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Corrections to Hawking radiation from asteroid-mass primordial black holes: description of the stochastic charge effect in quantum electrodynamics

Hawking radiation sets stringent constraints on Primordial Black Holes (PBHs) as a dark matter candidate in the $M \sim 10^{16}$ g regime based on the evaporation products such as photons, electrons, and positrons motivating the need for rigorous modeling of the Hawking emission spectrum. Using semi-classical arguments, Page [Phys. Rev. D 16, 2402 (1977)] showed that the emission of electron and positrons is altered due to the black hole acquiring an equal and opposite charge to the emitted particle. The Poisson fluctuations of emitted particles cause the charge $Z|e|$ to random walk, but since acquisition of charge increases the probability of the black hole emitting another charged particle of the same sign, the walk is biased toward zero charge, and after a long time reaches an equilibrium probability distribution with finite variance $\langle Z^2 \rangle$. This talk explores how this "stochastic charge" phenomenon arises from quantum electrodynamics
(QED) on a Schwarzchild spacetime as a collective effect where the Hawking-emitted particles are mediated by the long-range electromagnetic interaction. In particular, we prove the semi-classical variance $\langle Z^2 \rangle$ agrees with the variance of a quantum mechanical operator $\langle \hat{calZ}^2 \rangle$, where $\hat{calZ}$ may be thought of as an "atomic number" that includes the black hole as well as charge near it (weighted by a factor of $2M/r$). In future work, we will aim to compare the emitted $e^{\pm}$ spectrum in QED to the semi-classical prediction, which modifies the emitted charged particle spectrum at $calO(\alpha)$ where $\alpha \approx 1/137$ is the fine
structure constant.

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