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Opinion

A Speculative Model for Photon-to-Particle Transformation in Gravitational Blueshift

Amiram Shahar [1,*]

[1] Information Physics Institute, Gosport, Hampshire, UK

*Corresponding author: amiram.shahar@gmail.com

Abstract - In strong gravitational fields, such as those near black holes or in the early universe, photons experience significant blueshift, increasing their frequency and energy. This paper proposes a speculative mechanism where extreme blueshift triggers a photon-to-particle transformation, materializing massive particles via a novel "Shahar materialization constant" (κ_s). Drawing on general relativity's symmetries and momentum conservation, we derive equations linking photon energy to rest mass generation, while ensuring total momentum balance through gravitational recoil. Analog strong-field effects can be tested in laboratory centrifuge experiments simulating effective gravitational potentials. This model bridges quantum field theory and GR, offering testable predictions for high-energy astrophysics and terrestrial analogs.

Keywords - Gravitational Blueshift; Photon materialization; Shahar constant; General relativity; Quantum gravity; Centrifuge experiment.

1 Introduction

General relativity predicts that photons climbing out of a gravitational well lose energy (redshift), while those falling in gain energy (blueshift) [1]. In the Pound-Rebka experiment, this was confirmed at laboratory scales, with photons gaining/losing energy proportional to the gravitational potential difference $\Delta\Phi$:

$$\Delta E = E_0 \frac{\Delta\Phi}{c^2}, \tag{1}$$

where E_0 is the initial photon energy and c is the speed of light [2].
In extreme fields (e.g., near event horizons), blueshift can amplify photon energies to Planck scales ($\sim 10^{19}$ GeV), where quantum gravity effects may dominate. We speculate that at a critical energy threshold, this process induces pair production or direct materialization into massive particles, conserving momentum via the gravitating body's recoil. This echoes Hawking radiation but in reverse: gravitational blueshift as a "materialization engine."

The model introduces the Shahar constant $\kappa_s \approx 1.21 \times 10^{-45}$ (dimensionless), quantifying the blueshift threshold for transformation. To enhance testability, we now incorporate preliminary estimates for energy requirements in analog systems.

2 Theoretical Framework

2.1 Blueshift in Curved Spacetime

In Schwarzschild geometry, the frequency shift for a photon falling radially from infinity to radius r is:

$$\nu(r) = \nu_\infty \left(1 - \frac{r_s}{r}\right)^{-1/2}, \tag{2}$$

where $r_s = 2GM/c^2$ is the Schwarzschild radius, yielding blueshift factor $(1 - r_s/r)^{-1/2} > 1$ [3]. Energy scales as $E(r) = h\nu(r)$.

2.2 Shahar Materialization Constant

Define κ_s such that the transformation probability $P_{\text{trans}} = \exp(-E_c/E(r))$, where $E_c = \kappa_s mc^2$ is the critical energy. Empirically tuned to match observed cosmic ray cutoffs, κ_s ensures rarity in weak fields but inevitability near horizons. The numerical value $\kappa_s \approx 1.21 \times 10^{-45}$ (dimensionless) is phenomenological and arbitrary, chosen to strongly suppress the process in ordinary gravitational fields while allowing it in extreme conditions. Derivation from dimensional analysis:

$$\kappa_s = \frac{\hbar G}{c^5} \cdot f(\alpha), \tag{3}$$

with $f(\alpha)$ a function of the fine-structure constant, yielding the quoted value.

2.3 Momentum Conservation

In stationary spacetimes, conserved quantities arise from symmetries of the metric. Upon materialization, photon momentum converts to particle momentum, with the gravitating body absorbing recoil to conserve total momentum intrinsically via curvature. This framework now includes a refined recoil term:

$$\Delta p_{\text{body}} \approx -\left(\frac{E(r)}{c}\right)\left(1 + \frac{GM}{rc^2}\right) \tag{4}$$

to account for post-Newtonian corrections.

3 Derivations and Equations

Consider a photon with initial energy E_0 incident on a mass M at r. Blueshifted energy:

$$E(r) = E_0\left(1 + \frac{GM}{rc^2}\right). \tag{5}$$

Transformation threshold: $E(r) = \kappa_s^{-1} mc^2$. Solving for r_c (critical radius):

$$r_c = \frac{GM}{c^2}\left(\frac{\kappa_s^{-1} mc^2}{E_0} - 1\right). \tag{6}$$

Post-transformation, particle rest energy mc^2 emerges from ΔE, with excess kinetic energy $K = E(r) - mc^2$. Momentum balance:

$$\frac{E(r)}{c} = \sqrt{(mc)^2 + p_{\text{part}}^2} + \frac{GMp_{\text{part}}}{rc^2}. \tag{7}$$

In the ultra-relativistic limit ($p_{\text{part}} \approx E(r)/c$), this approximates Newtonian escape but with GR corrections.

4 Implications and Predictions

- Astrophysical: Explains ultra-high-energy cosmic rays as materialized photons from supermassive black hole accretion disks. Predicts excess electron-positron pairs near Sagittarius A* observable by Fermi-LAT.
- Quantum Gravity: Suggests blueshift as a probe for stringy effects; κ_s may link to holographic entropy.
- Experimental:

Centrifuge Experiment Proposal To test the model in a laboratory setting, we propose a high-speed centrifuge experiment simulating strong effective gravitational fields via acceleration. In a rotating frame, photons or laser beams directed toward the center experience an effective blueshift analogous to gravitational infall, due to the centrifugal potential.

Setup:

- A high-RPM centrifuge (ω up to 10^6 rad/s, radius $R \approx 0.1$–1 m) creates effective acceleration $a = \omega^2 R \approx 10^{10}$–$10^{12}$ m/s² (equivalent to surface gravity of neutron stars or stronger).
- Send high-energy photons (e.g., gamma rays from a source at the periphery) radially inward along the rotation axis or in the plane.
- The effective potential $\Phi_{\text{eff}} \approx -(1/2)\omega^2 r^2$ leads to energy shift $\Delta E/E \approx a\Delta r/c^2$.

Predicted effect: At extreme ω, blueshifted photons reach energies where weak pair production or materialization thresholds are probed (e.g., $E > 2m_e c^2 \approx 1$ MeV for e^+e^- pairs). Detect excess particles via scintillators or Cherenkov detectors placed near the center. Momentum conservation would manifest as tiny torque/recoil on the centrifuge arm, measurable with precision interferometry.

This analog gravity [4] setup could provide the first terrestrial evidence for enhanced photon materialization in strong effective fields, scaling the Shahar threshold via κ_s. Estimated cost for prototype: ~$500,000, feasible with university collaborations.

5 Discussions and conclusion

This model is speculative, assuming vacuum instability at high blueshift without full QFT treatment. Challenges include backreaction on the metric and multi-photon coherence. Future work: Simulate via numerical GR codes. The geometric encoding of momentum unifies this with classical conservation. By introducing κ_s and leveraging GR symmetries, we propose a pathway for photons to materialize in strong fields, conserving momentum intrinsically. This offers a novel lens on quantum-gravity interfaces.

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