From the Standard Model towards a renormalised quantum theory for black holes

Setting up the ontology principle for quantum gravity

Asoke Nath Mitra Memorial Lecture

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Abstract

The history of science shows how new theoretical constructions can be derived by *combining* theories that apply to different branches of science. New steps were made by learning how to include partial insights in more powerful generalised schemes.

This way of interpreting advances made in the past, is here referred to as the *Einsteinian principle.* We now propose to unify Quantum Mechanics and Gravity in the same spirit,

although this is *not* yet a complete solution.

For black holes, this will have a major impact. Many of today's theories entail that gravity allows information to disappear inside black holes. We postulate that no such thing may happen. Particles, when entering or leaving a black hole, will intimately have to unify.

Many theoretical attempts appear to fail when quantum particles approach the black hole too closely.

This is caused by the fact that it was not quite understood which mass, energy, and distance scales should be properly represented.
If we add a single black hole to our system of particles, we obtain a classical background, which may seem to be a step backwards, but it allows us a better view of the way information can be preserved.

The black hole is then classical, so that it can harbour energies much greater than the Planck energy,
while SM particles are quantised assuming that each particle represents much less energy than the Planck energy.

Thus particles and black hole degrees of freedom will remain well-separated. *And for both we already have accurate theories!*

It is expected that black holes emit particles. When they are put in a vacuum, they slowly evaporate. We may describe the process as a dynamical quantum system, in a background that changes so slowly that the relevant degrees of freedom may be considered as obeying Schrödinger equations where transitions only take place between states that carry almost the same total energies: the total mass/energy of a black hole may be attributed to quantised SM particles with energies $\ll E_{\mathrm{Planck}}$.

The Schwarzschild solution $\quad (Q = L = 0)$,

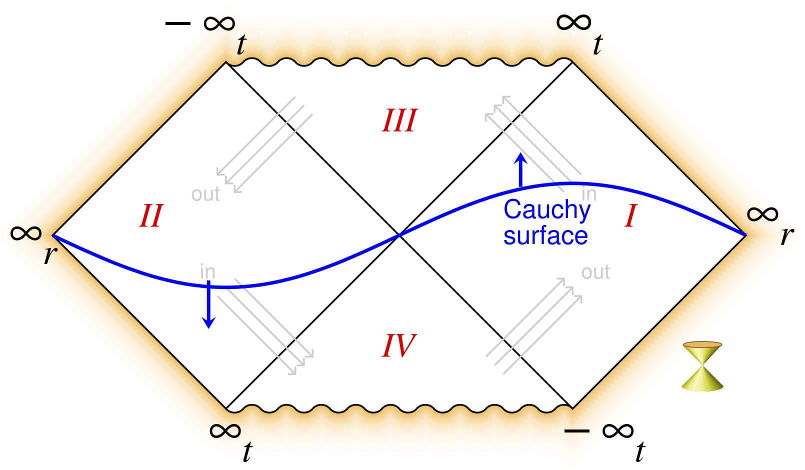
$$\mathrm{d}s^2 = \Big(\frac{2GM}{r} - 1\Big)\mathrm{d}t^2 + \Big(1 - \frac{2GM}{r}\Big)^{-1}\mathrm{d}r^2 + r^2\mathrm{d}\Omega^2,$$

$$\begin{cases} \Omega \equiv & (\theta, \varphi)\ , \\ \mathrm{d}\Omega \equiv & (\mathrm{d}\theta,\ \sin\theta\,\mathrm{d}\varphi)\ . \end{cases}$$

This describes a stationary system, but only if no other types of particles exist.

The metric described here, may have singularities at the horizon: $r = 2GM$.

Better coordinate frame:$(r, t) \to (x, y)$, the *Kruskal-Szekeres (KS) coordinates:*



Here r and t are replaced by x and y. These are defined by

$$\begin{aligned} x\,y &= \left(\frac{r}{2GM}-1\right)e^{r/2GM} , \\ y/x &= e^{t/2GM} . \end{aligned}$$

One derives that in he Kruskal-Szekeres frame, the Schwarzschild metric transforms into

$$\mathrm{d}s^2 = \frac{32(GM)^3}{r}\, e^{-r/2GM}\mathrm{d}x\,\mathrm{d}y \;+\; r^2\mathrm{d}\Omega^2 .$$

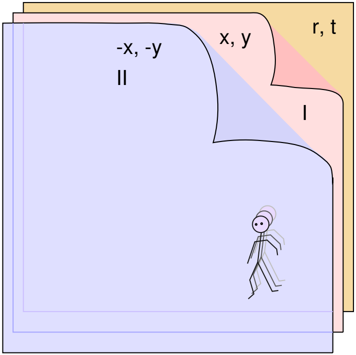
This is only singular at $r \to 0$.

There are no singularities near the central region of this coordinate frame.

Consequently, the central region of this space-time acts as Rindler's spacetime as a model for black holes.

But there is a *very important fundamental difference* between Rindler space and KS space:

Rindler spacetime holds two different black holes, whereas the KS coordinates can only hold one single black hole.



The clone theory pertains that the two black holes in the KS frame are *clones* of one another.

In that case, the *entropy* would only be half the entropy of the entire KS sheet system.

$$dM = T dS.$$

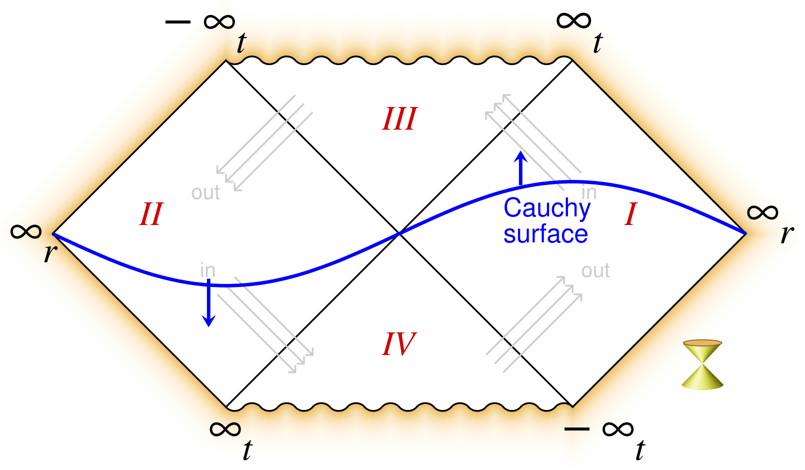
Since the mass (or energy) of the system remains the same, this would imply that the temperature T of the black hole in this theory should be *twice* the well-known expression given by Hawking.

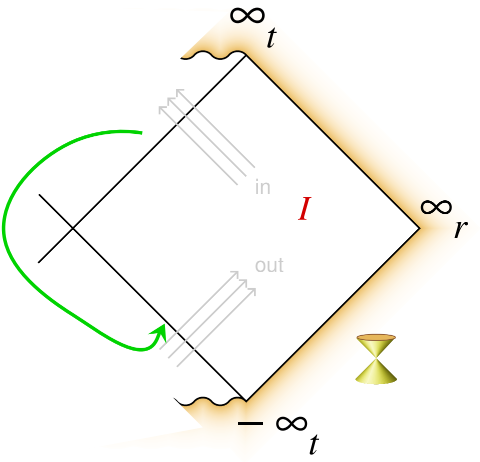
Regarding the region *II* as a clone of region *I* resolves the information problem elegantly, but it introduces something else: a conical singularity on the horizon.

It is not a true sungularity, but one that can be smoothened – generating the metric of a violent matter event.

and that is actually what we should have expected: the implosion that produced the black hole, together with its time reverse: the final evaporation. Both involve equal amounts of matter.

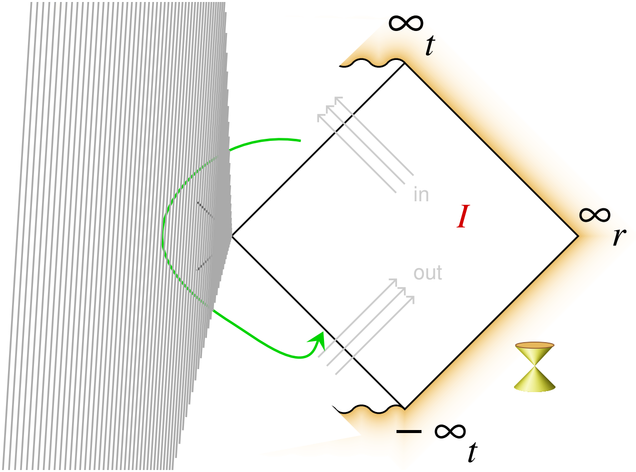
The environment of the horizon.





We want that the information that seems to leak away, returns to where it might belong.

This can be done !

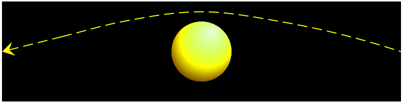


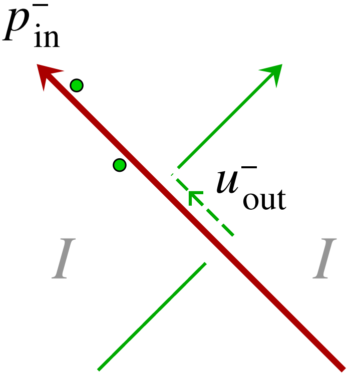
Introduce a *conical singularity*

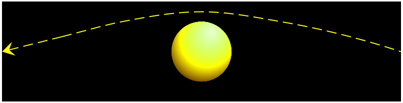
Take it to be over an angle of 180^o.

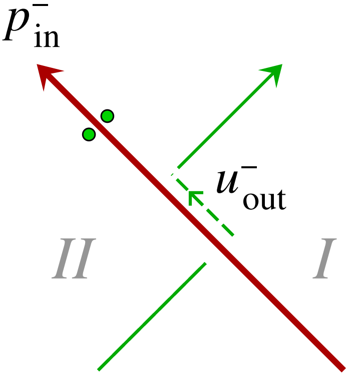
The space left over can only contain half of the original amount of information.

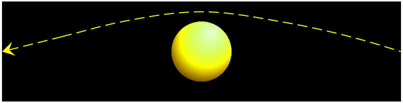
The information carried by particles is transferred directly to the outgoing particles, by a mechanism called the *Shapiro shift.*

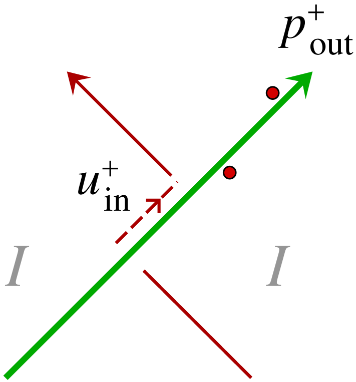



p^{-}_{in}
u^{-}_{out}
I
I




p^-_{in}
u^-_{out}
II
I




p^+_{out}
u^+_{in}
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I

I expected that this ‘minor issue’ should be resolved by now, but it is not. I still do not know what the Hawking temperature should be in our clone theory.

Perhaps the issue is related to my other pet theory:

ONTOLOGY in quantum mechanics.

Most quantum mechanical models exclude the existence of ontological hidden variables.

The operators representing the quantum model would not commute with those of the hidden variable. This general belief is based on a large number of paradoxical models that show what goes wrong.

The famous historic example is the experiment proposed by John Bell. Basically: one can check experimentally whether hidden vaiables can do the job. These experiments have in fact been done.

"Quantum Mechanics vindicated, it was claimed that no ontological model can reproduce this result,
just the magical phenomena predicted by QM are real!"

But the theoretical construction contains a fundamental weakness:

the assumption of

Statistical independence of the data used by two separated observers

(called Alice and Bob), is assumed to be totally free of any correlations, in particular entangled ones.

It is assumed that Alice and Bob both can both choose the orientation angle of their measuring apparatus by using statistically independent data.

But I claim that one can construct models where the data used cannot be entangled like that.

The ‘statistically independent fluctuating data’ are assumed to be situated in the far past. But consider the operation of time-reversal. When you situate the fluctuating data to be far in the future instead of far in the past, it is easy to see that the assumption that they are statistically independent is impossible to maintain. Even if one cannot detect any statistical relation, this does not mean that it is not there.

Give me your favorite paradoxical quantum model, and I'll show that hidden, statistical correlations can always be assumed such that the paradox seems maintained, whilst the model can work assuming complete ontology: all interactions can be chosen to be classical.

Examples: the

Greenberger-Horne-Zeilinger "entangled quantum state" –

Schrödinger's cat ...

Theorem:

If two models, A and B, have exactly the same set of energy eigenvalues, then they are physically indistinguishable, as they describe exactly the same physical system.

Proof: if these two systems have the same energy levels, they obey exactly the same Schrödinger equation(s):

An amusing exercise: let

$$E_n = n\hbar\omega, \quad n = 0,\ 1,\ 2,\ \dots\ .$$

Learn how the conventional

quantum mechanical harmonic oscillator

can be mapped onto

a particle running over a (fixed) circle

(or any other periodic curve),
with the same angular velocity ω.

This is the (single-handed) 'Quantum Grandfather Clock':
The pendulum is the oscillator, the hand is moving around in a circle.

quantizing it has little effect

Schrödinger equations:

$$\frac{\partial}{\partial t}\phi(t) = \omega \quad , \quad H = -i\omega\frac{\partial}{\partial \phi} \ .$$

$$H|e^{in\phi}\rangle = \omega n|e^{in\phi}\rangle \ \rightarrow \ H = \omega n \ .$$

This is exactly the spectrum of the Hamiltonian of the harmonic oscillator (adapted by a term $\frac{1}{2}\omega$):

$$H = \frac{1}{2}(p^2 + \omega^2 x^2 - \omega) \ .$$

Can we introduce interactions without disturbing the ontological nature of such a system?

Replace the circle by a complicated railway track, containing many switches.

This turns our system into a construction with variable, different, tunable, periodicities!

and try to apply such schemes to given quantum systems.