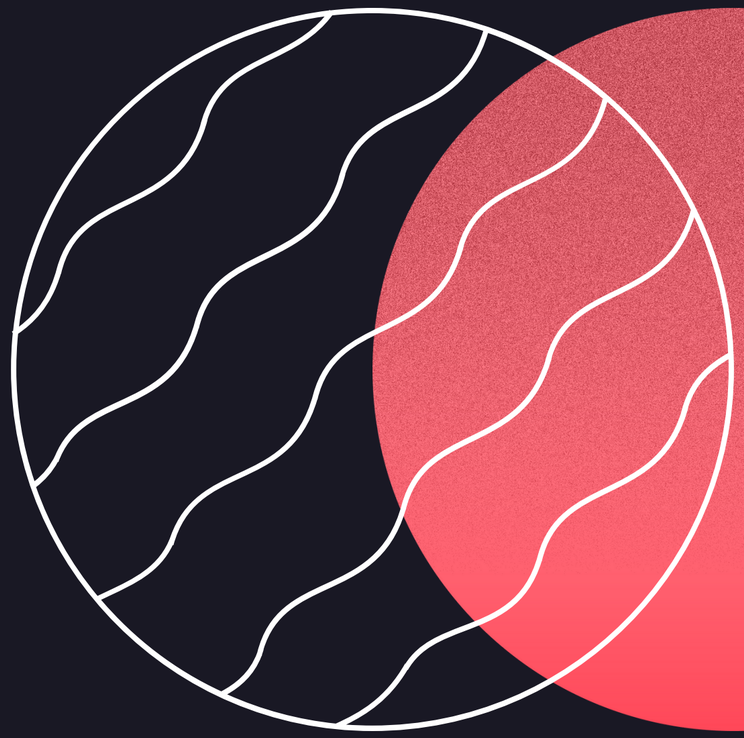
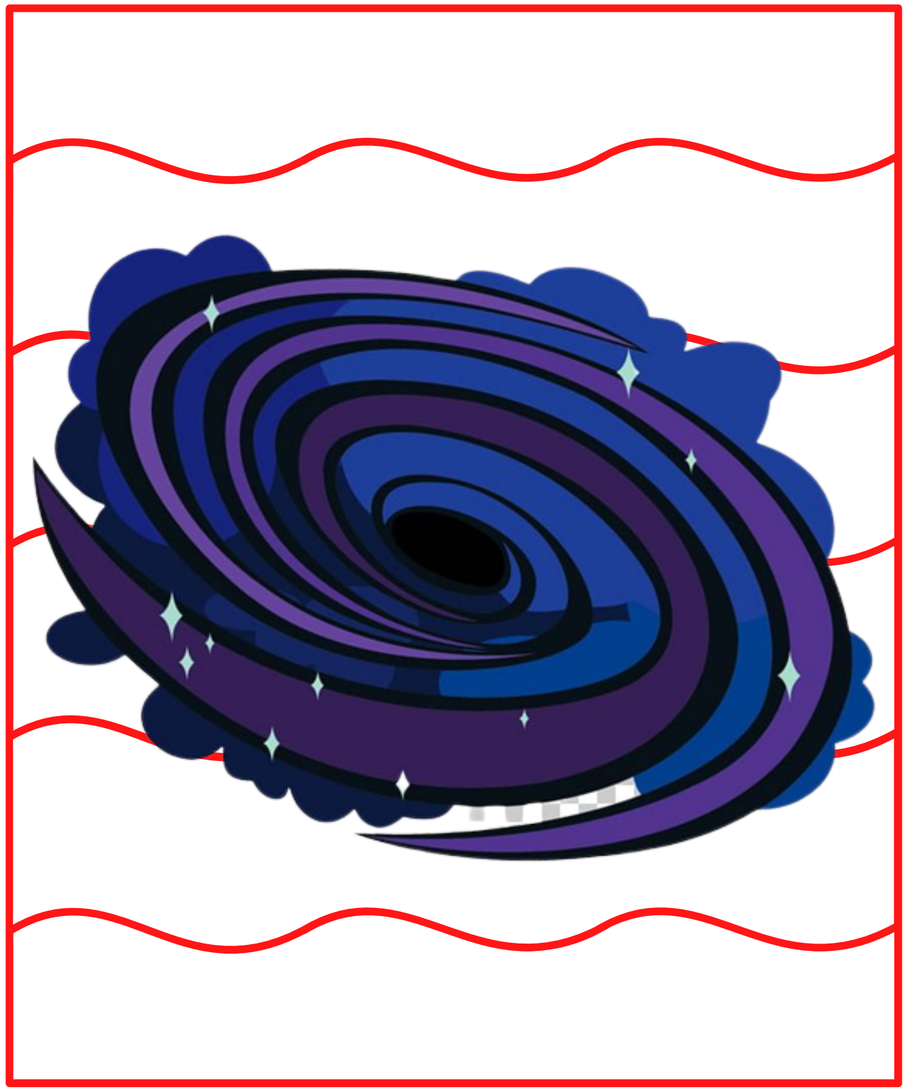


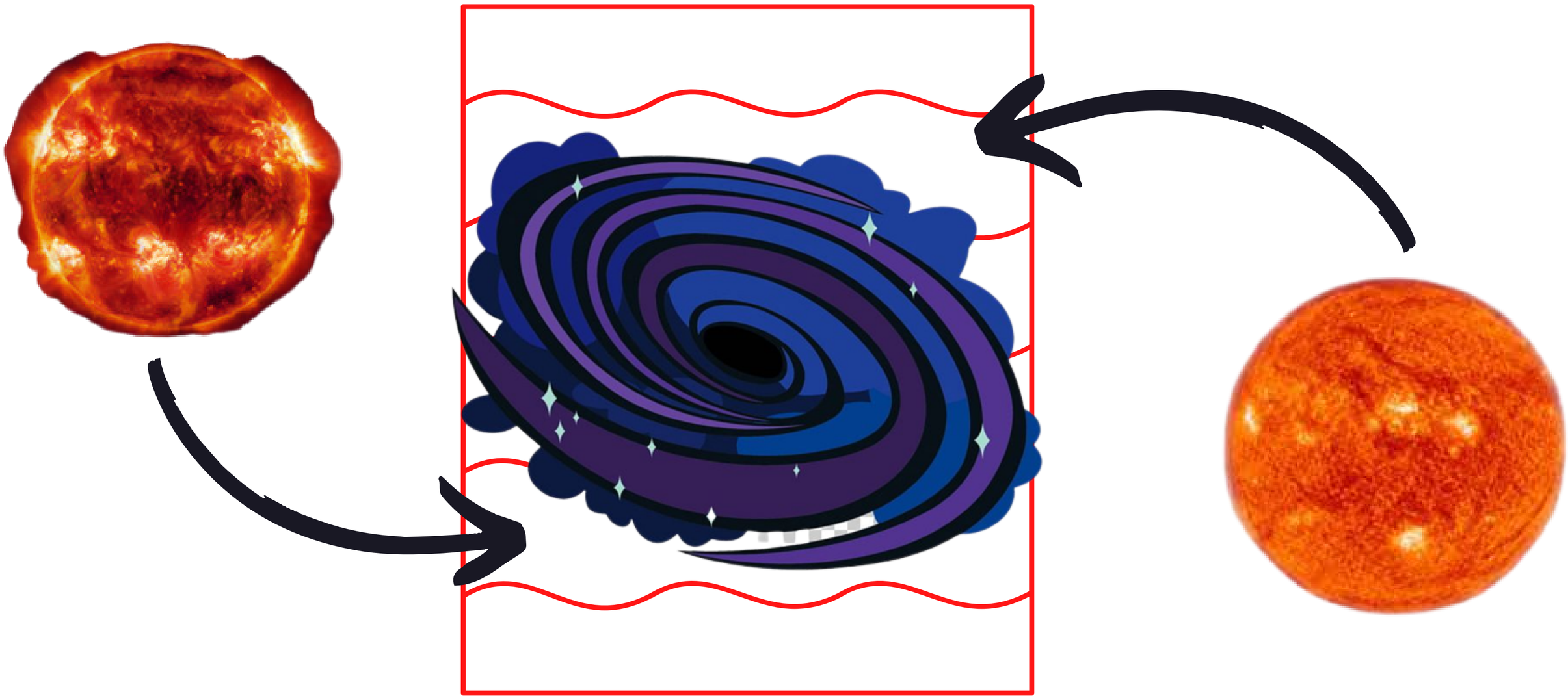
Termodinâmica de Buracos Negros e Radiação Hawking

Alexsandre L. Ferreira

BN são objetos termodinâmicos?



Perda de informação



Black Holes and Entropy*

Jacob D. Bekenstein†
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08540
and Center for Relativity Theory, The University of Texas at Austin, Austin, Texas 78712‡
(Received 2 November 1972)

$$S = -\sum_n p_n \ln p_n$$

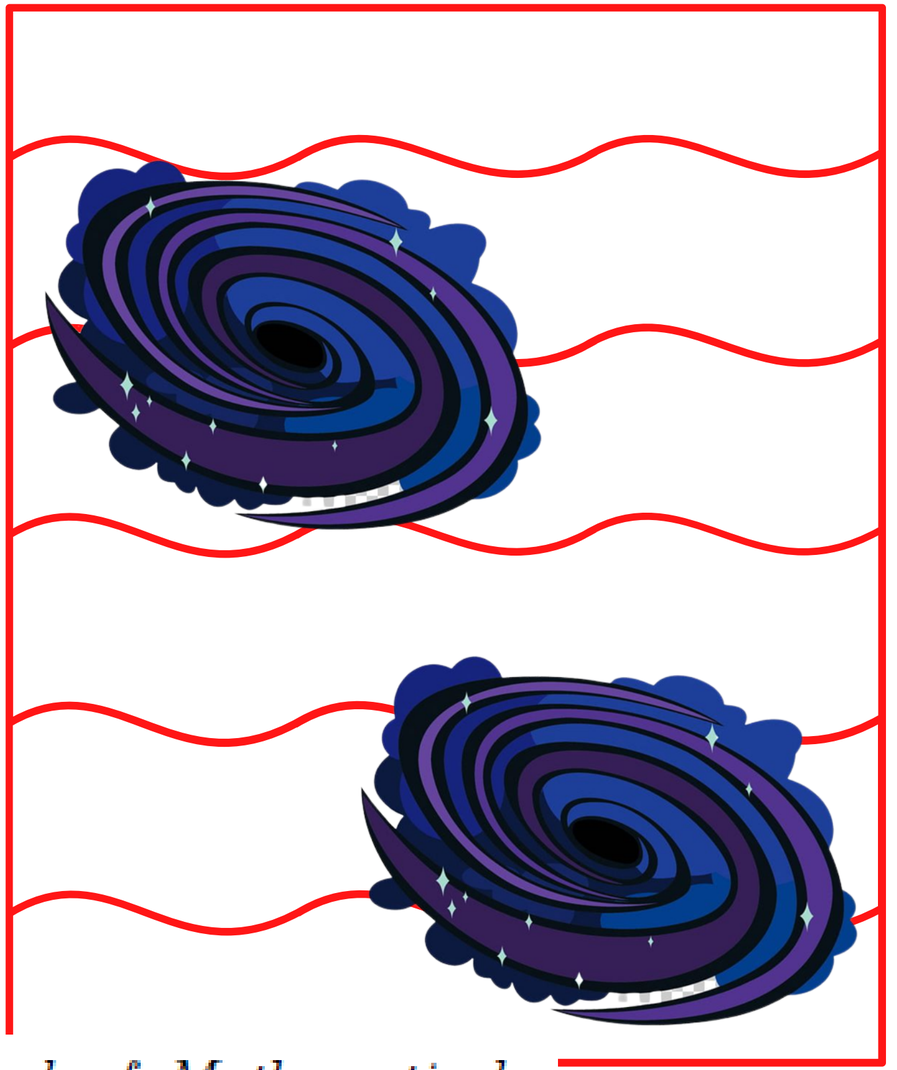
$$dE = TdS - PdV$$

$$dM = \frac{\kappa}{8\pi} dA + \Omega dJ + \Phi dQ$$

BN precisam irradiar.

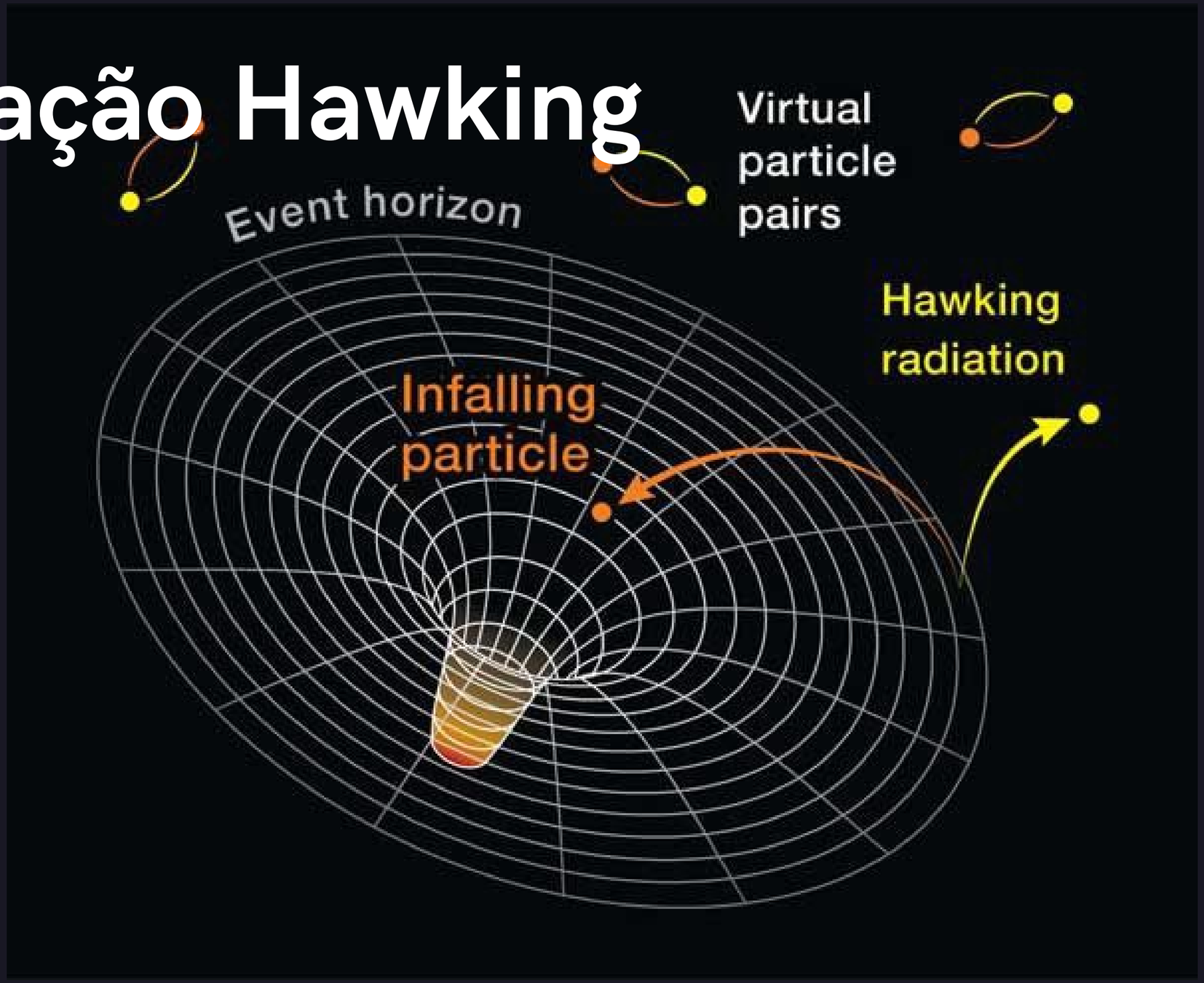
Não termalizam.

Entropia do Universo poderia diminuir.



Susskind, L. (1995). The world as a hologram. *Journal of Mathematical Physics 36*, 6377–6396.

Radiação Hawking



Particle Creation by Black Holes

S. W. Hawking

Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, England

Received April 12, 1975

$$\frac{\hbar\kappa}{2\pi k} \approx 10^{-6} \left(\frac{M_\odot}{M}\right) {}^\circ\mathrm{K}$$

Generalized Second Law: $S + \frac{1}{4}A$ never decreases

Exercício

$$\frac{1}{\sqrt{-g}}\partial_\mu\left(\sqrt{-g}g^{\mu\nu}\partial_\nu\phi\right) = m^2\phi,$$

$$ds^2 = -\frac{r-2GM}{r}dt^2 + \frac{r}{r-2GM}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2).$$

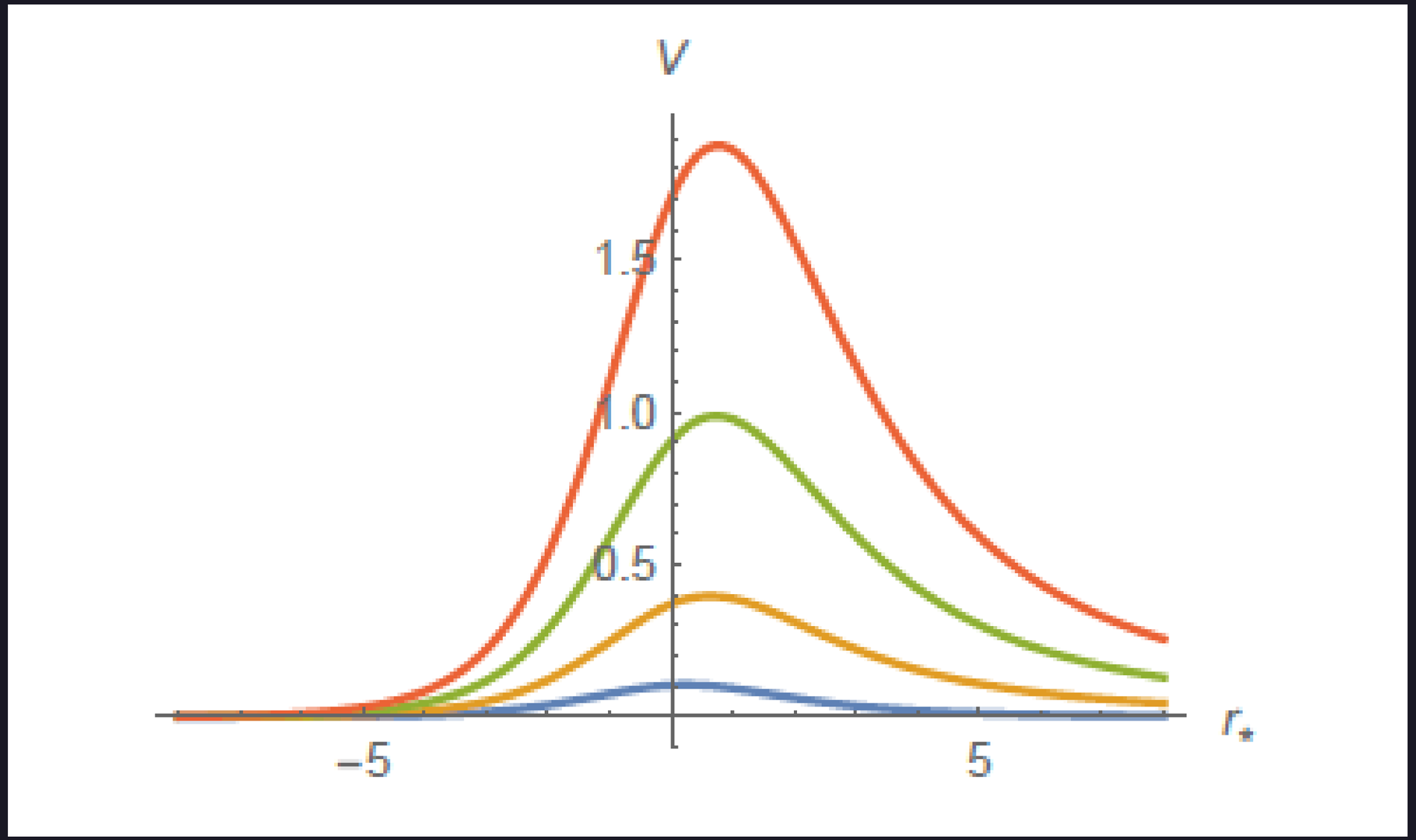
$$r_* = r + \ln|r/2GM - 1|,$$

Exercício

$$f_{\omega\ell m} = \frac{1}{r} Y_{\ell m}(\Omega) e^{-i\omega t} \psi_{\omega\ell}(r).$$

$$-\frac{d^2}{dr_*^2}\Psi_{\omega\ell} + V(r)\Psi_{\omega\ell} = \omega^2 \Psi_{\omega\ell},$$

$$V(r) = \frac{r-1}{r^3}\left(m^2 r^2 + \ell(\ell+1) + \frac{1}{r}\right).$$



Plots of V as a function of r_*, for $\ell = \{0, 1, 2, 3\}$.

Ok. Mas existe isso mesmo?

Não há prospescção de que seja detectado.

Ok. Mas existe isso mesmo?

Métodos independentes de cálculo.

Ausência da radiação leva a contradições.

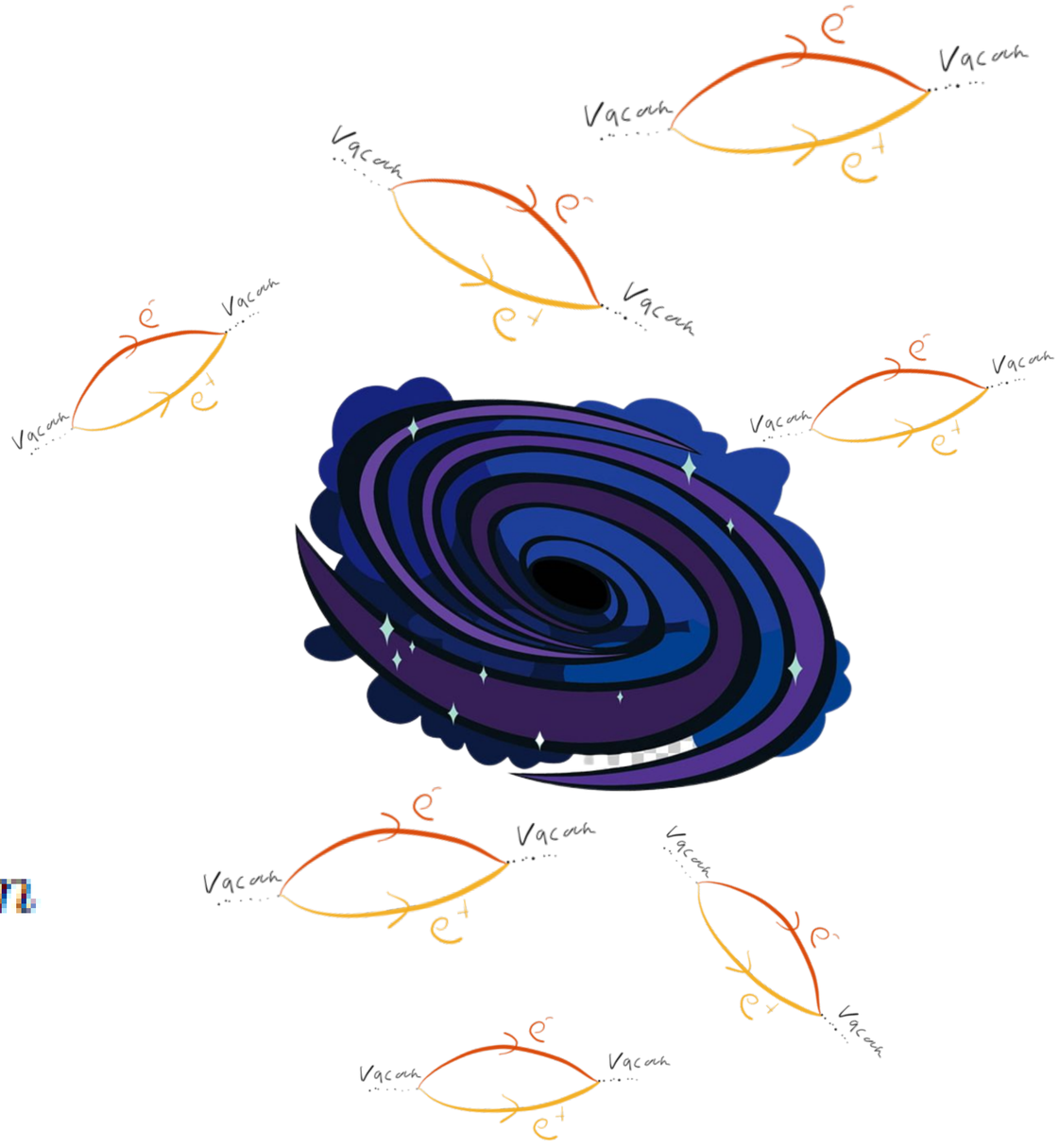
Radiação Hawking é uma consequência de TQC em espaços-tempos curvos!

Contrarreação

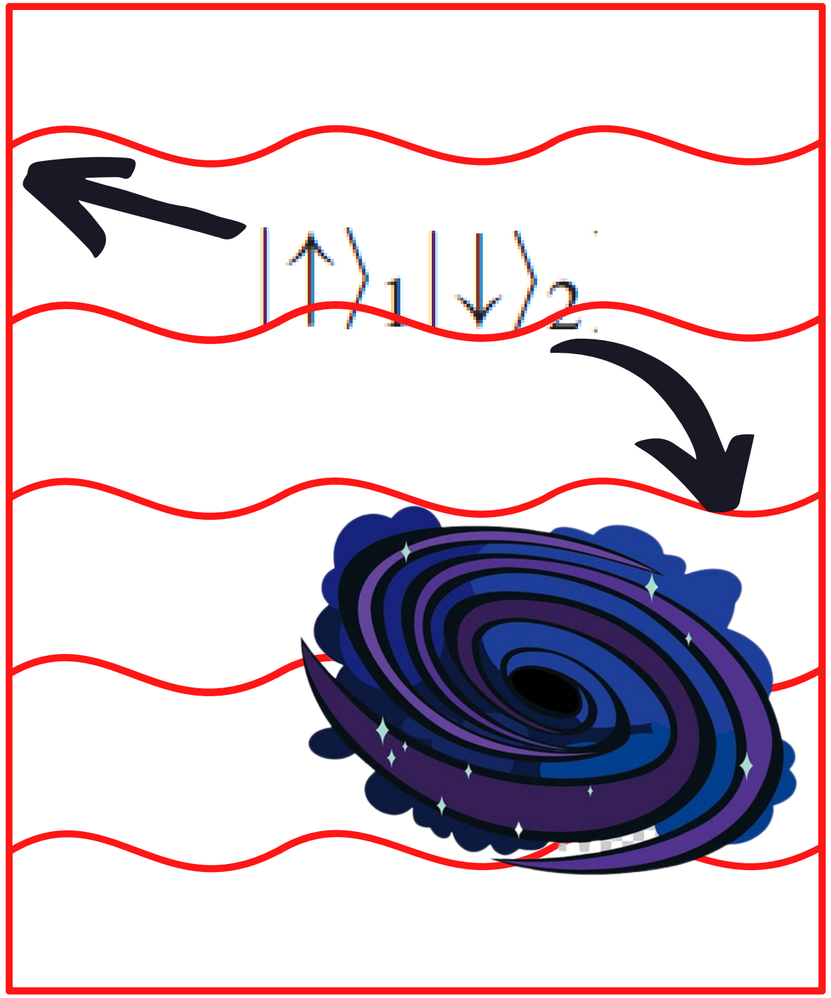
Métrica de Vaidya.

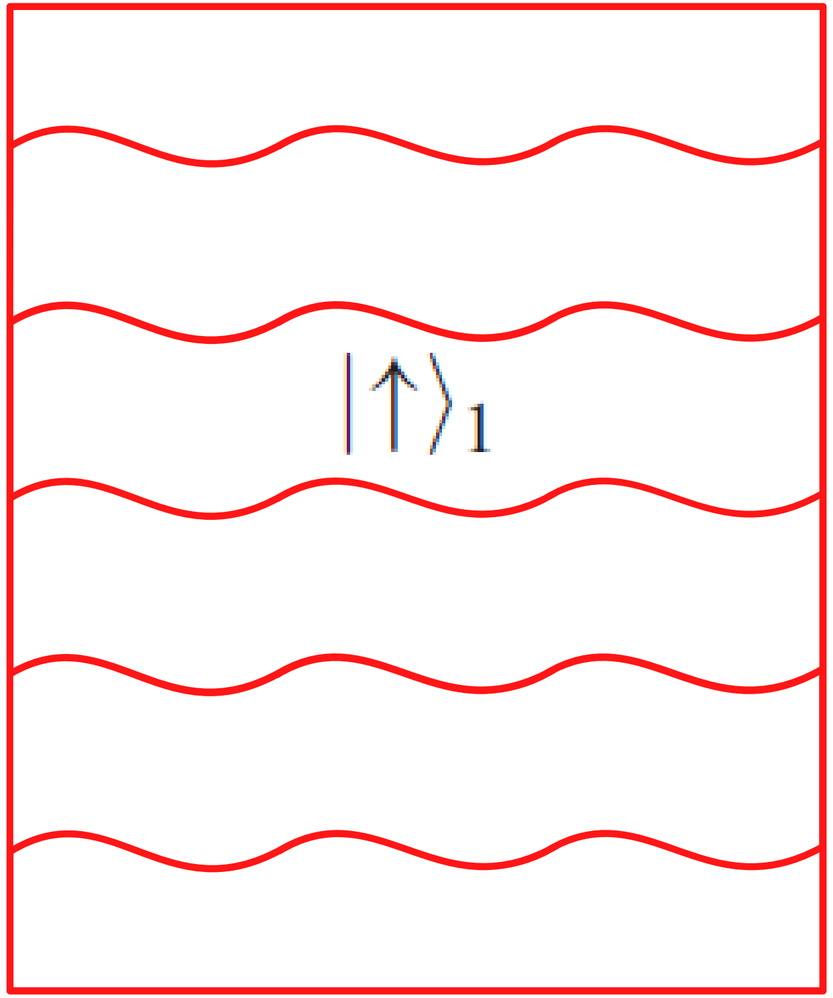
Gravitação semiclássica:

$$G[g] = 8\pi G \, \langle \psi | \, T[\hat{\phi}] \, | \psi \rangle_{ren}$$



Paradoxo da Informação





Por fim:

Apesar de elusiva, a radiação Hawking é um resultado impressionante de TQC em espaços-tempos curvos.

Além disso, indica caminhos na busca de teorias mais fundamentais: microestados de um BN.

Muito obrigado!

The case for black hole thermodynamics Part I: phenomenological thermodynamics

David Wallace*

June 14, 2018

Harlow, D. (2016). Jerusalem lectures on black holes and quantum information. *Reviews of Modern Physics 88*, 015002.