Why is There No Ultraviolet Catastrophe in Gravity?

Kirk T. McDonald
Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544
(February 5, 2026)

The "ultraviolet catastrophe" is the term given by Ehrenfest [1] to the prediction of classical electromagnetism that the intensity of blackbody radiation would be infinite at short wavelengths, as remarked by Rayleigh in 1905.[1,2]

Thermal agitation of the blackbody give its atoms electric oscillating electric dipole moments, which leads to the observed blackbody radiation. However, there is no gravitational dipole radiation,which is associated with quadrupole oscillations. Thermal agitation of bodies also leads to quadrupole oscillations, and if the energy of these oscillations were not quantized, there would be an ultraviolet catastrophe associated with the quadrupole, electromagnetic blackbody radiation. This quantization also serves to eliminate the ultraviolet catastrophe that could be associated with quadrupole, gravitational blackbody radiation. That is there is no purely classical gravitational blackbody radiation.

Hawking [7, 8] noted that quantum effects lead to electromagnetic (not gravitational) blackbody radiation of a black hole with surface gravity g with an apparent temperature $T = \hbar g/2\pi ck$, where c is the speed of light in vacuum and k is Boltzmann's constant. Being a quantum effect, there is no ultraviolet catastrophe in Hawking radiation.

The association of gravity with blackbody radiation implies that the gravitational blackbody radiation involves quanta (gravitons) with energies that are multiples of hv.[3] However, this does not give much insight into a possible full quantum theory of gravity.

This question was posed by Anwar Shiekh.

References

[1] P. Ehrenfest, *Welche Züge der Lichtquantenhypothese spielen in der Theorie der Wärmestrahlung eine wesentliche Rolle?* Ann. d. Phys. **36**, 91 (1911).
http://kirkmcd.princeton.edu/examples/QM/ehrenfest_ap_36_91_11.pdf

[2] Lord Rayleigh, *The Dynamical Theory of Gases and of Radiation*, Nature **72**, 54 (1905).
http://kirkmcd.princeton.edu/examples/EM/rayleigh_nature_72_54_05.pdf

[3] M. Planck, *Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum*, Verh. Deutsch. Phys. Gesell. **2**, 237-245 (1900).
http://www.ub.edu/hcub/hfq/sites/default/files/planck-energieverteilung.pdf
Translation: http://www.ffn.ub.es/luisnavarro/nuevo_maletin/Planck%20(1900),%20Distribution%20Law.pdf

[1] Already in 1900, Planck [3, 4] (see also [5]) had inferred that the departure of the blackbody radiation from classical expectations at short wavelength can be explained by supposing that the energy of oscillations with frequency ν of atoms in the black body have energies quantized in amounts of $h\nu$.

[2] Jeans [6] noted an error of a factor or 8 in Rayleigh's calculation, which is now known as the Rayleigh-Jeans law.

[3] Skeptical views of gravitons by Dyson are given in [9, 10].

http://kirkmcd.princeton.edu/examples/statmech/planck_vdpg_2_237_00.pdf
http://kirkmcd.princeton.edu/examples/QM/planck_vdpg_2_237_00_english.pdf

[4] M. Planck, *Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum*, Ann. d. Phys. **4**, 553-563 (1901).
https://doi.org/10.1002/andp.19013090310
http://kirkmcd.princeton.edu/examples/statmech/planck_ap_4_553_01.pdf
http://kirkmcd.princeton.edu/examples/statmech/planck_ap_4_553_01_english.pdf

[5] M. Nauenberg, *Max Planck and the birth of the quantum hypothesis*, Am. J. Phys. **84**, 709 (2016). http://kirkmcd.princeton.edu/examples/QM/nauenberg_ajp_84_709_16.pdf

[6] J.H. Jeans, *On the Partition of Energy between Matter and Æther*, Phil. Mag. **10**, 91 (1905). See p. 98. http://kirkmcd.princeton.edu/examples/EM/jeans_pm_10_91_05.pdf

[7] S.W. Hawking, *Black Hole Explosions*, Nature **248**, 30 (1974).
http://kirkmcd.princeton.edu/examples/GR/hawking_nature_248_30_74.pdf

[8] S. W. Hawking, *Particle Creation by Black Holes*, Comm. Math. Phys. **43**, 199 (1975).
http://kirkmcd.princeton.edu/examples/GR/hawking_cmp_43_199_75.pdf

[9] F. Dyson, *Is a Graviton Observable?* Int. J. Mod. Phys. A **28**, 133041 (2013).
http://kirkmcd.princeton.edu/examples/GR/dyson_ijmpa_28_1330041_13.pdf

[10] F. Dyson, *Why General Relativity and Quantum Mechanics Can't be Unified* (Nov. 10, 2017). https://www.youtube.com/watch?v=pcicI_GJGcM&t=61s