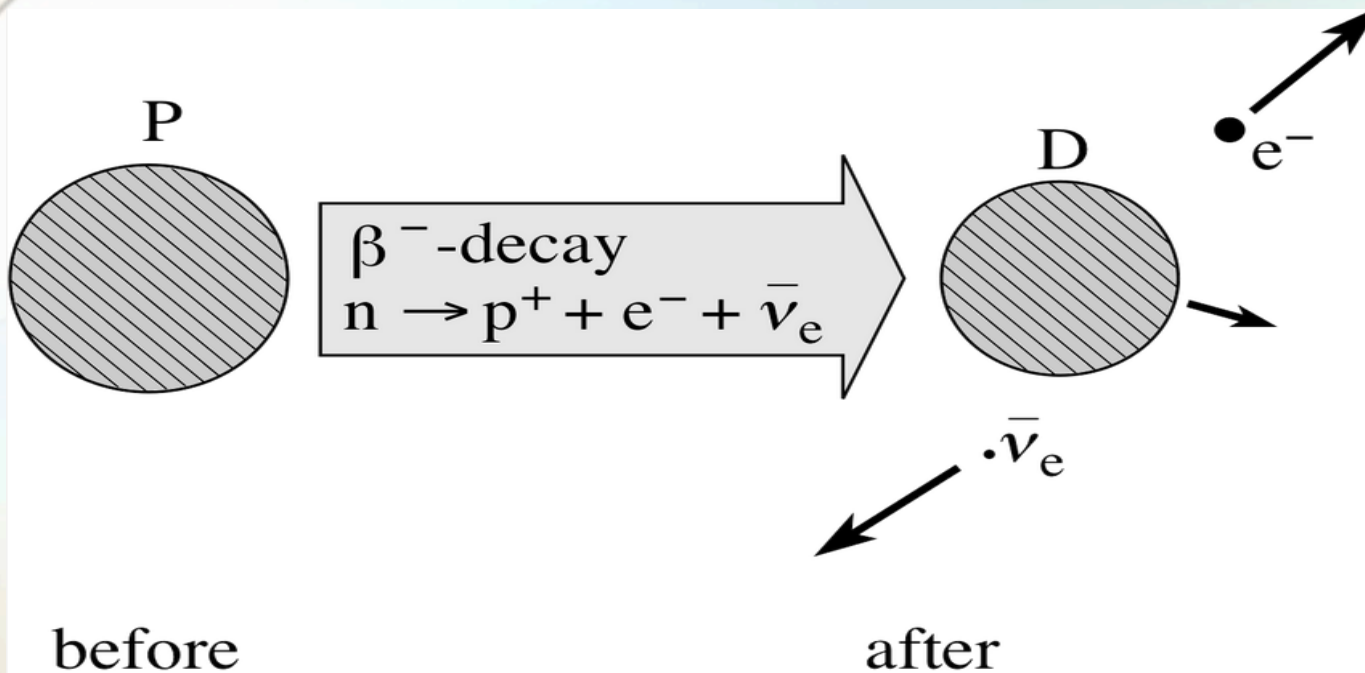


Black Holes and Information

By: Ronaldo Ortez

6/7/18

Violation of a Conservation Law?



- E not Conserved?
- P not Conserved?



“I have done a very bad thing today by proposing a particle that cannot be detected; something a theorist should never do.” - 1930

Black Holes: No Hair Theorem

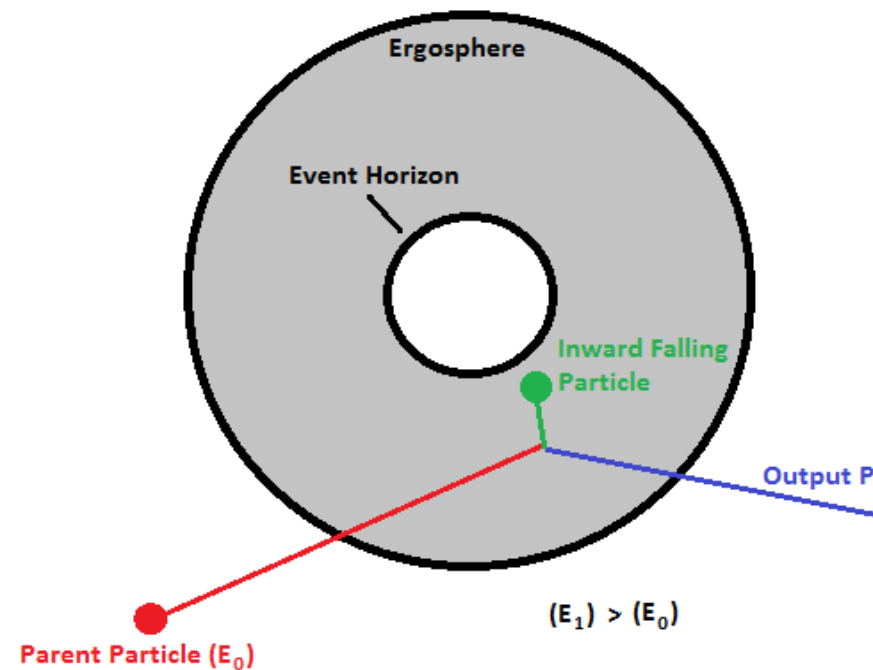
In standard gravity theory the most general stationary black hole exterior is described by Kerr-Newman(KN) solution with $M, Q,$ and J as its only parameters. –Wheeler 1971

- Beckenstein: Black hole entropy?
- Generalized Second Law:
- Postulated Form for S :

Black Hole Thermodynamics

- Use standard Thermo variational techniques
- Ergosphere: Frame-dragging region produced by rotating BH
- Vary the mass!
- 1st Law :

Penrose process

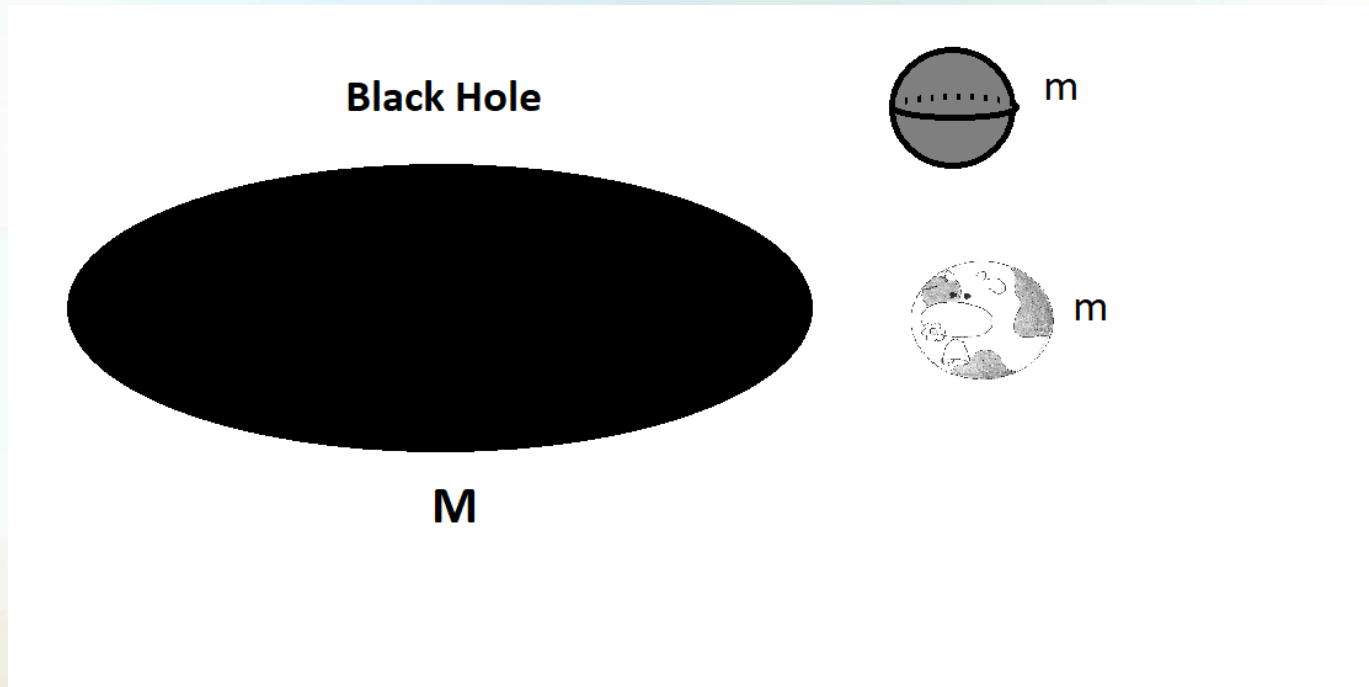


Some Interesting Observations

- Entropy is proportional to the area not volume!
 - Holographic Principle
- The entropy is VERY large:
- There should be microstates!

- Provides a physical information bound
- Bounds on information flow
- Black holes aren't Black!

Information Paradox: Simple Example



- Sphere and Cow are indistinguishable after they cross the horizon
- Only a problem because since BH has a temperature it will radiate via SB law!
- Is it really a big deal? QM and Unitarity!

What is the mechanism for T?

- QFT on curved Space-Time: Hawking(1975)
 - Hawking Radiation
- Unruh radiation(1976):
 - In curved ST, one cannot uniquely define the vacuum in a universal way:
 - Vacuum Expectation Value:
- By the equivalence principle we can understand this as follows:

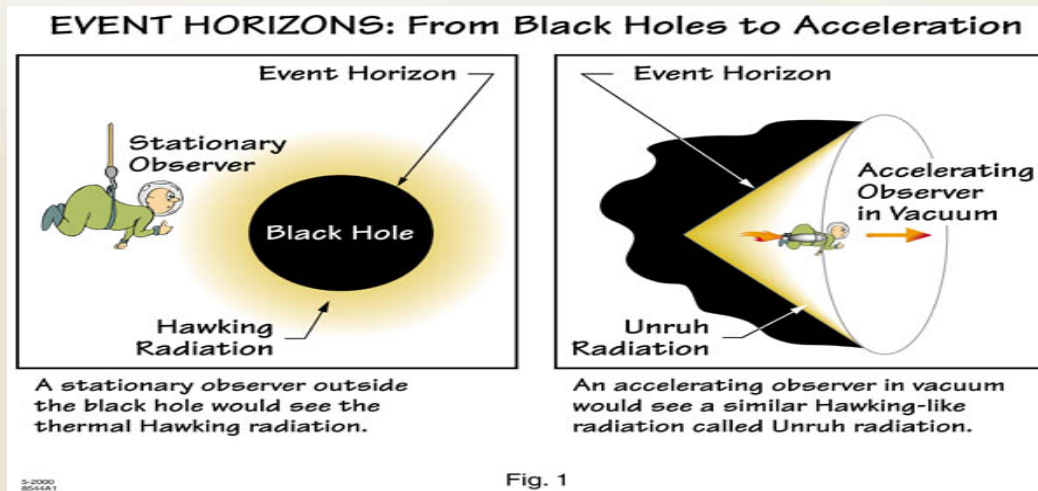


Fig. 1

Entanglement Entropy

Von Neumann entropy of entanglement:

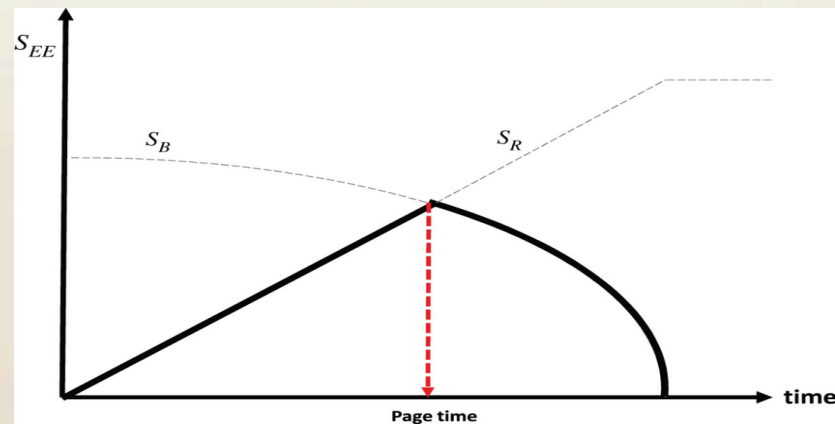
- - ρ is the density matrix:
 - Product States are diagonal:
 - Off-diagonal terms induce correlations and nonzero entropy

Conserved for unitary process.

A measure of correlations between two states.

Conclusions/Resolutions?

- Tiny correlations preserve the information
- Remnant Theories
- The information goes into a different universe: white hole.
- Firewall problem:



AdS/CFT

- Holographic Principle
- A quantum gravity theory in AdS space is dual to a CFT on the boundary.
- In principle it is possible unitarily evolve our BH scenario and work out the correlations.
- Very hard to do in practice and details have not been work out

