Contribution ID: **36** Type: **not specified**

Quantum approach to radiation from falling charges into a Schwarzschild black hole

Friday 20 December 2024 11:45 (15 minutes)

The detection of gravitational waves has ushered in a new era for general relativity, particularly in the study of black hole physics and other strong-field regimes. In this context, understanding the dynamics of fundamental fields near black holes is crucial. By analyzing the radiation emitted during these processes, one can extract signatures of the black hole and its surrounding matter. While a complete quantum theory of gravity remains an open challenge, quantum field theory in curved spacetimes provides an effective framework for studying quantum fields in a classical spacetime background. This approach has led to significant breakthroughs, such as the prediction of black hole radiation (Hawking radiation) and the observer-dependent nature of particles (the Unruh effect). In this work, we use quantum field theory at tree level to investigate electromagnetic radiation emitted by a charged particle in radial free fall towards a Schwarzschild black hole. This semiclassical analysis allows us to calculate one-particle emission amplitudes, which in turn yield the total energy released and the energy spectrum of the emitted radiation. We explore these quantities for particles with varying initial velocities and starting positions. Additionally, we extend our study to consider the case of a charged "string," falling into the black hole, offering further insights into this radiation setting.

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