

Planck's constant and space-time basic structure

Quantum gravitational field and space-time: equivalence of identity

"Some people speculate that space-time is quantized, and the fundamental size of that unit is the Planck length of 10^{-35} meters (for the space coordinates) and the Planck time for the time dimension (that is the time it takes light to travel one Planck length).

The reason for this view is that if general relativity continues to hold on these scales, and so does the Heisenberg uncertainty principle of quantum physics, then the "vacuum" becomes a foam of tiny black holes, each about a Planck length in size, and each one forming and evaporating in a Planck time".

CLASS	FREQUENCY	WAVELENGTH	ENERGY
Y	300 EHz	1 pm	1.24 MeV
HX	30 EHz	10 pm	124 keV
	3 EHz	100 pm	12.4 keV
SX	300 PHz	1 nm	1.24 keV
	30 PHz	10 nm	124 eV
EUV	3 PHz	100 nm	12.4 eV
NUV	300 THz	1 μm	1.24 eV
	30 THz	10 μm	124 meV
NIR	3 THz	100 μm	12.4 meV
MIR	300 GHz	1 mm	1.24 meV
FIR	30 GHz	1 cm	124 μeV
	3 GHz	1 dm	12.4 μeV
EHF	300 MHz	1 m	1.24 μeV
SHF	30 MHz	10 m	124 neV
UHF	3 MHz	100 m	12.4 neV
VHF	300 kHz	1 km	1.24 neV
HF	30 kHz	10 km	124 peV
MF	3 kHz	100 km	12.4 peV
LF	300 Hz	1 Mm	1.24 peV
VLF	30 Hz	10 Mm	124 feV
VF/ULF	3 Hz	100 Mm	12.4 feV
SLF			
ELF			

Wikipedia: Planck time units

"A Planck time unit is the time required for light to travel a distance of 1 Planck length in a vacuum, which is a time interval of approximately 5.39×10^{-44} s." [35]

<http://abyss.uoregon.edu/~js/cosmo/lectures/lec20.html>

Basic point of disagreement:

On the Planck time and Planck length formulation

The given definition of Planck time:

"The time required for light to travel a distance of 1 Planck length in a vacuum"

(vacuum = space-time)

Light ... but of what known wavelength?

The lowest known experimental wavelength is gamma radiation:

1 ... 10 pm. (picometer: 10^{-12} m.) with a corresponding max energy of 124 KeV... 1.24 MeV.
(energy of gamma photons).

It's said: **Fundamental size unit is the Planck length of 10^{-35} meters = 1 period (T_p) of Planck wave.**

Planck's Length is the length below which the concept of length loses its meaning: What exactly does that mean and what are the incredible implications this fact has upon our reality?

The basic Planck wave essentially represents a Planck quantum and not a real walkable length.

1 Planck wave is Planck's electromagnetic wave period ($T_p = 10^{-35}$ meters), it is the discrete unit, 1 "quantum", below which nothing is definable, by definition of quantum!

To put it in the digital technique: It is the last significant bit.

- No smaller wavelength has ever been calculated, tested, or defined. Therefore, it represents a quantum. Moreover, there is no quantum length!

It can't have a shape, as shape implies differences in length.

- Only more than one Planck quantum can define a length (1D).

The definition given exchanges the length dimension with the fundamental electromagnetic wave: 1 Planck wave = T_p = 1 Planck quantum!

A dimension of length 1D implies the presence of more than one quantum, hence multiple Planck periods T_p in a row.

A shape implies differences in length.

Let's say:

“To travel... a distance of 1 Planck length in a vacuum” (space-time). It is meaningless!

It's like wanting to travel in a point! A point is not a length dimension.

"Quantum mechanics does not allow particles to occupy a space smaller than their wavelengths."

Consequently, **it makes nonsense** to speak of Planck time.

That 10^{-44} does not exist. Because, the time dimension conceived as the 4th dimension of 3D space can arise only from multiples of Planck waves. It is the minimum amount of time that belongs to space-time and can only be referred to a multiple Planck resonant wave, organized in a geometry: The geometry of space-time.

The minimum resonant multiple wave (a T_L period) can be defined as the quantum length of the space-time cell.

Each length (1D) of the space-time cell must be an integer multiple of the Planck wavelength, this necessarily means being its resonance!

Multiple resonance wave ($1T_L$) on Planck's fundamental wave (T_p).

$$1T_L = n T_p$$

Where n is the number of periods of the Planck wave required to achieve the best-known experimental resonance of the T_L period

The space-time cell is born (in turn) precisely because of the existence of a quantum length, T_L element of minimum length 1D that composes it.

Quantum length, T_L represents the last significant bit, of a length, capable of composing the space-time cell.

Multiple contiguous space-time cells, in turn, build the basic uniform space-time (4D) structure. Whose geometry and dynamics are illustrated below.

How can an electromagnetic wave propagate through such a space-time structure?

Uniquely in a quantized way: Step by step, cell-cell between space-time.

This cadenced dynamic process, in space-time, necessarily turns out to be a constant, and its propagation dynamics is independent of any reference system.

Indeed, the speed of light "c" is a fundamental constant. It is the absolute basic dynamic process. (in the absence of matter). **It is the conceptual basis of propagation and interaction!** In the most general and basic sense.

The propagation process, the constant speed "c" operates on **several "Planck quantum"**: Among the **quantum length** (1D), step by step in the concerned dimension of the space (3D).

The basic space-time cannot leave quantum "gaps" in its 4D structure that it constitutes. By basic space-time structure we mean space-time in the total absence of other particles and/or matter. (classically called, cosmic void)

The basic space-time structure can host in it (without leaving quantum "voids") **matter/energy** (a more complex structure) **but, this alters the ordered basic structure of origin. It alters its symmetry.**

In the presence of other particles the composition of the cells deforms, giving rise to the "curvature" of space-time.

The minimum quantum deformation of the cell represents the quantum gravity and the associated wave/particle is the "graviton".

After the electronic neutrino, element that composite the cell space-time, follow the muon neutrino and, next, the tau neutrino. The muon neutrino should introduce the minimal space-time cell deformation i.e. gravity and therefore identify the "graviton".

Therefore, the gravitational field is generated. As per General Relativity,

But until today: ***"The geometric interpretation of general relativity is not fundamental but "resulting"."***

Instead, with the present configuration, general relativity would come to be both functionally and geometrically fundamental. It is through quantum electrodynamics that it must be possible to combine Special Relativity with General Relativity.

LINKED QUESTION:

How many wavelengths of Planck 1D, how many periods (T_p), make up the multiple resonant wave that defines the quantum length (1D) of the space-time cell (symbolically static view in 3D, which frame of 4D)?

Which resonant wave-particle (T_L) on the Planck fundamental (T_p) is it about?

Considerations-requirements to the questions, respecting simplicity, symmetry and synergy:

The multiple resonant wave, the best candidate, must have the resonance peak (in the spectrum of a Gaussian) the narrowest experimentally known:

Because, this characteristic constitutes the best purity and synergy that a basic wave-particle can possess!

- The electron, as far as we know, is the wave-particle with the narrowest resonance peak.

- The electron is the only known wave-particle that interferes with itself.
- The electron has no substructure and is truly an elementary particle.
(Müller) <https://physicsworld.com/a/fundamental-constant-measured-at-highest-precision-yet/>
- A real electron can emit or absorb a real photon.
- The electron is the only wave-particle always present in all known fundamental processes.
- The wave-particle “electron” is closely linked to the fundamental constant of fine structure “ α ”. The adimensional constant “ α ” is closely related to the Planck constant and to the constant “c”.

"The fundamental constant" α "describes the speed at which electrons move around the nucleus of an atom on the first orbital."

*"There is a most profound and beautiful question associated with the observed coupling constant, and the amplitude for a real electron to emit or absorb a real photon". "It has been a mystery ever since it was discovered more than fifty years ago, and all good theoretical physicists put this number up on their wall and worry about it. Immediately you would like to know where this number for a coupling comes from: is it related to π or perhaps to the base of natural logarithms? Nobody knows. It's one of the greatest damn mysteries of physics: a magic number that comes to us with no understanding by man. You might say the "hand of God" wrote that number, and "we don't know how He pushed his pencil." **Feynman***

If the best candidate is the electron, its inevitable antiparticle, in respect of **symmetry**, is the **positron**. (no particle can exist without its antiparticle)

It follows that the wave-particle/antiparticle pair best candidate to constitute a dimension (1D) of the space-time cell and characterize the light propagation process, the constant "c", must be the electron/positron.

This e^-/e^+ pair is defined, it is known, as “exciton”. (e^-/e^+) = 1 exciton.

What is the geometry and its dynamics, composed of such wave-particle/antiparticle pairs, (excitons) **that structure the space-time cell?**

How can a 3D structure made of excitons be created without leaving “quantum voids” and therefore in the most compact way possible?

The fundamental space-time basic cell determines the reason for being of the fundamental constant "c", that is, the possibility that light (electromagnetic wave) always has the same speed of propagation in space-time.

Space-time means "full" quantum background (called "vacuum") which forms the structural basis in which the Universe "works".

The Universe is determined by the fundamental constants "h", "c" and " α ".

The basic fundamental cell of space-time must necessarily be:

- simple, symmetrical and synergistic.

- must be able to structure space-time without leaving quantum "gaps" in the 4D structure that it constitutes. So: **quantized and compact**.

Tetragonal geometry is the most compact type of geometry we know of. So let's imagine that the (minimum) cell must be a tetragon and on each side of it, dynamically, resides an exciton.

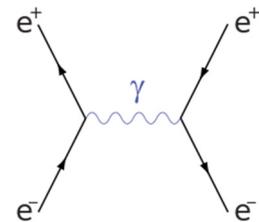
The cells must be compact, no stand-alone (do not leave quantum "gaps"), each face of the tetrahedron shares the face of the adjacent tetrahedron. By sharing the sides (the relative excitons).

The excitons (sides of the tetrahedra) undergo the well-known phenomenon of electron-positron annihilation / recreation of pairs.

This is the basic dynamics of adjacent and interconnected tetrahedra.

Dynamically interconnected to the rhythm of the constant "c".

Feynman diagram of the annihilation of a positron and an electron into a gamma photon, which then re-decays into a positron and an electron through the pair-making process.



This dynamic represent the zitterbewegung.

The quantized structure of dynamic excitons does not reside in space-time. They are space-time!

How does the structure of the space-time cell, so quantized, relate to zitterbewegung and entanglement?

How can the space-time cell dynamically function while respecting the phenomena of zitterbewegung and entanglement?

A multi-tetragonal system (set of adjacent tetragonal cells) acquires omnidirectionality of entanglement due to the continuous process of annihilation / creation of pairs at speed "c". To the rhythm of the zitterbewegung.

The space-time is made up of the set of tetragonal cells, which allow the functional connection between zitterbewegung and entanglement.

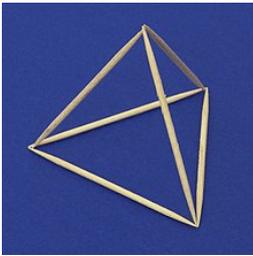
The functional connection between zitterbewegung and entanglement leads to the relativistic characteristic of locality and non-locality: To their mutual coexistence.

The Universe is holistically and entropically interconnected through zitterbewegung and entanglement in a tetragonal-based geometrodynamics.

Why this and not another geometry?

*"Due to its **simplicity**, the simplex is generally considered the **"base block"** with which to build more complicated n-dimensional spaces through a process called triangulation."*

*"The zero-dimensional **simplex** is a single point, the two-dimensional simplex a triangle and the **three-dimensional simplex** a tetrahedron."* <https://it.wikipedia.org/wiki/Simpleso>



*Einstein proposed a problem:
 Given six toothpicks, construct four equilateral triangles.
 None of those present managed to place the toothpicks on a plane to form the required triangles, which is in fact impossible, whereupon Einstein composed a tetrahedron with the six toothpicks and said:
 If you don't know how to use the third dimension, which you experience every day, how do you hope to understand the fourth?*

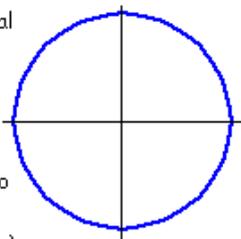
A geometric interpretation of electromagnetism in “The single Field Theory”.

Localization of the particle:

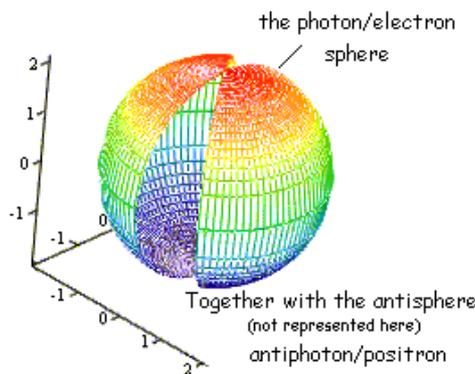
The harmonic motion electric field and the harmonic motion magnetic field, orthogonal to each other and with a phase difference of 90°, build up a circumference

(Lissajous picture)

The two orthogonal axis of the circumference are the two axis of Planck related to the two fields (electric/magnetic).



The spinning of the electromagnetic standing wave (the circumference) builds up the electromagnetic sphere on the third axis.

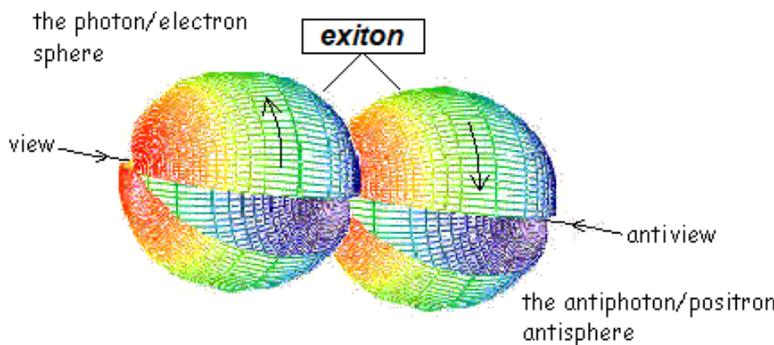


the photon/electron sphere

Together with the antisphere (not represented here) antiphoton/positron

The harmonic motion electric field and the harmonic motion magnetic field, orthogonal to each other and with a phase difference of 90°, build up a circumference. (Lissajous picture)

The two orthogonal axes of the circumference are the two axes of Planck related to the two fields (electric and magnetic). The spinning of the electromagnetic standing wave, the circumference, builds up the electromagnetic sphere



(photon/electron) forming a three-dimensional picture. The second counter-rotating harmonic motion electric field and the second harmonic motion magnetic field, build up the second sphere, the antisphere.

One sphere is the photon / electron, the counter-rotating sphere is the antiphoton / positron. Both are the exciton.

Exiton is a neutral wave-particle. Corresponds to the **electron neutrino**.

The antineutrino is represented by the same wave-particle, but "seen" from the opposite side. Because a physically settling antineutrino would not find a place in the space-time cell described so far. This model considers neutrino and antineutrino to be the same particle.

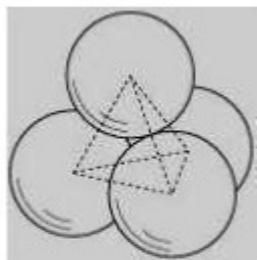
“It is still unknown whether the neutrino is equal to its antiparticle, the antineutrino; if this were the case, the neutrino would be a Majorana fermion.”

“The Majorana neutrino, if it really existed, should coincide with its own antiparticle.”

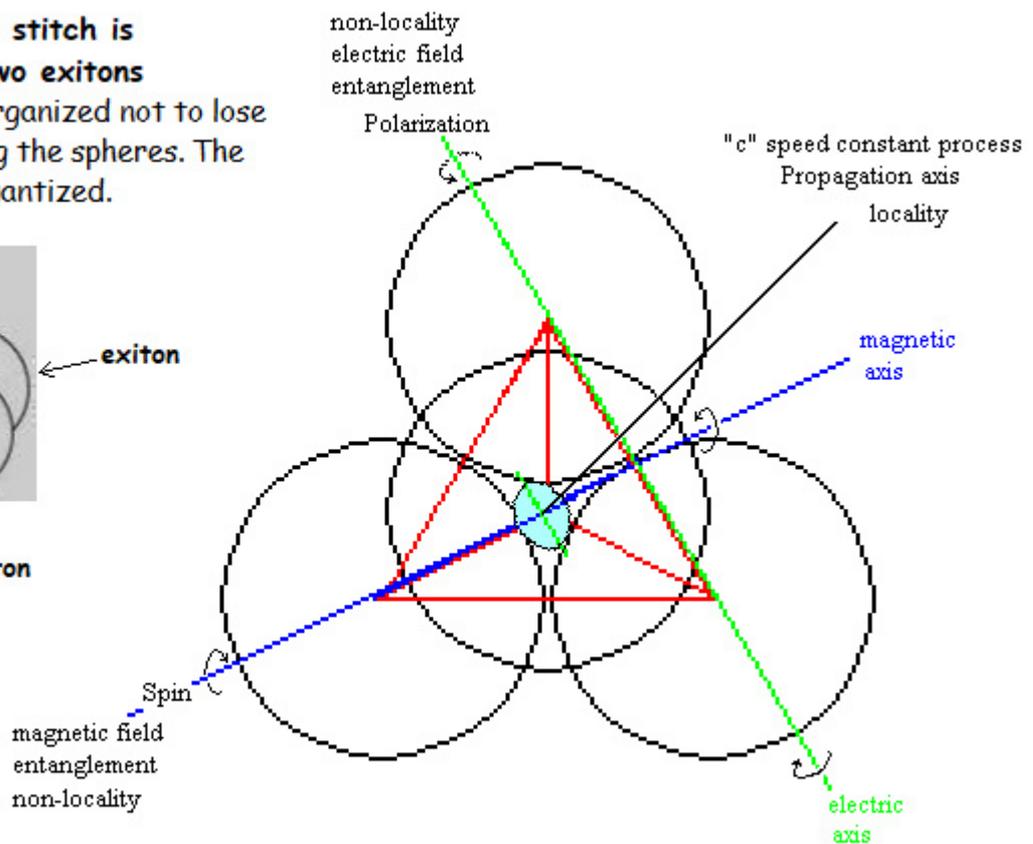
*“The Standard Model ... is incomplete, in the sense that its equations cannot justify the asymmetry between matter and antimatter. A possible explanation of the phenomenon, provided by different extensions of the Standard Model, foresees that **neutrinos are Majorana particles**, that is, they coincide with their own antiparticle. In other words, that **neutrino and antineutrino are the same thing.**”*

<https://www.wired.it/scienza/lab/2019/09/23/neutrino-majorana-gerda-caccia/>

The space-time stitch is composed of two exitons geometrically organized not to lose any space among the spheres. The space is fully quantized.



exiton
exiton



The perpendicular axes, electric and magnetic field, are not on the same plane:
The quantum jump of the annihilation/recreation process, the propagation process

EXPERIMENTAL CONSIDERATIONS

Wikipedia: *“All scientific experiments and human experiences occur over time scales that are many orders of magnitude longer than the Planck time, [36] making any events happening at the Planck scale undetectable with current scientific technology”.*

Undetectable Principle: An indetermination!?

No technology can directly experience 1 Planck wave, $T_p = 10^{-35}$ m. Obviously.

It is not an indetermination, because it is not a 1 Planck length understood as a real length, but a quantum Planck and a quantum, by logical definition, cannot represent a length (1D).

Nor to support the logic of a Principle. It is simply the postulate of quantum!

And since the measure is an interaction, more than one quantum Planck is needed.

The Compton wavelength of the electron is $2.42631023867 \times 10^{-12} \text{ m}$.

Very short gamma rays are smaller than atom nuclei (proton / neutron).

As of October 2020, the smallest time interval uncertainty in direct measurements was on the order of 247 zeptoseconds ($2.47 \times 10^{-19} \text{ sec}$).^[37]

*zeptoseconds... ultrafast reaction processes in atoms and molecules visible.
<https://phys.org/news/2020-10-zeptoseconds-world-short.amp>*

The researchers set the energy of the X-rays so that one photon was sufficient to eject both electrons out of the hydrogen molecule.

The ejection of the first electron resulted in electron waves launched first in the one, and then in the second hydrogen molecule atom in quick succession, with the waves merging.

Fundamental QUESTIONS that relate quantum to relativity

The Universe is made up of properties of space-time

The phenomena of locality/non-locality and the geometrodynamics of space-time.

"What does the existence or absence of non-local phenomena imply about the fundamental structure of space-time?

How does this elucidate the proper interpretation of the fundamental nature of quantum physics? "

https://books.google.it/books?id=uyXXDwAAQBAJ&pg=PA296&lpq=PA296&dq=What+does+the+existence+or+absence+of+non-local+phenomena+imply+about+the+fundamental+structure+of+space-time?&source=bl&ots=fz4TSICf_&sig=ACfU3U2LO-ZXxVRizVS1QLpQrkSlrdEVdQ&hl=it&sa=X&ved=2ahUKEwj69NLdri_uAhXN26QKHfGnByYQ6AEwAnoECAEQAg#v=onepage&q=What%20does%20the%20existence%20or%20absence%20of%20non-local%20phenomena%20imply%20about%20the%20fundamental%20structure%20of%20space-time%3F&f=false

1) How complex will the geometrodynamics of space-time be?

"A system coexists as "superposition" in a "pure state" which is said to be coherent. The process that converts a pure into a mixed state is known as "decoherence".

Our, conceivable, relationships leave in the locality, but we must also observe the "tunnel effect" as a transition effect between coherence and decoherence. The nature is made of these mixed states. Our experimental view can refer on one of the two aspects showing the other.

The minimal conceivable aspect must be referred to the space-time cell."

(The single Field Theory)

2) How does the space-time cell structure annihilate in a black hole?

Normally the system "space-time cell" is a "superposition" of a "pure state" which is said to be coherent and an entropic state known as "decoherence".

The black hole forms when the coherence state of electrons/photons maximizes and the entropy disappears.

This means that the tetragonal cells, normally composing the space-time, disappear and only parallel aligned e^+/e^- and polarized γ^+/γ^- remain.

The space-time disappears and with it the possibility of containing mass particles.

Without space-time structure, no light propagation is possible. Disappears also the constant "c".

A very high magnetic field takes place because of the spin of the aligned electrons around the black hole in the plane containing its axis.

A laser cavity forms just outside the black hole, where polarized gamma photons appear, along its axis. These are the gamma rays bursts detected.

The gamma photons represent the electric field aspect respect the corresponding electrons that represent the magnetic field aspect.

3) If the space-time structure cannot be separated from entanglement, how can they geometrically and functionally coexist?

Reflection: contiguous entanglement, between adjacent space-time cells, "switches" to the rhythm of the zitterbewegung at speed "c". "**Narrow locality**". Conversely, only under conditions of coherence, of low entropy (Bose-Einstein state, in 2D nanomaterials such as graphene, black hole) can the conditions of "**extended non-locality**" be obtained.

We could represent **entanglement and its geometry** as a channel (tunnel) along which a macrocoherence prevails over the disorder (decoherence) normally dictated by zitterbewegung (entropy).

A coherence of spin-polarized (aligned) excitons is established, which are subtracted from the normal tetrahedral orientation, from the dynamic geometry that composes the space-time cells (the entropic ones from zitterbewegung). The affected (intercepted) space-time cells take on the specific direction of entanglement. The specific excitons affected align and that series of cells no longer belong to the space-time domain.

Therefore **the space-time** cell can dynamically assume **two possible geometries**:

a) The normal entropic geometry of the zitterbewegung, in the absence of conditions of preferential orientations. It is **the basic condition** of the underlying space-time.

b) More than one space-time cell (aligned) can undergo the same **coherent phase orientation** (spin), determining the axis, the direction of entanglement. Those cells no longer "work", they no longer allow the propagation process, but in the phase coherence regime they instantly transmit their phase in that specific direction, until an interception occurs (collapse of coherence) and a return to prevail of the zitterbewegung. Locality/non-locality switching.

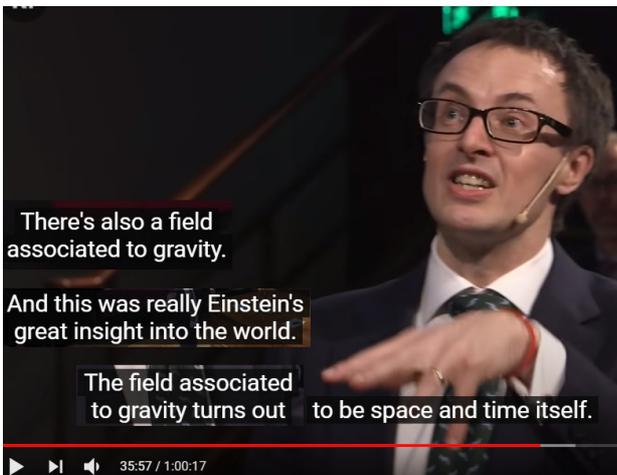
Black holes belong to point b). They are a huge macro consistency of excitons.

Where space-time collapses and with it the process of propagation of light "c" and the existence of time as the 4th dimension of space.

*"General relativity contains solutions in which two distant black holes are connected through the interior via a wormhole, or **Einstein-Rosen bridge**. These solutions can be interpreted as maximally entangled states of two black holes that form a complex EPR pair".*

4) Does the collapse of space-time cells into an entangled macro-state of coherent particles mean "gravitational collapse" near the Schwarzschild radius of the black hole?

- *"The geometric interpretation of general relativity is not fundamental but" resulting "."*
- *"Space, in general relativity, is a continuum. In every part of it, one can define regions of arbitrarily small volume, and every little region can be divided further into yet smaller regions, ad infinitum".*



In the case of gravity, if interpreted according to Einstein, in the introduction to the Theory of General Relativity:

Quantum gravitational field and space-time are indistinguishable.

- the gravitational acceleration and the gravitational gradient are indistinguishable. (Principle of equivalence)
- The fall of bodies in space-time is independent of the body type.

https://www.youtube.com/watch?app=desktop&v=zNVQfWC_evg (min.35:47)

5) Quantum gravity, how does quantized gravity derive from the geometry of the space-time cell?

The basic space-time structure can host in it (without leaving quantum "voids") matter/energy (a more complex structure) but, this alters the ordered basic structure of origin. It alters its tetrahedral symmetry.

In the presence of different particles the geometry of space-time cells changes, deforms, with respect to their basic tetrahedral geometry, this gives rise to the deformation of space-time, to its "curvature".

The minimum quantum deformation of the cell represents the "quantum gravity" and the wave / particle associated is the "graviton".

Thus, the gravitational field is generated. Confirming the identity equivalence of gravitational quantum field and space-time (albeit deformed, curved space-time).

- The **Single Field Theory** (SFT) is a quantum theory that satisfies special and general relativity by defining the geometry of the space-time cell in a quantum way.
- The existence of **time**, as the 4th dimension of space (in the 3D cell), is due to **zitterbewegung**: the basic quantum dynamics.

- It implies the existence or absence of **local/non-local phenomena** (locality/non-locality) regarding the fundamental structure of space-time, due to the presence of **zitterbewegung** and **entanglement**.

The structure of the space-time cell of the SFT "works", it relates to the fundamental phenomena zitterbewegung and entanglement.

- The cell respect the fundamental constants by giving them physical, deterministic meanings.

For example, the constant "c" is directly represented in the basic process of electromagnetic wave propagation.

The constant "c" is the basis of Special Relativity.

6) Is the SFT a quantum-relativistic theory of space-time?

The Single Field Theory can bring out the quantum characters attributable to General and Special Relativity by capturing the discrete nature of geometrodynamical space-time at the fundamental level.

"I was confident the idea was too good not to have a place in the grand scheme of the natural world."

Roger Penrose

... these two distinct classical concepts [particles and waves] are merged and transcended into something that has no classical counterpart: the quantized field which is a new conception of it, a unity that replaces classical duality.

J. Schwinger

7) Is the SFT an exhaustive "theory of everything"?

Quantum and General Relativity:

By **"theory of everything"** we mean a theory that would allow all four **fundamental integrations** to be derived from it: to date only **three of them find a unification in quantum field theory**.

Quantum and General Relativity are poorly reconciled because in the regions of space where gravity is strong, the observability of space is precluded and where space is extremely small it cannot be measured with certainty.

Moreover, the fact that the rules are of two types generates inconsistency.

"The current geometric interpretation in General Relativity is not fundamental but resulting".

Another problem is self-reference, or the attempt to prove something by means of that same thing.

"No system of representation can be powerful enough to consistently understand itself in its entirety."

Gödel.

Any formal system that encompasses **mathematics**, even in its simplest form, arithmetic, is contaminated.

The mathematician André Weil (1906-1998) said:

"God exists, because mathematics is not contradictory. And the devil exists, because we can't prove it."

A **theory of everything** seems impossible to formulate, but attempts at unification are not foolish if the scientific method is respected.

An **exhaustive physical description** must be based on a **logical interpretation** capable of **elaborating meanings** in a **simple, symmetrical and synergic** way to recognize **the true from the false**.

Any scientific theory:

- It must be **rigorous on a logical and mathematical level** (it must not contradict itself).
- It must not contradict **already known experiments**: (knowing = trying and succeeding)
- Being possible doesn't have to become impossible.
- It may have another explanation, but it **must be consistent**.
- It must have as object **measurable and quantifiable entities within a definable precision** (verification).

Intuition can be illuminating but also illusory.

"The universe is not only stranger than we imagine, but it is stranger than we can imagine."

Sir Arthur Eddington

The best approach:

"Great science requires a childlike curiosity", maintaining its naivety. Because cunning is a prejudice.

REFERENCES / news fundamental interactions technology.

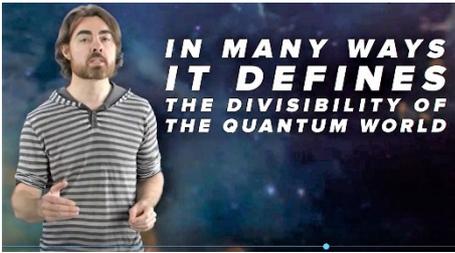
(Müller) <https://physicsworld.com/a/fundamental-constant-measured-at-highest-precision-yet/>

<https://www.wired.it/scienza/lab/2019/09/23/neutrino-majorana-gerda-caccia/>



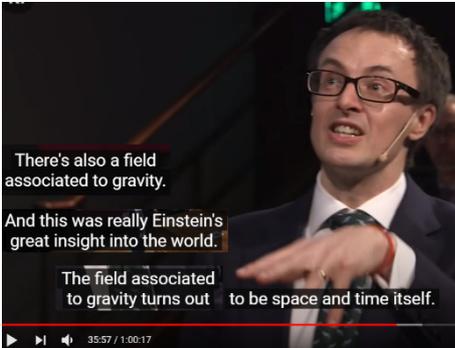
Why Space Itself May Be Quantum in Nature

<https://www.youtube.com/watch?v=dW7J49UTns8>



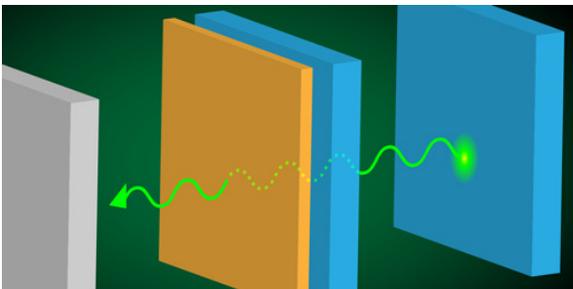
Planck's Constant and The Origin of Quantum Mechanics

<https://www.youtube.com/watch?v=tQSbms5MDvY&t=594s>



Quantum Fields: The Real Building Blocks of the Universe - with David Tong (minutes: 26 ... 31)

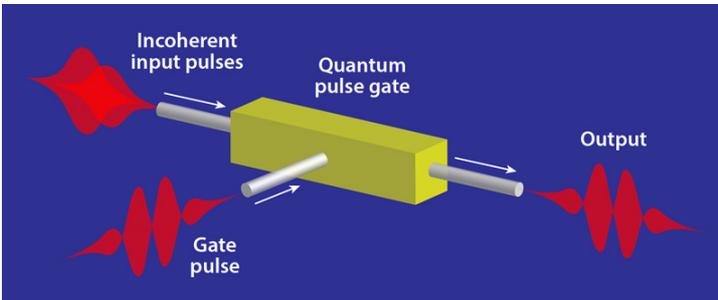
<https://www.youtube.com/watch?v=zNVQfWC evg>



... use this principle to look for energy-level perturbations caused by **new fundamental interactions**.

The technique would be sensitive to scalar interactions ... causing changes to quark masses or to the **fine structure constant**.

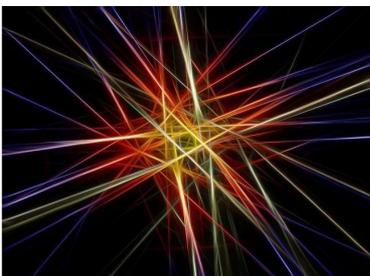
<https://physics.aps.org/articles/v13/s163>



The results obtained may presage the application of the quantum pulse gate ... on **femtosecond resolution**.

Femtosecond multidimensional spectroscopy can help identify **quantum coherences**.

<https://physics.aps.org/articles/v14/1>



Quantum "light squeezer"

The laser light can exit the system in a squeezed state, which can be used to make more precise measurements, for instance, in quantum computation and cryptography, and in the **detection of gravitational waves**.

https://physics.aps.org/articles/v14/1?utm_campaign=weekly&utm_medium=email&utm_source=emailalerthttps://phys.org/news/2020-07-squeezer-quantum-noise-lasers-gravitational-wave.html