the general science journal

THE GRAVITATIONAL RED-SHIFT

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Abstract: It is shown that the derivation of the equation for the calculation of the Gravitational Red-Shift does not account the time during which the photon wavelength changes from λ_{emit} to λ_{obsv} under static-weak gravitational field. If we solve this task in the frame of the idea of the possibility of using Newton's classical law of universal gravitation and the second law of Newton to explain the dynamic changes of the photon momentum even if its rest mass, $m_0 = 0$, we get a new equation for the calculation of Gravitational Red-Shift that takes into account the time. This new mathematical model allows us to calculate gravitational red-shift of the electromagnetic radiation photons with no recourse to the theory of general relativity in the Newtonian limit, i.e. when r is sufficiently large compared to the Schwarzschild radius $\sqrt{\frac{2GM}{c^2}}$. This raises grave doubts over the introduction of the measurement of the gravitational red-shift in the list of crucial tests of the theory of general relativity.

Keywords: photon; Newton's law of universal gravitation; redshift; Newton's second law of motion; static-weak gravitational field; Schwarzschild radius; photon mass.

Einstein's theory of general relativity predicts that the wavelength of electromagnetic radiation photon will lengthen as it climbs out of a static gravitational well. Photons must expend energy to escape, but at the same time must always travel at the speed of light, so this energy must be lost through a change of frequency rather than a change in speed. If the energy of the photon

$\mathbf{E = h\upsilon = mc^2}$ decreases, the frequency also decreases. This corresponds to an increase in the wavelength of the electromagnetic radiation photon, or a shift to the red end of the electromagnetic spectrum – hence the name: **GRAVITATIONAL REDSHIFT**. This effect was confirmed in laboratory experiments conducted in the 1960s. For radiation photons emitted in a strong gravitational field, such as from the surface of a neutron star or close to the event horizon of a black hole, the gravitational redshift can be very large and is given by:

$$1 + z = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$$

In the Newtonian limit, i.e. when r is sufficiently large compared to the Schwarzschild radius $\sqrt{\frac{2GM}{c^2}}$, the redshift can be approximated as:

$$\boxed{z = \frac{GM}{rc^2}}$$

If a photon of mass $m = \frac{h\upsilon}{c^2}$ is moving under the influence of a weak gravitational field generated by a massive central object of mass M, Newton's law of gravitation shows that the force of gravitation experienced by the photon is given by $\frac{GMm}{r^2}$, where G is Newton's universal constant of gravitation and r is the distance of the photon from the central massive object. The momentum of the photon ($p = mc = \frac{h}{\lambda}$) is poised to vary in the object's gravitational field while its velocity remains as a constant ($c = 3 \times 10^8$ m/s). From this, there is still the possibility of using Newton's classical law of universal gravitation and the second law of Newton to explain the dynamic changes of the photon momentum even if its rest mass, $m_0 = 0$.

$$-\frac{dp}{dt} = \frac{GMm}{r^2}$$

where m is the energy equivalent mass of the photon based on $\mathbf{E = h\upsilon = mc^2}$, h represents the Planck constant. The (−) sign for the change of momentum indicates the reduction of the photon momentum by the gravitational force as it moves away from the central point of a large mass.

Since: $p = \frac{h}{\lambda}$. Therefore:

$$\frac{p^2}{h}\frac{d\lambda}{dt} = \frac{GMm}{r^2}$$

This equation can be rearranged to:

$$d\ln\lambda = \frac{GM}{cr^2}\ dt$$

On integration within the limits of λ_{emit} to λ_{obsv} for wavelength of photon and 0 to t for time we get,

$$\ln\left(\frac{\lambda_{obsv}}{\lambda_{emit}}\right) = \frac{GM}{cr^2}\ t$$

$$\lambda_{obsv} = \lambda_{emit}\ \boldsymbol{e}^{\frac{GM}{cr^2}t}$$

$$\frac{\lambda_{obsv} - \lambda_{emit}}{\lambda_{emit}} = \boldsymbol{e}^{\frac{GM}{cr^2}t} - 1$$

$$\boxed{1 + z = \boldsymbol{e}^{\frac{GM}{cr^2}t}}$$

Thus, we have the formula for the calculation of the Gravitational Red-Shift, which takes into account the **time during which the photon wavelength** changes from λ_{emit} to λ_{obsv} under static-weak gravitational field. In the above derivation of the expression for the gravitational red-shift, no appeal has been made to any aspect of the theory of general relativity. Hence, the question will be raised as to how and why the measurement of the gravitational red-shift could ever be considered a real test of the **Einsteinian general theory of relativity?**

The equation $1 + z = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$ breaks when r is equal to $\frac{2GM}{c^2}$. However, the equation:

$$1 + z = \boldsymbol{e}^{\frac{GM}{cr^2} t}$$

is not going to break even when r is equal to $\frac{2GM}{c^2}$.

According to the approximation of the first order for a weak gravitational field (where r is inadequately large as opposed to the Schwarzschild radius $\frac{2GM}{c^2}$), the formula:

$$1 + z = \frac{1}{\sqrt{1 - \frac{2GM}{rc^2}}}$$

for redshift emerges as,

$$z = \frac{GM}{rc^2}$$

$$1 + z = e^{\frac{GM}{cr^2}t}$$

$$\ln(1 + z) = \frac{GM}{cr^2}\ t$$

$$\frac{\ln(1+z)}{z} = \frac{\frac{GM}{cr^2}\ t}{\frac{GM}{rc^2}}$$

$$t = \frac{r}{c}\ \frac{\ln(1+z)}{z}$$

Conclusion:

As an example, take the white dwarf star Sirius B, with a gravitational field ~100,000 times as strong as the Earth's. Although it sounds extreme, this is still considered a relatively weak field, and the gravitational redshift can be approximated by:

$$\ln(1 + z) = \frac{GM}{cr^2}\ t$$

where z is the gravitational redshift, G is Newton's gravitational constant, M is the mass of the object, r is the photon's starting distance from M, and c is the speed of light. The above formula for redshift emerges as,

$$z = \frac{GM}{rc^2}$$

only if

$$t = \frac{r}{c} \frac{\ln(1+z)}{z}$$

Hence, the **time during which the photon wavelength** changes from λ_{emit} to λ_{obsv} under static-weak gravitational field is given by:

$$\boxed{t = \frac{r}{c} \frac{\ln(1+z)}{z}}$$

References:

- **Gravitational Frequency Shifts for Photons and Particles** by Jing-Gang Xie.
- **Fundamentals of Physics** by David Halliday.
- **Concepts of Physics** by H. C. Verma.