Gerard 't Hooft

Fundamental Quantum Mechanics, Gravity and Black Holes

A Turning Point?

Erice 2022

Institute for Theoretical Physics,
Science Faculty, Utrecht University,
Princetonplein 5, 3584 CC Utrecht
The Netherlands

With the identification of the Higgs particle, a branch of science, *Elementary Particle Physics,* has reached a turning point.

A theoretical doctrine, called *The Standard Model*, turned out to match the observations more accurately than anticipated – as if the gauge group $SU(3) \otimes SU(2) \otimes U(1)$ were the only allowed local symmetry group, and the 3 families of quarks and leptons form the most complete representation possible, of that gauge group. Only one Higgs field is needed to account for all mass terms . . .

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AND THAT IS IT

and, oh yes, we also have gravity

Other sciences are not at all suffering:

cosmology, gravity wave research, material science, nanophysics, they still have a lot to do. Even experimental physicists do not experience that they are hitting against a closed door.

The problem is in *THEORETICAL PARTICLE PHYSICS.*

Universally accepted wisdom:

QFT has over 20 freely adjustable 'constants of nature'. We can measure these constants but we cannot derive or understand them.

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Experimental measurements and observations revealed something very special . . .

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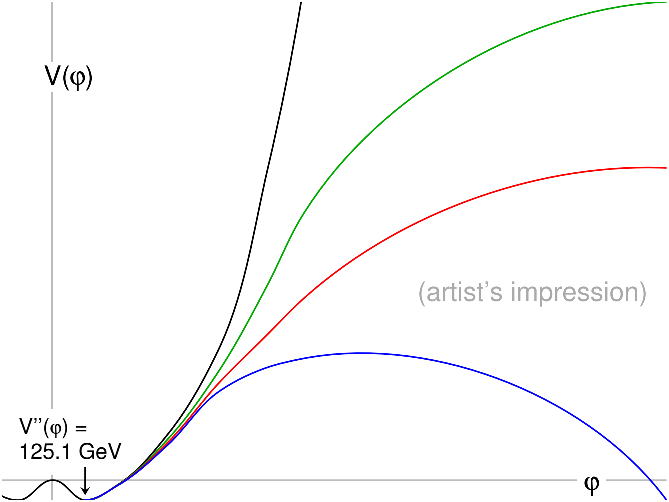

$$V(\varphi) = \frac{1}{4!}\lambda(\varphi)(\varphi^2 - F^2)^2 \ .$$

Why is this so important?

The problem is related to questions of the *interpretation of QM*. This is not just the domain of philosophers. In a few words:

Quantum Mechanics does not have to be based on pilot waves and/or many world scenarios.

It may be nothing more than a *vector representation* of a totally realistic theory.

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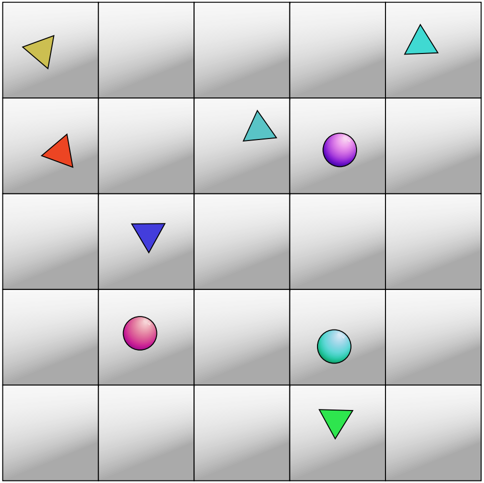
It may be nothing more than a *vector representation* of a totally realistic theory.

This realistic theory might well be a *classical* cellular automaton (CA).

The cellular automaton.



If so, the Standard Model already carries a lot of information about this CA.

That information is in the symmetries. If the CA is defined at or near the Planck scale, then all the SM particles known today have their mass protected by some *approximate symmetry law.*

The Higgs mass has to be protected by a global, approximate Goldstone symmetry.

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But isn't the Higgs field an $SU(2) \otimes U(1)$ isospinor ?

The global Goldstone symmetry must be acting only on the length (or norm) of this isospinor. But since the Higgs mass is only 10^{-17} times the Planck mass, this Goldstone symmetry law, at the Planck scale, is only disobeyed in one out of 10^{34} automaton configurations.

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Such as string theory, AdS/CFT, attempts to quantise gravity.

Perturbation theory will never disclose the origin of the perturbation parameter such as a coupling constant, or $\alpha = e^2/4\pi\hbar c$

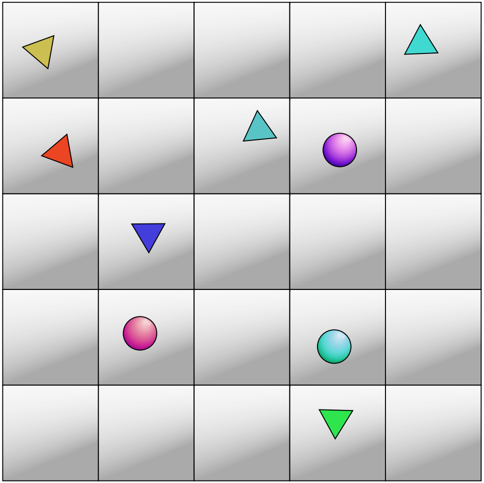
Important exception: $1/N$ expansions!

There, a theory is defined at some finite value of N. One way to avoid uncontrolable perturbation expansions is to interpret the expansion parameter in terms of a large integer, if you can find it!.

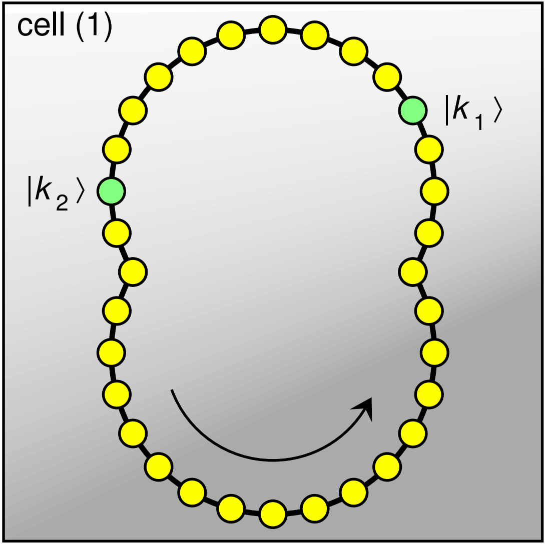
What are the large integers of the *Standard Model* ?

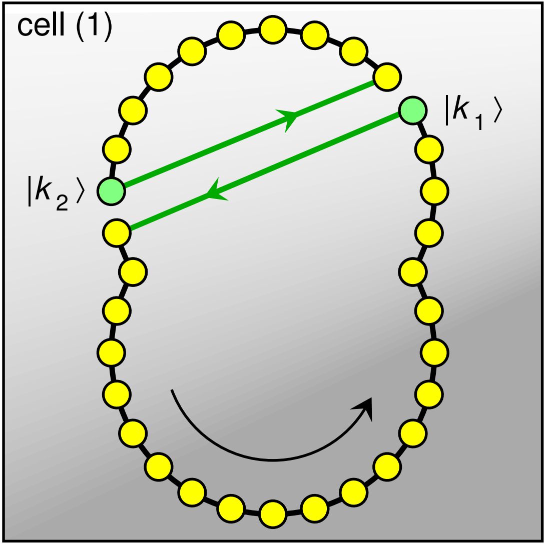
There may be a way!

The cellular automaton.



By using mathematical trisks a classical CA can be turned into a quantum mechanical one . . .


cell (1)
$|k_1\rangle$
$|k_2\rangle$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Black holes contain a region of space-time where particles boosted to infinite Lorentz contraction meet. New physics is required to understand what is going on.

Quantum gravity has to be reformulated to allow application in black holes. String theory is not fool-proof; string theories allow investigators to make the same mistakes as any other approach.

What errors are being made?

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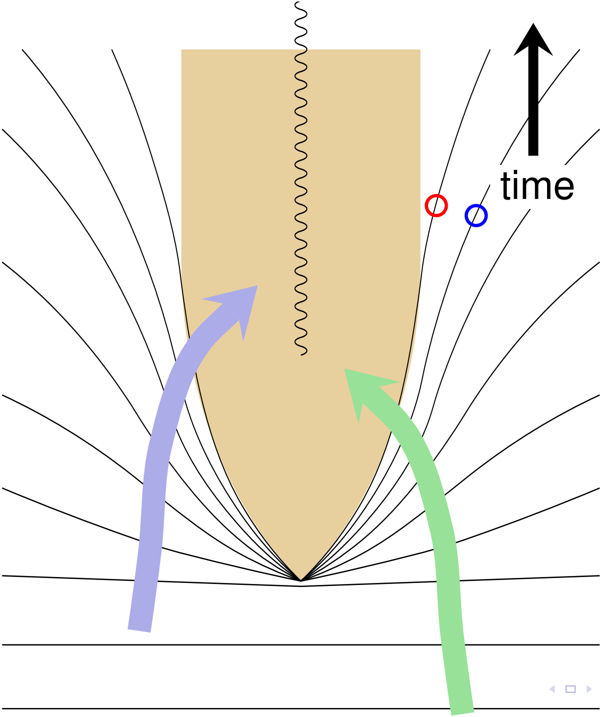
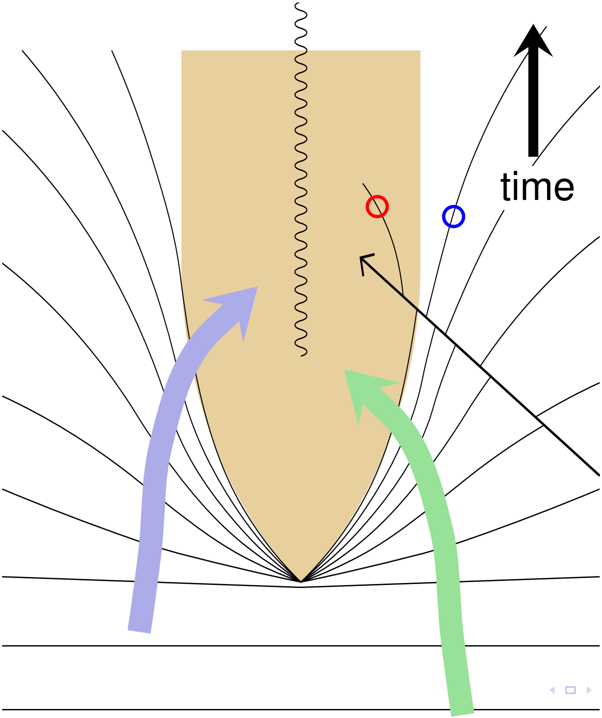
That's all right as long as we realise this. The real world may be different from what we think.


time


time

Particles disappearing behind the horizon seem to disappear, dragging along with them all information they carry.
But all known physical systems appear to obey unitary Schrödinger equations. Perhaps blak holes are exceptions, which means we understand very little about them.
But we can also search for equations such that their Schrödinger equations do conserve probabilities (i.e., they are unitary).

All that is needed is a little work with some insight.

Let me explain (in words and in equations) how this goes:

After initial collapse, a black hole quickly attains an almost stationary state. Schwarzschild Metric:

$$
\begin{aligned}
\mathrm{d}s^2 &\;=\; \frac{1}{1-\frac{2GM}{r}}\mathrm{d}r^2 - \left(1-\tfrac{2GM}{r}\right)\mathrm{d}t^2 + r^2\mathrm{d}\Omega^2 \;; \\
\Omega &\;\equiv\; (\theta,\, \varphi) \;, \\
\mathrm{d}\Omega &\;\equiv\; (\mathrm{d}\theta,\, \sin\theta\,\mathrm{d}\varphi) \;.
\end{aligned}
$$

Go to Kruskal-Szekeres (or 'tortoise') coordinates x, y, defined by

$$\begin{aligned} x\,y &= \left(\frac{r}{2GM} - 1\right) e^{r/2GM} \quad ; \\ y/x &= e^{t/2GM} \quad . \\ \mathrm{d}s^2 &= \frac{32(GM)^3}{r}\, e^{-r/2GM}\, \mathrm{d}x\, \mathrm{d}y + r^2 \mathrm{d}\Omega^2 \quad . \end{aligned}$$

At $r \to 2GM$, we have $x = 0$: future event horizon, and
$y = 0$: past event horizon.

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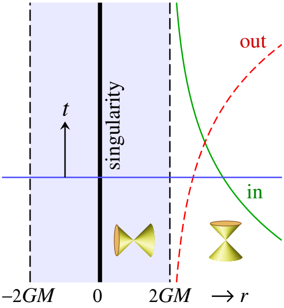
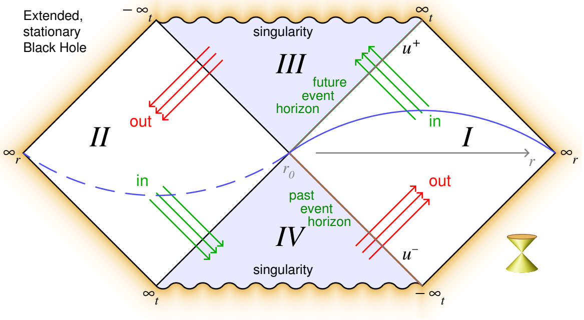
$y = 0$: past event horizon.

For every point (r, t, θ, φ), there are *two* points in these new coordinates: with every (x, y, θ, φ) there is also $(-x, -y, \theta, \varphi)$.

Schwarzschild

KS





In Schwarzschild coordinates (left) you see one outside region and one inside region (blue)

In the more regular Kruskal-Szekeres coordinates (right) you see two outside regions and two inside regions (blue)

The regions *I* and *II* are two 'universes' outside the black kole. It is often thought that *II* is the 'inside'. But no, regions *III* and *IV* are the inside. More interesting:
Regions *I* and *II* are *quantum clones* of one another.

Solve the equations with the *comstraint* that the wave functions in *I* and *II* are the same !

Calculations: this gives a unitary evolution law!

At the crossing point of future- and past-horizon, early in-going particles meet the late out-going particles with tremendous c.m. energies – they could form new black holes while colliding . . . (?)

A new language has to be invented to handle this situation. We found such a language when in- and out-particles onlt exchange their gemetric data: positions and momenta. That exchange is unitary

Setting up the correct equations at this point must be possible. The in- and out-going particles are very similar to the vertex insertions used in string theories. String theory managed to obtain complete Virasoro algebras to establish or restore Lorentz invariance and unitarity in their formalisms. Same thing should be possible here.

String theory also obtained QFT structures by taking the zeo slope limit (low momentum limit).

I beieve we have to repeat string theory procedures but now in this setting.

Note that I never 'assumed' string theory to be valid. I only want to steal their advanced math methods

such as extra, transverse, dimensions ??

Conclusion:

To find ways of improvement, new questions are to be asked, and new pathways to be found. New signals from experimental observations will always be important!

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THANK YOU