A No-Go Theorem for In-Flight Photon Retuning in Gravitational Redshift

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We present a simple no-go result for the common intuition that photons "adjust" their frequency to the local gravitational potential during propagation. Using an operational definition of frequency as the ratio of phase cycles to an observer's proper time, we show that any in-flight retuning mechanism that keeps the photon frequency locally locked to the clock rate would cancel gravitational red/blue shift identically. Since non-zero shifts are observed (e.g., Pound–Rebka, GPS, astrophysical spectroscopy), such retuning cannot be correct. We then summarize the standard general-relativistic formulation in terms of a conserved quantity associated with a timelike Killing vector, emphasizing that the observed shift arises from comparing distinct clock rates (metric time-scaling) between emission and reception, not from a dynamical change "within the photon". Finally, we state the corresponding postulate in the Radial Scaling Gauge and provide the direct connection to the Segmented Spacetime (SSZ) time-dilation factor $\mathrm{D}_{\mathrm{SSZ}}(\mathrm{r}) = 1/(1 + \Xi(\mathrm{r}))$.

Consider a background star S whose light is deflected by a gravitational lens L. A distant observer A measures the frequency of the lensed starlight far outside the lens potential. A second observer B is stationed deep in the gravitational field of L and measures the frequency of the very same wave train as it passes near the lens.

The core problem: If a photon were to adjust its frequency to the local gravitational potential along the way, there would be no measurable gravitational red/blue shift.

This is not an opinion, but a logical necessity.

The "adjustment idea" fails due to this simple logic: Both the emitter and the observer are "deformed." Atoms in a deep potential oscillate more slowly. Clocks in a deep potential run slower, and measuring rods are stretched.

Assume: The photon's frequency increases as it falls (blueshift), exactly as it corresponds to the local potential.

Then: The faster photon frequency reaches an observer, whose clock measures exactly that much faster.

Result: The observer measures no frequency shift.

This contradicts the idea that the shift is generated by an in-flight energy exchange that is locally 'undone' by climbing out of the potential.

Experimentally (Pound-Rebka, GPS, astronomical) it is perfectly clear that the shift exists. Therefore, it necessarily follows that the photon does not adjust itself along the way.

The correct interpretation, subtle yet stark, can therefore only be that the photon is not a locally clocked oscillator.

It is a phase-coherent transport along a null geodesic. Its frequency is not an intrinsically local object, but arises only upon comparison with a clock. The shift thus does not originate in the photon itself, but in the comparison.

This is also consistent with Maxwell and General Relativity. Maxwell's equations are locally invariant. The wave trains are conserved. The spacetime metric scales the observer, not the signal.

In the Radial Scaling Gauge[1], we have already presented the formalism for this: The field (the wave) is rigid, the geometry "transports" it, and the observer is the deformed element.

It thus becomes evident that gravitational redshift is not an energy loss of the photon, but a scale difference between emission and detection. It is not the light that turns red, but the observer slows down.

The idea that the photon adapts is inconsistent. Such a mechanism would eliminate the shift. The fact that we measure a shift is proof: The photon carries its information through spacetime independently of the field. Gravity acts on the clocks, not on the signal.

No-Go Theorem: "Local photon matching eliminates gravitational shift"

Setup:

Two stationary observers/emitters A and B in a static gravitational field (e.g., Schwarzschild outside), each with identical atomic clocks. A sends a photon to B. Both are stationary in their local frames.

Let us assume, that the photon frequency ν "adjusts" to the local potential during propagation such that it is always locally proportional to the local atomic clock frequency:

$$\nu_{photon}(r) \propto \nu_{atom}(r)$$

Then the measured frequency shift between A and B would be zero:

$$z \equiv \frac{\nu_B - \nu_A}{\nu_A} = 0$$

Frequency is always measured as "wave trains per proper time". If the photon's frequency "adjusts" exactly as the local clocks slow down/speed up, then the numerator (photon) and denominator (clock) scale equally. The quotient remains constant and no shift could be measured.

However, since we experimentally measure $z \neq 0$ (Pound-Rebka, GPS, spectral lines), the retuning hypothesis is false:

The photon is not a locally re-clocked oscillator. The shift arises from the comparison of different proper times (emitter vs. receiver), not "within the photon".

The key point is operational: Frequency is not an intrinsic property carried by the photon independent of measurement, but the ratio of phase cycles to the observer's proper time. If the photon were continuously "retuned" to the local gravitational environment, the observable shift between A and B would cancel identically. Since gravitational shifts are observed, the effect must arise from comparing distinct clock rates (proper times), not from an in-flight adaptation of the photon.

Physically correct form (GR standard)

In a static field, a timelike Killing vector exists. This implies a conserved quantity along the light geodesic:

$$E_\infty \equiv -\mathrm{k}_\mu \xi^\mu = \mathrm{constant}$$

where k^μ is the wave vector.

The local measured frequency is

$$\nu(r) = -\mathrm{k}_\mu \mathrm{u}^\mu(\mathrm{r})$$

with 4-speed u^μ of the local observer. For stationary observers, the following applies:

$$\nu(r) = \frac{E_\infty}{\sqrt{-g_{tt}(r)}}$$

This results in the following between A and B :

$$\frac{\nu_B}{\nu_A} = \sqrt{\frac{-g_{tt}(A)}{-g_{tt}(B)}}$$

The shift therefore comes from the metric (clock rate), not from "photon learns potential".

Proof Sketch: No-Go “Photon adapts to local potential“

Definition 1 (measured frequency):

The locally measured frequency of a light signal is

$$\nu(r) = -\mathrm{k}_{\mu}\mathrm{u}^{\mu}(\mathrm{r})$$

Where k^{μ} is the wave vector of the signal and $u^{\mu}(r)$ is the 4-velocity of the local (stationary) observer [2].

Definition 2 (clock rate):

The local atomic/clock rate is proportional to the proper time $\Delta\tau(r)$; measurement means “cycles per $\Delta\tau(r)$“

Lemma (which states exactly what "photon matching" claims):

“Photon adapts” means, operationally:

$$\nu\mathrm{ph}(\mathrm{r}) \propto \nu\mathrm{clock}(\mathrm{r}) \Leftrightarrow \frac{\nu_{\mathrm{photon}}(\mathrm{r})}{\nu_{\mathrm{clock}}(\mathrm{r})} = \text{const along the path}$$

Step 1 (what the receiver measures):

The receiver B does not measure “ν absolutely”, but rather the ratio:

$$Measuredvalue_{B} = \frac{\nu_{\mathrm{photon}}(B)}{\nu_{\mathrm{clock}}(B)}$$

Analog at the transmitter A:

$$Measuredvalue_{\mathrm{A}} = \frac{\nu_{\mathrm{photon}}(\mathrm{A})}{\nu_{\mathrm{clock}}(\mathrm{A})}$$

Step 2 (Consequence of the adaptation assumption):

The following follows directly from the lemma:

$$\frac{\nu_{\mathrm{photon}}(\mathrm{B})}{\nu_{\mathrm{clock}}(\mathrm{B})} = \frac{\nu_{\mathrm{photon}}(\mathrm{A})}{\nu_{\mathrm{clock}}(\mathrm{A})}$$

This means the observed shift would be

$$z \equiv \frac{Measuredvalue_B \text{ - } Measuredvalue_\mathrm{A}}{Measuredvalue_\mathrm{A}} = 0$$

Here ν_A, ν_B denote the locally measured frequencies (i.e. ratios of phase cycles to proper time).

Step 3 (Conflict with observation):

Experiments have shown that $z \neq 0$. Therefore, the assumption that photons adapt is false.

Conclusion:

The photon is not a locally "resynchronized" oscillator. Gravitational redshift/blueshift arises from the comparison of different proper times (clock rates) of emission and detection – not from an in-flight adjustment that cancels out the effect.

If the photon were continuously re-normalized to the local clock rate, the observable shift would cancel identically. Since a non-zero gravitational shift is measured, the effect is a clock-rate comparison (metric/time-scaling), not an in-flight photon retuning.

Radial Scaling Gauge (RSG)

RSG postulate (measurement-related):

The electromagnetic field coherently transports phase/wave trains (no local renormalization of the photon frequency as a dynamic process).

The measured frequency is always a ratio to the local timescale:

$$\nu_{\text{meas}} = \frac{\text{wave trains}}{\Delta\tau(r)}$$

Gravity primarily affects the measurement process via $\Delta\tau(r)$ (Clock-Rate), not via an “in-flight” change that cancels out the effect.

SSZ version (directly connectable)

$$\frac{\nu_B}{\nu_A} = \frac{\mathrm{D_{SSZ}}(A)}{\mathrm{D_{SSZ}}(B)} = \frac{1 + \Xi(B)}{1 + \Xi(A)}$$

$$\text{Any „}\textit{in-flight Photon adjustment}\text{“ } \nu(r) \propto \mathrm{D_{SSZ}}(r) \Rightarrow \nu_B/\nu_A = 1\ (No - Go).$$

SSZ shift is purely a clock rate ratio $D_{SSZ}(A)/D_{SSZ}(B)$; any additional "photon adjustment" would inevitably cancel out the observed shift.

References:

1. Wrede, C.N., Casu, L.P., Bingsi (2025). Radial Scaling Gauge for Maxwell Fields - A geometric reparametrization with invariant local light speed. Researchgate [Preprint]. https://doi.org/10.13140/RG.2.2.35891.08480
2. Misner, C. W., Thorne, K. S., Wheeler, J. A., Gravitation, W. H. Freeman (1973).