Is the threshold curvature that corresponds to the onset of the uselessness of mass-energy for work a variable measure?

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Abstract

A duality between entropy and curvature is discussed.

1 Discussion

According to the laws of black hole thermodynamics and the holographic principle [1–4], the activity of the quantum fields at the event horizon radius

$$R_{\text{bh}} = \frac{2GM}{c^2} \tag{1}$$

of a Schwarzschild black hole over some macroscopic period of time corresponds to a Bekenstein-Hawking entropy of

$$S_{\text{bh}} = \frac{A_{\text{bh}}}{4\ell_p^2}, \tag{2}$$

where

$$A_{\text{bh}} = 4\pi R_{\text{bh}}^2. \tag{3}$$

In terms of information theory, it takes S_{bh} natural units of information to encode the number of distinct microstates $e^{S_{\text{bh}}}$ that are formed by the activity of the quantum fields at R_{bh}.

The black hole entropy S_{bh} is the maximal entropy that this given amount of mass-energy M can possess, and if M were to be in the form of every day material instead (ie. a car), then the entropy S of M would surely be less than the maximum S_{bh}. The black hole entropy S_{bh} also corresponds to a threshold where this given amount of mass-energy M becomes unusable for work.

Dividing the black hole's entropy by the black hole's event horizon area provides a measure of curvature

$$\kappa_{\text{bh}} = \frac{S_{\text{bh}}}{A_{\text{bh}}} = \frac{1}{4\ell_p^2} \tag{4}$$

that is common to all Schwarzschild black holes. It is important to stress that this measure of curvature corresponds to the threshold where mass-energy is hidden behind a black hole event horizon, and to stress that this curvature threshold is dual to the aforementioned entropy threshold where mass-energy becomes unusable for work. From this we may conclude that being behind an event horizon and being unusable for work are analogous circumstances.

The quantum fields outside of the event horizon are also active to a lesser extent, and some of this activity eventually leads to and corresponds to photons that escape the black hole's gravitation, ultimately causing the black hole to leak both energy and entropy. It is important to stress that these escaping photons and the black hole proper continue to form a single closed system, and to stress that a closed system cannot undergo a decrease in entropy. In other words, these escaping photons remain unusable for work, because if they were to spontaneously become usable for work then this would lead to a forbidden breakdown in the second law of general thermodynamics $dS/dt \geq 0$. From this we may conclude that these escaping, unusable photons produce a dark background that fills the black hole exterior.

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The quantum field activity of these dark photons at some distant shell of radius

$$R_{\text{shell}} \gg R_{\text{bh}}, \tag{5}$$

$$A_{\text{shell}} = 4\pi R_{\text{shell}}^2 \gg A_{\text{bh}} \tag{6}$$

over some macroscopic period of time corresponds to a Planck black body spectrum of temperature

$$T_{\text{shell}} = \frac{\hbar c^3}{8\pi k_b G M}, \tag{7}$$

which, via M, corresponds back to the black hole entropy

$$S_{\text{shell}} = S_{\text{bh}}. \tag{8}$$

Since $R_{\text{shell}} > R_{\text{bh}}$ by definition, the shell's measure of curvature

$$\kappa_{\text{shell}} = \frac{S_{\text{shell}}}{A_{\text{shell}}} \tag{9}$$

will be less than the maximum of $\kappa_{\text{bh}} = 1/(4\ell_p^2)$.

May we conclude, similar to the entropy-curvature threshold duality at the black hole event horizon, that this (non-maximum) curvature κ_{shell} defines a local (non-maximum) threshold at R_{shell} where a small test mass-energy M_{test} of sufficient curvature

$$\kappa_{\text{test}} = \frac{S_{\text{test}}}{4\pi\left(\frac{2GM_{\text{test}}}{c^2}\right)^2} \geq \kappa_{\text{shell}} \tag{10}$$

would become unusable for work because M_{test} would become hidden behind a virtual event horizon? In other words, may we conclude that κ_{shell} marks the boundary between real and virtual mass-energy?

Is such a dark photon background generated by a galaxy, and if so, could this background possibly be the *raison d'être* for the dark matter particles that are commonly thought to produce the non-Newtonian nature of the galactic rotation curves? Likewise, is such a dark photon background generated by the Earth, and if so, could this background possibly explain the non-observation of cosmic rays with ultra high energies above the GZK threshold? In other words, is it possible that individual dark matter particles and individual above-GZK cosmic rays each possess too much entropy to be usable for work (as defined locally by κ_{shell}), even though none of these individual particles are black holes in the traditional sense?

References

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