Distinguishing Photon Interactions: Source Well vs. External Fields

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February 21, 2024

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09-02-2024

Abstract:

This study delves into the nuanced interactions of photons or waves with gravitational fields, focusing on the distinction between their encounters with the gravitational wells of source objects and external massive bodies. When photons or waves escape a source gravitational well, such as that of a star or black hole, they expend energy, leading to a gravitational redshift characterized by an increase in wavelength. Conversely, when traversing through the gravitational field of external massive bodies like planets or galaxies, photons or waves maintain their inherent energy. However, their paths may bend a result of momentum exchange with the gravitational field. By discerning between these interactions, we gain deeper insights into how gravitational effects manifest in the behaviour of photons or waves, offering valuable contributions to the fields of astrophysics and gravitational physics. The mathematical formulations presented in this study provide a quantitative framework for understanding these interactions, further enhancing our comprehension of the intricate relationship between gravity and light propagation in the universe.

Keywords: Photon interactions, Gravitational well, external gravitational fields, Energy expenditure, Gravitational redshift, Momentum exchange, Propagation of light, Wave behaviour, Astrophysics,

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The author declares no potential competing interests.

Introduction:

The behaviour of photons and waves in gravitational fields holds significant implications for our understanding of astrophysical phenomena and the fundamental principles of gravitational physics. Central to this understanding is the distinction between interactions occurring within the gravitational wells of source objects and those within the gravitational fields of external massive bodies. When photons or waves traverse these gravitational landscapes, they exhibit distinct behaviours, each shedding light on fundamental aspects of gravitational physics.

This study focuses on elucidating the subtle nuances between photon interactions in source gravitational wells and external gravitational fields. In the former scenario, when photons or waves escape the gravitational grasp of a source object such as a star or black hole, they undergo energy expenditure, resulting in a gravitational redshift characterized by an increase in wavelength. Conversely, when traversing through the gravitational fields of external massive bodies like planets or galaxies, photons or waves maintain their inherent energy. However, their trajectories may bend due to a consequence of momentum exchange with the gravitational field.

By discerning between these two types of interactions, we gain deeper insights into how gravitational effects manifest in the behaviour of photons or waves. This distinction offers valuable contributions to our understanding of astrophysical phenomena and the nature of gravitational interactions in the cosmos. Through a combination of textual elucidation and mathematical formulation, this study aims to provide a comprehensive exploration of the mechanisms underlying photon interactions in gravitational fields, further advancing our understanding of the intricate relationship between gravity and light propagation.

Methodology:

Literature Review: The methodology for this study involves an extensive review of relevant literature in the fields of astrophysics, gravitational physics, and quantum mechanics. This literature review encompasses peer-reviewed articles, scientific journals, textbooks, and reputable online resources. By synthesizing information from various sources, we aim to build a comprehensive understanding of photon interactions in gravitational fields.

Conceptual Framework Development: Based on the insights gained from the literature review, we develop a conceptual framework to elucidate the distinctions between photon interactions in source gravitational wells and external gravitational fields. This framework integrates key principles from gravitational physics, including gravitational redshift, energy expenditure, momentum exchange.

Mathematical Formulation: To complement the conceptual framework, we derive mathematical formulations to quantitatively describe the phenomena under investigation. These mathematical expressions incorporate fundamental equations from quantum mechanics and general relativity, such as the Planck equation, energy-momentum conservation laws, and gravitational redshift equations.

Analysis and Interpretation: The derived mathematical formulations are analysed and interpreted to elucidate the underlying mechanisms governing photon interactions in gravitational fields. Through rigorous analysis, we aim to discern the unique characteristics of interactions occurring in source gravitational wells versus external gravitational fields, shedding light on the intricacies of gravitational physics.

Comparison and Synthesis: Finally, the findings from the analysis are compared and synthesized to elucidate the overarching patterns and implications of distinguishing between photon interactions in different gravitational contexts. By synthesizing the results within the broader framework of astrophysical phenomena, we aim to provide valuable insights into the nature of gravitational interactions and their implications for our understanding of the universe.

Through this methodological approach, we aim to comprehensively investigate and elucidate the distinctions between photon interactions in source gravitational wells and external gravitational fields, thereby advancing our understanding of astrophysical phenomena and the fundamental principles of gravitational physics.

Mathematical Presentation:

1. Interaction with Source Gravitational Well:

When a photon or wave escapes a gravitational well, such as the gravitational field of a massive object like a star or a black hole, it expends energy in the process. This energy expenditure due to a change in energy ΔE follows the Planck equation:

- $\Delta E = h\Delta f$

2. Interaction with External Gravitational Field:

I. Consistency of Photon Energy in External Gravitational Fields:

The total energy of a photon (Eg) remains equivalent to its intrinsic energy (E) under gravitational influence. Changes in photon momentum $(\Delta\rho)$ exhibit symmetry, represented by $\Delta\rho = -\Delta\rho$. The constant speed of electromagnetic waves
$(\ell p/tp = c)$ maintains its significance, emphasizing energy conservation in gravitational interactions:

- $Eg = E$
- $\Delta\rho = -\Delta\rho$
- $(\ell p/tp = c)$

II. Momentum and Wavelength Changes under Gravitational Influence:

Strong gravitational fields induce variations in photon momentum $(\Delta\rho)$ and wavelength (λ). The total energy of the photon (Eg) accounts for these changes, but the photon's original energy (E) remains unchanged. The equations $h/\Delta\lambda = h/-\Delta\lambda$ illustrates the symmetrical effects of wavelength changes due to gravity:

- $Eg = E + \Delta\rho = E - \Delta\rho = E$
- $h/\Delta\lambda = h/-\Delta\lambda$

III. Photon Energy Variation in Strong Gravitational Fields:

Under strong gravitational fields, photons experience changes in energy (ΔE), denoted by ΔE. The total energy of a photon (Eg) includes these changes, but the photon's intrinsic energy (E) remains constant. Thus, Eg = E, indicating that the photon's total energy in a gravitational field equals its original energy:

- $E_g = E + \Delta E = E - \Delta E$
- $E = E_g$

Through these mathematical formulations, we elucidate the principles governing photon interactions in source gravitational wells versus external gravitational fields, enhancing our understanding of gravitational physics in astrophysical contexts.

Discussion:

The distinction between photon interactions in source gravitational wells and external gravitational fields is crucial for understanding the diverse manifestations of gravitational effects on light propagation in the universe.

Source Gravitational Wells:
When photons or waves escape the gravitational wells of massive objects such as stars or black holes, they undergo energy expenditure, resulting in a gravitational redshift. This redshift, characterized by an increase in wavelength, is a consequence of the energy lost by the photon or wave as it climbs out of the gravitational well. The observed decrease in frequency and increase in wavelength provide empirical evidence of the energy-mass equivalence principle and the effects of gravitational time dilation predicted by general relativity.

External Gravitational Fields:
In contrast, when photons or waves traverse through the gravitational fields external to the source object, their inherent energy remains unchanged. While the gravitational field of external bodies may influence the path of photons, causing gravitational lensing effects, the total energy of the photon remains conserved. This conservation principle implies that any gain or loss in energy experienced by the photon due to gravitational interactions within external gravitational fields is balanced, resulting in a net change of zero. Consequently, any redshift or blueshift observed in photons passing through external gravitational fields reflects an equalization of gains and losses, maintaining the overall energy balance of the system.

Implications and Significance:
Distinguishing between these two types of interactions provides valuable insights into the fundamental principles of gravitational physics and their implications for astrophysical phenomena. The observed gravitational redshift in photons escaping source gravitational wells serves as a powerful tool for probing the gravitational fields of distant objects and studying the structure and dynamics of the universe. Conversely, gravitational lensing effects in external gravitational fields offer unique opportunities for gravitational wave detection, precision cosmology, and the study of dark matter distribution.

Future Directions:
Further research in this area could explore the intricate interplay between gravitational effects and other fundamental forces, such as electromagnetism and the weak and strong nuclear forces. Additionally, advancements in observational techniques and theoretical models will continue to refine our understanding of photon interactions in gravitational fields and their implications for our comprehension of the cosmos.

In conclusion, by discerning the distinct behaviors of photons or waves in source gravitational wells versus external gravitational fields, we deepen our understanding of the intricate relationship between gravity and light propagation, paving the way for new discoveries and insights into the nature of the universe.

Conclusion:

In this study, we have explored the nuanced distinctions between photon interactions in source gravitational wells and external gravitational fields, shedding light on fundamental aspects of gravitational physics and their implications for astrophysical phenomena.

Through our analysis, we have elucidated how photons or waves undergo energy expenditure when escaping source gravitational wells, leading to a gravitational redshift characterized by an increase in wavelength. This phenomenon provides empirical evidence for key principles of general relativity, including the energy-mass equivalence principle and gravitational time dilation.

Conversely, when traversing through external gravitational fields, photons or waves maintain their inherent energy, but their trajectories may bend due to the momentum exchange within the gravitational field. This gravitational lensing effect, while altering the path of the photon or wave, conserves its energy, highlighting the symmetrical nature of gravitational interactions.

By distinguishing between these two types of interactions, we have gained deeper insights into the profound influence of gravitational effects on the propagation of light and other waves in the universe. The observed gravitational redshift and gravitational lensing effects serve as powerful tools for probing the structure and dynamics of the cosmos, enabling advancements in fields such as precision cosmology, gravitational wave detection, and the study of dark matter distribution.

Looking ahead, further research in this area holds promising avenues for exploring the intricate interplay between gravity and other fundamental forces, refining our understanding of astrophysical phenomena, and unravelling the mysteries of the universe.

In conclusion, by discerning the distinct behaviours of photons or waves in source gravitational wells versus external gravitational fields, we deepen our understanding of the intricate relationship between gravity and light propagation, paving the way for new discoveries and insights into the nature of the cosmos.

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