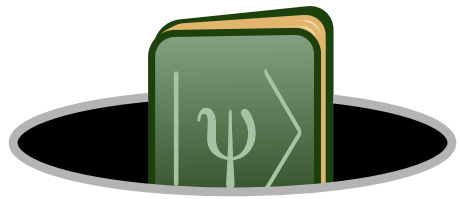
Rethinking Hawking on black hole entropy



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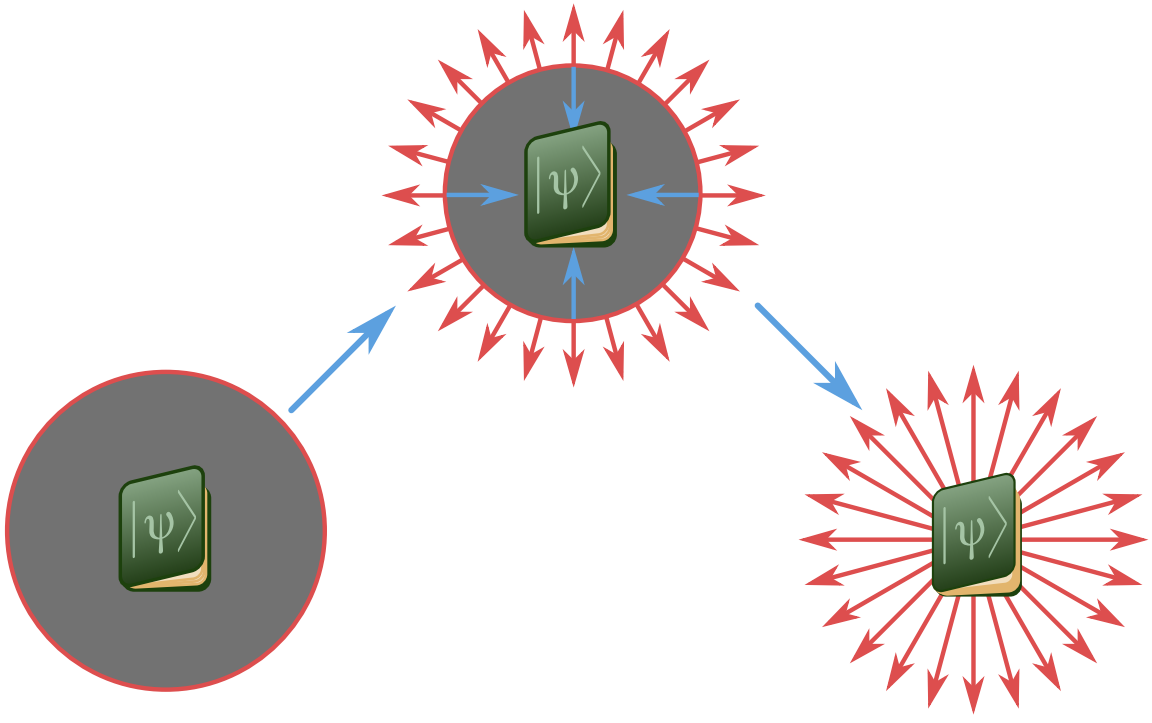
Black holes can evaporate

- Hawking discovered that black holes glow. This means they can leak energy and evaporate. Does this destroy information?

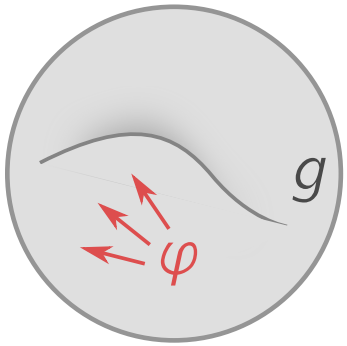


- If evaporation is unitary, BH starts and ends in a pure state with quantum entropy $S = 0$. Goal: find radiation entropy!

Hawking's answer

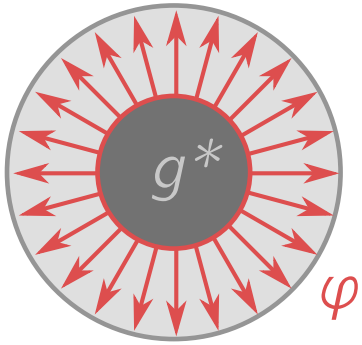
- Hawking calculated entropy from a partition function. This sums over metrics g (with a boundary circle) and matter φ:

$$Z[\beta] = \sum_{g,\varphi} \exp(-\beta$$



$$)$$

$$\approx \exp(-\beta$$



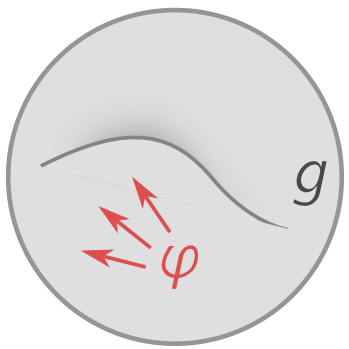
$$).$$

- This sum is dominated by the black hole metric g^* and matter in a thermal state φ^*. So S seems to be big!
- Problem: this only gives quantum entropy for thermal states!

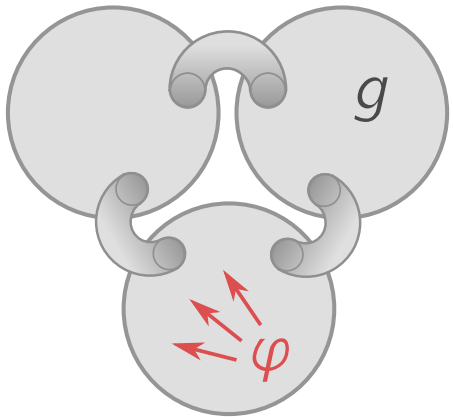
Replica wormholes

- More generally, we use the replica trick. This involves a partition function $Z_n[\beta]$ on n boundary circles, then $n \to 1$.
- Two options for sum over metrics: keep copies separate, or connect with "replica wormholes". The second gives $S = 0$!

$$Z_3[\beta] = \left[\sum_{g,\varphi} \right]^3$$



vs. $\sum_{g,\varphi}$



- We've solved the information paradox. This is awesome!
- But many questions remain. What are replica wormholes? Does gravity = statistical averaging? And is this unitary?

Thanks for listening!