]^{\ 1/2} \qquad \text{(B-12)}$$

The ratio of these two frequencies is shown in Eq (B-13).

$$f_{rcvr} / f_{source} = \{\ [\ 1 - 2GM / (\ r_{rcvr}\ c^2\ )\ ]\ / [\ 1 - 2GM / (\ r_{source}\ c^2\ )\ ]\ \}^{\ 1/2} \qquad \text{(B-13)}$$

where

f_{source} is the frequency of photons from the emitter at the point of emission nearest the gravitational center of the Earth. This is the source of photons within the gravitational field of the Earth that are measured in a weaker gravitational field at the receiver. ***This value is the frequency that is measured at the receiver's location because the frequency of photons does not change as they propagate away from the Earth.***

f_{00} is the frequency of photons emitted by a hypothetical, equivalent source measured beyond any gravitational field.

f_{rcvr} is the frequency of photons emitted by an equivalent source located at the receiver. This is the reference frequency by which the frequency of photons from the emitter deeper within the gravitational field of the GB is compared. ***This value is not the frequency that is measured at the receiver's location. The frequency of photons is redshifted at the source emitter compared with the equivalent emitter located at the receiver.***

G is the universal gravitational constant.

M is the active gravitational mass of the Earth.

r_{source} is the distance of the emitter from the gravitational center of the GB. r_{source} is smaller than r_{rcvr}.

r_{rcvr} is the distance of the receiver from the gravitational center of the Earth.

c is the velocity of light.

The left side of Eq (B-13) appears to be inverted for those accustomed to the belief that gravitational redshift occurs as the photons radiate away from the GB toward the point of measurement. As I have argued, gravitational redshift originates and is fixed at the time dilated source of radiation, not on the journey out of the gravitational well of the GB.

As r_{source} is smaller than r_{rcvr}, Eq (B-13) tells us that the emission frequency of the source is less than that of the reference at the receiver. The emission is redshifted relative to the known reference at the receiver.

$$f_{source} < f_{rcvr} \tag{B-14}$$

The frequency of the source emitter is slowed by time dilation and is redshifted relative to its counterpart at the receiver. The comparison is real, but illusory when attributed to a decrease in frequency of the photons as they climb out of the gravitational well of the GB.

B.8 Measurement of the Gravitational Blueshift When Both Source and Receiver are Within the Gravitational Field of the Earth

Gravitational blueshift refers to the apparent increase in frequency of a photon moving from a weak gravitational field to a stronger one. The increase in frequency is illusory, not real, because the change in frequency is an artifact of the measurement, not a real change in frequency of the photon. The apparent increase in frequency of the photon occurs not during the photon's passage from a weak gravitational field to a stronger one, but is measured to have changed in comparison with the reference emission of the time dilated receiver.

In the treatment to follow it is assumed that both the source of radiation and the receiver are both near the surface of the Earth, so the GB is the Earth and M is the active gravitational mass of the Earth. The source of radiation is farther from the center of gravity of the Earth than is the receiver and is thus in a weaker gravitational field than the receiver.

The objective of this test is to measure the difference in frequency of photons moving between two points at different distances from the gravitational center of the Earth. To simplify the analysis, assume a monochromatic source emitter and an equivalent reference emitter at the receiver.

Due to time dilation the process (or frequencies) of both the emitter and receiver are less than those of a hypothetical, equivalent source located beyond any gravitational field. Equations (B-15) and (B-16) quantify these relationships.

$$f_{source} / f_{00} = [1 - 2 GM / (r_{source} c^2)]^{1/2} \quad \text{(B-15)}$$

$$f_{rcvr} / f_{00} = [1 - 2 GM / (r_{rcvr} c^2)]^{1/2} \quad \text{(B-16)}$$

The ratio of these two frequencies is shown in Eq (B-17).

$$f_{rcvr} / f_{source} = \{ [1 - 2GM / (r_{rcvr} c^2)] / [1 - 2GM / (r_{source} c^2)] \}^{1/2} \quad \text{(B-17)}$$

where

f_{source} is the frequency of photons from the source emitter at a point farther from the gravitational center of the Earth than the receiver. This is the source of photons within the gravitational field of the Earth that are measured in a stronger gravitational field at the receiver. ***This value is the frequency that is measured at the receiver's location because the frequency of photons does not change as they propagate toward the center of the Earth.***

f_{00} is the frequency of photons emitted by a hypothetical, equivalent source measured beyond any gravitational field.

f_{rcvr} is the frequency of photons emitted by an equivalent source located at the receiver. This is the reference frequency by which the frequency of photons from the emitter is compared.

G is the universal gravitational constant.

M is the active gravitational mass of the Earth.

r_{source} is the distance of the emitter from the gravitational center of the GB. r_{source} is greater than r_{rcvr}.

r_{rcvr} is the distance of the receiver from the gravitational center of the Earth.

c is the velocity of light.

The left side of Eq (B-17) appears to be inverted for those accustomed to the belief that gravitational blueshift occurs as the photons radiate from a source in a weak gravitational field to a receiver in a stronger field.

The reference emitter at the receiver is in a stronger gravitational field than its counterpart at the source. Time dilation is greater at the receiver than at the source emitter. Accordingly the frequency of the reference emitter at the receiver is slowed by time dilation and is less than that of the source emitter.

$$f_{rcvr} < f_{source} \qquad \text{(B-18)}$$

The higher frequency of the source emitter is blueshifted when compared with its counterpart at the receiver. The comparison is real, but is not attributable to an increase in frequency of the photons as they descend into the gravitational well of the GB. The measurement of blueshift is an artifact of the measurement itself.

Notice that Eq (B-17) for blueshift is identical to Eq (B-13) for redshift. The only difference is in their application. In the calculation of redshift, the source emitter is closer to the gravitational center of the GB than the receiver; in the calculation of blueshift, the receiver is closer to the gravitational center of the GB than the source emitter.

B.9 Summary of the Effects of Time Dilation on Gravitational Redshift and Blueshift

Table B.2 Summary of the Effects of Time Dilation on Gravitational Redshift and Blueshift
Gravitational redshift is caused by time dilation of the source of radiation at the gravitational body. This real redshift occurs and is fixed at the source of radiation. This real redshift is unchanged by the motion of photons from a strong gravitational field to a weaker one and is measured at the receiver.
Gravitational blueshift is caused by time dilation of the receiver within a gravitational field. The measured blueshift is illusory and is an artifact of the measurement itself.
Photons are not directly subject to gravity.

Appendix C

Gravitational Redshift of the White Dwarf Sirius B

C.1 Gravitational Redshift of Light from the White Dwarf Sirius B

The gravitational redshift of a stellar source of photons is given in Eq (B-11) and is repeated below as Eq (C-1) with changes in subscripts where appropriate:

$$f_{star} / f_{00} = [\ 1 - 2\ GM_{star} / (\ r_{star}\ c^2\ )\ ]^{\ 1/2} \qquad \text{(C-1)}$$

where

f_{star} is the frequency of photons emitted by the star at the point of emission near the surface of the star.

f_{00} is the frequency of photons emitted by a hypothetical equivalent source beyond any gravitational field.

G is the universal gravitational constant.

M_{star} is the active gravitational mass of the star.

r_{star} is the radius from the gravitational center of the star at which the photons from the star are emitted.

c is the velocity of light.

The term $2\ GM_{star} / (\ r_{star}\ c^2\ ) << 1$, so Eq (C-1) may be approximated as shown in Eq (C-2).

$$f_{star} / f_{00} = 1 - GM_{star} / (\ r_{star}\ c^2\ ) \qquad \text{(C-2)}$$

The value of the second term in Eq (C-2) is the relative change in gravitational frequency of photons from the star. This value can be expressed by the recessional velocity of the star that would produce the same redshift via the Doppler effect as shown in Eq (C-3).

$$f_{star} / f_{00} = 1 - v_{star} / c \tag{C-3}$$

Equating the second terms of Eq (C-2) and Eq (C-3), we have:

$$v_{star} / c = GM_{star} / (r_{star} c^2) \tag{C-4}$$

or

$$v_{star} = c [GM_{star} / (r_{star} c^2)] \tag{C-5}$$

C.2 Discussion of Table C.1

Data from reference [13] was used to calculate the redshift of light from the white dwarf Sirius B. Table C.1 shows that using Eq (C-5) for the calculated value of gravitational redshift for Sirius B is within the error boundary for the experimental value given in the reference.

> 'Therefore, a new set of observations was obtained with the STIS (Space Telescope Imaging Spectrograph) instrument on Hubble, observing both Sirius A and Sirius B in sequence … This latest measurement gave a redshift of 80.65 ± 0.77 km/s and mass of 1.017 ± 0.025 solar masses, in good agreement with the dynamical measurement. The corresponding white dwarf radius is 0.00808 ± 0.00011 Solar radii.'
>
> 'When astronomers give values for the gravitational redshift, they usually quote a speed value – this is simply the speed at which a body would need to recede from you to produce the same redshift by means of the Doppler effect.' [13]

The close agreement between the calculated and observed values of redshift of light from Sirius B shows that the redshift of photons emitted at the star accounts in full for the measurement of redshift of those photons in a lesser gravitational field.

While calculations for Table C.1 have been carried out to 11 decimal places it does not imply such precision in the date or the findings.

Table C.1 Gravitational Redshift of Light from the White Dwarf Sirius B		
Parameter	**Value**	**Units**
GM of the Sun	1.327E+11	km^3 / sec^2
Radius of the Sun	6.963E+05	
Speed of light c	3.00E+05	km / sec
Speed of light squared	8.99E+10	km^2 / sec^2
GM of Sirius B	1.350E+11	km^3 / sec^2
Radius of Sirius B	5.626E+03	
$GM / (r_{SiriusB} c^2)$	2.669E-04	Dimensionless
$[1 - 2 GM (r_{SiriusB} c^2)]^{1/2}$	9.9973308408E-01	Dimensionless
$1 / [1 - 2 GM (r_{SiriusB} c^2)]^{1/2}$	1.0002669872E+00	Dimensionless
Calculated Redshift of light from Sirius B $c GM / (r_{SiriusB} c^2)$ Eq (C-5)	8.001E+01	km / sec
Sirius B mass / Solar mass	1.017E+00	Dimensionless
Sirius B radius / Solar radius	8.080E-03	Dimensionless
Measured Redshift of light from Sirius B	80.65 +- 0.77	km / sec