A summary of TAU.

A unified theory of physics.

Andrew Holster.

Draft from: *Explaining Relativity.*

ATASA Research. August 2021.

Abstract.

This is a summary presentation of TAU, a theory proposed to explain relativity and unify physics. It is a radical change, because it proposes six dimensions of space, instead of the usual three (normal physics) or nine (string theory). It starts with an alternative foundation for Special Relativity, and leads to a unified theory of physics. It is a *realist theory* because it is realist about space and time.

The TAU concept is briefly introduced here, and its results explained in three main areas, *particles, gravity* and *cosmology*. In these areas it makes strong predictions and has several tests. This presentation is based around these applications and the key questions of *completing a full particle model,* and *completing tests of gravity and tests of cosmology*. These will decide its fate as an empirical theory.

Contents

A Summary of TAU.

Introduction.

This is a summary presentation of TAU, a theory proposed to explain relativity and unify physics. It is a radical change, because it proposes six dimensions of space, instead of the usual three (normal physics) or nine (string theory). It starts with an alternative foundation for Special Relativity, and leads to a unified theory of physics. It is a *realist theory* because it is realist about space and time.

The TAU concept is briefly introduced here, and its results explained in three main areas, *particles, gravity* and *cosmology*. In these areas it makes strong predictions and has several tests. This presentation is based around these applications and the key questions of *completing a full particle model,* and *completing tests of gravity and tests of cosmology*. These will decide its fate as an empirical theory.

The aim here is to give an overview, in reasonable detail for generalists to see how the model works, but with a minimum of theoretical derivations, so we do not get too bogged down in equations. There are a lot of illustrations instead. Please note this is only a survey of the theory, and a more detailed introduction with proofs follows in Chapters 2-6, where it is developed in stages. In the first half here, we go quickly over the main concepts, in the second half, we give some equations for cosmology and gravity solutions in more detail, because they are more novel.

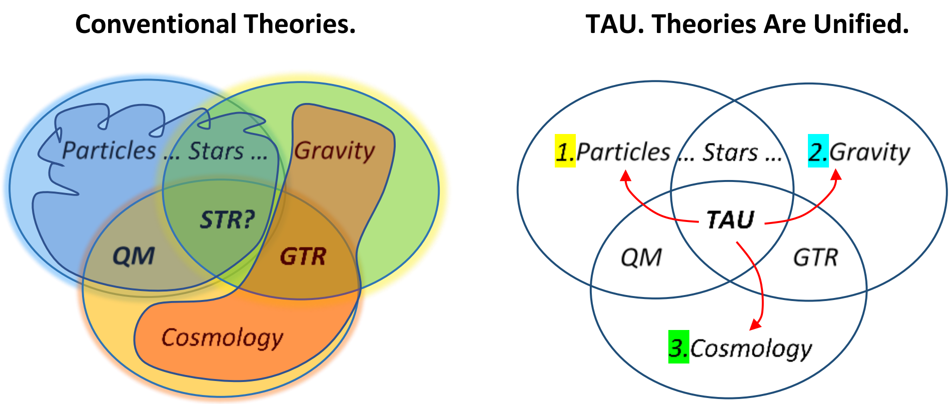


Figure 1. LHS. Conventional theories do not quite fit together. RHS. We reorganise the theories around TAU, which replaces STR in the center. This gives a single unified theory. Is it true? That is the question. It has a number of fine-grained empirical differences with ordinary GTR, QM and Cosmology. And a number of novel predictions and differences.

The state of the conventional theories is illustrated by the somewhat messy diagram on the left. The theories just don't quite fit together as a logical structure. It looks a bit like the digestive tract of an artificial organism. This is evident in the problem of *unification,* the lack of a unified theory.

We make a list below of over thirty fundamental questions that physics cannot presently answer. A unified theory should answer these, or help answer them.

TAU, the neatly organised structure illustrated on the right, is proposed as a theory that provides a full unification, and it does provide answers to most of these questions. Whether they are the correct answers is the other question of course. But it provides specific answers, and we explain them as we go. A summary is given at the end.

Table 1. A list of questions physics cannot answer.

- What is dark matter?
- What is dark energy?
- Why are different measures of the Hubble constant incompatible?
- Did stars and galaxies form unexpectedly fast in the early universe?
- What is the quantum wave function?
- What is wave function collapse and what causes it to occur?
- What provides the space-like connection for quantum entanglement?
- Is there a deterministic level of physics underlying quantum mechanics?
- What is the speed and frame of reference for wave function collapse?
- Is it possible to transmit information faster than light?
- Is quantum mechanics the fundamental description of particles?
- Are the mass or charge parameters in the Standard Model related?
- Does the Standard Model represent the complete set of particles?
- Is there a reduction of the Standard Model to something simpler?
- Can particle masses or force coupling constants be predicted?
- Why do the electric charges of the electron and proton exactly match?
- What are the neutrino masses and can they be predicted?
- Why does the weak force fail time and space reversal symmetry?
- What is the quantum description of gravity?
- Why does gravity travel at the same speed as light?
- Is the black hole event-horizon singularity physically real?
- Is the black hole central singularity physically real?
- Is General Relativity fundamental or an approximation?
- What is the source of irreversibility of processes?
- Why are the laws asymmetric in time?
- Why are the laws asymmetric in space?
- What is the flow of time?
- What generated the low-entropy state of the universe?
- What will the future expansion of the universe be like?
- What happened in the very early universe before the Big Bang?
- Why is the universe made of matter instead of anti-matter?
- Do the coincidences in dimensionless ratios reflect physical relationships?
- Do the fundamental constants c, h, G change with time?
- How many dimensions does space have?
- Is String Theory the only way to generalise to a multi-dimensional space?

These are all important questions that current physics cannot answer. The range of questions shows the extent of the problem. These are quite fundamental questions. They are not simply empirical questions, to be answered by better experiments or by tweaking theories in the process of “normal science”. They indicate fundamental issues with the theoretical framework. A unified theory should answer at least some of these. TAU does: it provides answers to most of them. We explain these in this chapter, and give a list of our answers at the end.

This list beings us back to the crisis in modern physics. Theoretical physics has been stuck with a fundamental problem for over fifty years now – more than half its life-time. The two foundational theories, *quantum mechanics* (QM) and the *General Theory of Relativity* (GTR), are incompatible with each other, and no adequate consistent *unified theory* is known. QM describes forces and particles on the small scale, in the Standard Model of particles. The Special Theory of Relativity (STR) provides its mechanics in “flat space-time”. GTR describes gravity and space-time on the large scale, and is the foundation for cosmology. GTR provides its mechanics in “curved space-time”. They are successful in their own domains, but wherever they meet we find intractable problems. GTR cannot be quantised, and the Standard Model of quantum particles cannot be merged with the curved geometry. It is incomplete as a logical structure. Cosmology has introduced “dark matter” and “dark energy”, which have gravitational effects, but cannot be identified with any particles in quantum mechanics. Physics is now at an impasse on multiple questions.

This is unlikely to be solved without a successful unified theory. There have been many attempts to create unified theories, including *string theory, supersymmetry, quantum gravity, many worlds quantum mechanics, Grand Unified Theories (GUTs), quantum determinism, discrete space-times,* and others. They all describe *some interesting feature* of physics. But none of the main-stream theories has succeeded in providing a unified theory, and they look increasingly unlikely. They are all about 50 years old, but have failed to work in the straightforward ways they were expected to. They have come to look like theoretical mirages. And how many of the problems in our list above do they solve?

Yet all the clues we have from different branches of physics seem enough to *overdetermine* the solution to a unified theory, and we expect it should be obvious when it is recognised. It should provide a clearly unified model, and have multiple points of verification. But it must go back to something very fundamental. We will go back to the most fundamental level: the STR equation and the number of dimensions of space. Our first step is to replace STR with a higher-dimensional metric TAU. We have other material discussing this, so we briefly restate this. Then we consider how well it matches the particle model and the gravity and cosmology models.

The questions in our list are general questions about physical reality, not specialised questions about particular theories – except the last, which mentions string theory. This is the most pertinent place to start, because TAU is distinguished by its multi-dimensional model for *space*. There are two main types of modern theories: *three dimensional space* theories, and *multi-dimensional space* theories. This is a fundamental divide. Either space is three dimensional, in which case multi-dimensional theories will never work properly; or space has more than three dimensions, in which case conventional theories will never work properly. We think the choice of *dimensionality* is a prime feature to fix on.

String theory is fixated on nine dimensions, as the lowest possibility. But it has no specific model. TAU proposes a *six-dimensional spatial manifold.* It has an extremely specific model. They are very different, and disagree over almost everything. But they agree that the apparent three-dimensionality of space may be illusory, and our identification of space as three dimensional, through our senses is contingent. Additional spatial dimensions, to the three we recognise is entirely possible in physics. In fact, it would be something of a coincidence if there were just three! It would mean that *we happen to see all the spatial dimensions*, and space is represented to us completely, by our innate 3D visual-spatial field. What about the possibility of other dimensions, curled up in micro-dimensions? To think we see all the spatial dimensions through our senses may be illusory like thinking that what we see *in the visual spectrum of light* are all the things that exist. But we cannot see the air. Or the cosmic microwave background. Or colours in UV or infrared, that some animals and insects and flowers use. We cannot see any fourth or higher dimension of space with our eyes. But perhaps we can reason to them.

A more specific motivation for going to higher dimensions in physics is that 3D space just does not seem to have enough *complexity,* in the spatial relations it provides, to explain all the weird and wonderful phenomenon that physics has revealed over the last 100 years.

The underlying complexity of causation just does not seem to fit into 3D space properly any more. In our view, it has been abstracted into mathematical constructions – complex wave functions, curved space-time geometries, abstract algebras, non-spatial momenta, non-local probability functions.

> "Quantum tunnelling! Entangled electrons, Batman! Whats happening to reality? Why the instantaneous non-local wave collapse for Plancks' sake?"
> "Careful with the language Boy-Wonder."

TAU proposes that most all this mathematical complexity is generated out of a surprisingly simple *six dimensional geometry*. The idea of a multi-dimensional geometric model for physics is no longer strange. But what will be strange to physicists is the low dimensionality.

So far, string theory is the only extensively researched multi-dimensional theory, and it tells us we have to start with nine dimensions of space (as a minimum). There is a "foundational proof" in string theory that *any higher-dimensional space (…for physics as we know it…) must have at least nine spatial dimensions.* This has prevented physicists from considering lower-dimensional spaces. But TAU changes the assumptions of string theory, and finds a much simpler 6D spatial geometry that works very well.

How is this possible if there is a general proof against spaces below 9D? Because TAU ignores certain String Theory assumptions, and the string theoretic "proof" does not apply. We impose another set of assumptions in its place, and it makes different predictions.

String theorists and other theory developers like to generalise from the *algebraic forms and symmetries* of known equations – primarily *covariance* and *gauge symmetry*. These are in effect assumed as the known forms for the laws of nature, as exemplified in ordinary QM or QFT or GTR. String theory, supersymmetry, GUTs, and almost all other theories, are intent on duplicating these formal-symmetry properties.

But TAU starts from a concrete model, which explains why STR works so well, and then why QM and GTR work so well, but it does not imitate them, or copy their equations. It reconstructs them. We must be able to re-derive known physics from a more fundamental basis in TAU.

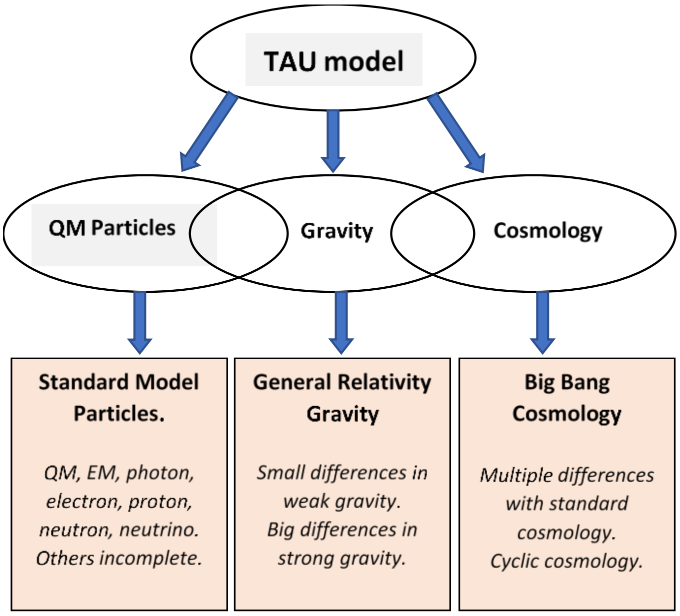


Figure 2. TAU predicts *quantum particles, gravity* and *cosmology.* It makes strong predictions, and has a realist concept.

We will review TAU in these three areas in turn. They can be considered as three theories in their own right. But they are bound by a fundamental model.

- A number of significant empirical coincidences are required for these three areas of the theory to all work together.
- Several quantitative and qualitative coincidences required appear to be present at once.
- These are individually surprising, and even more striking as a whole.

There are several accurate predictions, relating diverse phenomenon in unexpected ways. This represents the strongest evidence for the theory. Equally, strong predictions make it vulnerable to empirical testing and failure. It can be tested at multiple points. Hence I had better finish writing it up quickly before it is disproved.

A short statement of key claims for the present theory is given in Appendix 1. This summarises the state of development in three parts: QM particles, gravity, and cosmology.

The aim here is to introduce and quickly survey the whole scope of the theory.

- The first step is the model for Special Relativity, particle physics and electrodynamics. Because TAU matches with conventional physics closely here, we just observe how it matches key points and equations of these conventional theories. We then discuss the question of solving for the full Standard Model.
- The second step is the gravitational model, and we see how TAU gravity arises from the physical model, and represents a kind of generalisation of GTR.
- The third step is the cosmology, and this is more novel, so we state the model in more detail, and give some simple derivations. We review how it applies to measurements of gravity, the Hubble constant and the age of the universe.
- Then we return to the unification of QM and gravity, where the two wave functions merge, the model for particle-wave duality, the explanation of quantum entanglement and interpretation of the wave function.

Preliminary. Explaining the STR metric.

We originally started in *Explaining Relativity* with the question:

- Why does the physical world behave relativistically, instead of classically?
- How can we explain the strange feature that relativity brings to the world?

The feature in question is most generally and simply seen as this. .

- Special Relativity tells us that when we move physical systems around in space, their *internal processes slow down.* Everything runs at the rate: $d\tau/dt = \sqrt{(1-v^2/c^2)}$.

If you move things around, they slow down *inside*. Clocks slow down. Cells slow down. Molecules slow down. Atoms slow down. Processes slow down. They all slow down, and in a way that exactly compensates for their motion in space. It doesn't matter what type of processes they are: electrical, chemical, radioactive, mechanical, biological. The law is simple and the same for all: $c^2d\tau^2 = c^2dt^2 - dr^2$. This is just the previous equation, squared and multiplied out by dt.

This is the defining equation of the Special Theory of Relativity. It makes everything in relativity theory work. It pretty much *is STR.* Its primarily effect is to slow processes in moving systems. To preserve conservation of momentum, this also requires mass to increase, with the familiar law of mass dilation: $m = \gamma m_0$. In turn this means the conserved quantity of energy is: $E = mc^2$. These are all the essential laws of STR. The Lorentz transformations follow from the metric too: for: $c^2d\tau^2 = c^2dt'^2 - dr'^2$ we must have: $x' = \gamma(x-vt)$ and: $t' = \gamma(t-vx/c^2)$.

It looks completely innocent. But this tiny equation has led to a crisis!

The idea of *explaining relativity* will seem strange today, but it did not to Lorentz, Maxwell, Fitzgerald and others who first encountered it. They sought a mechanical explanation for slowing of clocks and shrinking of rulers, in terms of the aether. Unfortunately, a 3D aether does not exist. Since Einstein and Minkowski, physicists have come to take the metric equation for granted, as the unquestioned fact of the *space-time manifold*. The STR equation above is taken as the *metric* or *geometric function* for "distance" in this manifold. As such, it is taken for granted: it is not *explained or explainable*, any more than Pythagoras' Theorem for distance in space, in classical geometry. It is a fundamental *fact* of the representational space of modern physics. It is bound up in the tensor calculus, the universal form of mathematical expression for laws of nature. To most physicists, it is beyond the bounds of physical explanation, and it is just a *fundamental law.*

But we do question it, and ask for an explanation. It is responsible for all the strange behaviour of STR. The fact remains it is weird. If you move things around in space, their internal processes slow down, to compensate precisely for the motion. It entails physical effects, not just definitions of geometry or coordinate systems. It is a great unsolved mystery of modern physics: how does *motion through space* cause processes to slow down? Isn't space invisible, and frictionless, with no resistance to motion? Yet in STR, motion does have these effects! It slows processes down! It makes things shorter! It makes things heavier! The relativistic effects of motion *are all predicted from the STR metric law above,* along the principle of conservation of momentum. Also, the equation is not just a *geometric metric*: it has the speed of light in it! A fundamental empirical physical constant! It is about dynamics! And another thing: we know it is not consistent with curved space-time, in General Relativity, or with cosmology. For a quick summary of the metric relation.

- The law: $c^2d\tau^2 = c^2dt^2 - dr^2$ is the defining equation of the Special Theory of Relativity,
- As a time differential it means: $c^2(d\tau/dt)^2 + (dr/dt)^2 = c^2$.
- We can rewrite this as: $\sqrt{(u^2 + v^2)} = c$.
- We define: $dw = cd\tau$ and: $u = dw/dt$.

The second term is v^2, the velocity squared, and the first term is the *proper-time speed squared,* which we write as u^2. So we can rearrange the STR equation as a Euclidean triangle law for a particle with *total speed c.*

It means *processes (u) slow down if their general speed (v) through space is increased.*

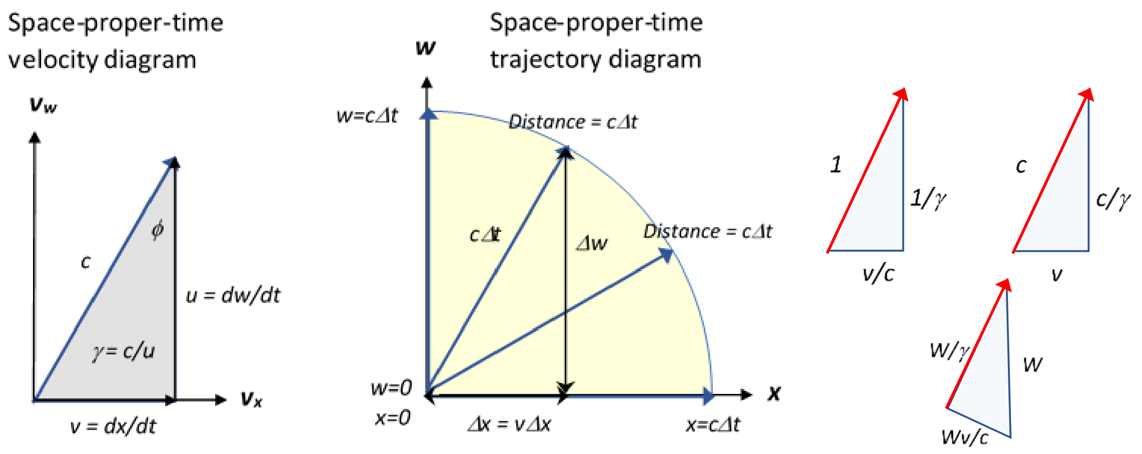


Figure 3. Left. Space-proper-time *velocity diagram*. Middle. Space-proper-time manifold diagram. Right. The triangle relation of STR.

We will visualise the relativistic relation through these *space-proper-time* diagrams, where we see the STR law as a Euclidean speed metric, instead of the usual *space-time metric.* The metric can be rearranged as a function giving the proper time speed from the spatial speed: $d\tau/dt = \sqrt{(1-v^2/c^2)} = 1/\gamma$. Or inversely, as the real-time rate: $dt/d\tau = \gamma = 1/\sqrt{(1-v^2/c^2)}$. These equations are all equivalent.

Table 2. Arrangements of the Metric Equation.

Common arrangements of the metric equation.	**STR metric – divide by proper time.**	**TAU metric – divide by real time.**
Metric equation.	$c^2d\tau^2 = c^2dt^2 - dr^2$	$c^2d\tau^2 + dr^2 = c^2dt^2$
	$ds^2 = c^2dt^2 - dr^2$	$ds^2 = dw^2 + dr^2 = c^2dt^2$
Differential equation.	$c^2 = c^2(dt/d\tau)^2 - (dr/d\tau)^2$	$(d\tau/dt)^2c^2 = c^2 - (dr/dt)^2$
Rearrange. Use chain rule: $(dr/d\tau) = (dt/d\tau)(dr/dt)$.	$c^2 = (dt/d\tau)^2(c^2 - v^2)$ $u^2 = c^2 - v^2$	$(dw/dt)^2 + (dr/dt)^2 = (ds/dt)^2 = c^2$ $u^2 + v^2 = c^2$
Rate of time flow.	$dt/d\tau = 1/\sqrt{(1 - v^2/c^2)} = \gamma$	$d\tau/dt = \sqrt{(1 - v^2/c^2)} = 1/\gamma$
Definition of Gamma.	$\gamma = 1/\sqrt{(1 - v^2/c^2)}$	$1/\gamma = \sqrt{(1 - v^2/c^2)}$

The concept of TAU.

TAU begins a simple concept, which changes a foundational assumption in the current interpretation of relativity theory. The changed assumption is *realism about space and time.* It means that *time and space are different types of things.* This leads us first to directly confront the fundamental law of STR, the metric equation:

$$c^2 d\tau^2 \quad = \quad c^2 dt^2 - dr^2 \qquad \text{STR metric – combining space and time.}$$

Proper time ***Space-time manifold***

The equation in this form reflects the normal interpretation, which combines *time and space* together on the RHS, giving the space-time interval, and equates this to *proper time,* which is a "physical invariant", on the LHS. But given our assumption that time and space are different things, we will reinterpret this, and separate space and time. The key role of *time* in our realist view is as *the differential operator for motion* in *a spatial manifold* in which particles have *trajectories.* So we start by putting *time on one side,* and *proper time and space together* on the other side, and instead of modelling it as a *space-time manifold,* we interpret it as a "space-proper-time" manifold.

$$c^2 dt^2 \quad = \quad c^2 d\tau^2 + dr^2 \qquad \text{STR metric rearranged.}$$

Time ***Space-proper-time manifold***

We want to combine *proper time with space* in a *spatial manifold* on the RHS*.* We first convert proper time to its spatial measure, defined by the variable *w*:

$$w = c\tau \qquad \text{Definition of } w.$$

We then define the metric on the *space-proper-time* manifold by:

$$ds = \sqrt{(dw^2+dx^2+dy^2+dz^2)} \qquad \text{Metric for space-proper-time manifold.}$$

This is a simple Euclidean metric for a 4D space. So we naturally write the relationship as:

$$\frac{ds}{dt} = \frac{\sqrt{(dw^2+dx^2+dy^2+dz^2)}}{dt} = c \qquad \text{The STR metric as a speed law.}$$

Speed = *4D-distance / Time* = *Constant*

This says: *everything moves at the speed c in a 4D-Euclidean "space-proper-time" manifold.*

This is still equivalent to the original STR equation, so far. Note the time-differential formulation is perfectly valid, because the fundamental variables of STR are the *3D spatial trajectory function,* ***r****(t),* and the proper time function, *$\tau(t)$,* and both are fully parameterized by *t* for all particles or fields. The general foundational assumption of classical and modern physics is that particles have *analytic, time-differentiable trajectories.*

Note that the *metric* quantity of distance, *ds,* is defined in TAU so that: *ds/dt =c,* while in ordinary relativity theory, the interval is defined on the *space-time manifold* as the interval: $ds = cd\tau$. But the latter is now just an ordinary spatial distance for us: $dw = cd\tau$. We have rearranged the metric, and we will reinterpret the model.

Speed in this *proper time* dimension will be: $u = dw/dt$, in analogy with: $v = dr/dt$, and we have: $u^2+v^2=c^2$ as two orthogonal components of speed in the *space-proper-time manifold,* or *WXYZ manifold*. Similarly, momentum is: $\mathbf{p} = m\mathbf{u} + m\mathbf{v} = m\mathbf{c}$, as a vector addition. There is conservation of momentum in each direction. We can put the equation in this form because the fundamental assumption in STR, just as in classical physics, is that *there are time differentials for the trajectory and proper time functions for all particles and systems.*

The STR treatment is focused on differentiating by *proper time* (to create *4-vectors*). But remember differentials in *proper time* do not exist for light, so a special treatment has to be given in STR. The function *gamma* gives *the rate of change of real time w.r.t. proper time.* However for light, $d\tau = 0$, and γ has no value. Proper time τ cannot be used to parametrise the motion of light.

But the *real time functions*: $\mathbf{r}(t)$ and: $\tau(t)$ always have values. And differentials. If we differentiate by real time, we get the TAU metric instead. And we have these simple relations in 4D:

$u^2+v^2 = c^2$	Speed-vector addition in 4D.
$p = mc = m(\surd(u^2+v^2))$	Definition. 4D Momentum linear.
$p = \surd((mu)^2+(mv)^2) = \surd(p_w{}^2+p_r{}^2)$	4D Momentum direction components.
$E = p^2/m = mu^2+mv^2 = mc^2$	4D Energy-momentum components.

Because of its complex *space-time metric,* STR normally starts with tensor calculus, which is a formalism for dealing with differentiation in this awkward "metric". But we have a nice simple 4D Euclidean system, and we can analyze it by looking at simple examples that we can work out from first principles. All we will need are basic principles of differential calculus. So we do not need to start by writing down tensor equations. (And when we do, they are quasi-classical).

We can contrast two "metaphysical" views about space and time.

Table 3. Alternative Metaphysical Views.

Conventional STR **Relativist Assumptions about Space-Time.**	**TAU.** **Realist Assumptions about Time and Space.**
Time is fundamentally the same as space.	**Time is fundamentally different to space.**
Time flow is unreal.	Time flow is real.
There are no objective simultaneity relations.	There are objective simultaneity relations.
Relativity theory requires a *space-time manifold.*	Relativity theory requires a *space manifold with positions and time differentials.*
Space-time is intrinsically curved (must use Riemannian geometry).	Space is extrinsically curved in higher dimensions (Whitney's theorem).
Laws should be written in covariant form (relativistic tensor equations).	Laws should be written as time differential equations.
The Lorentz transformations are fundamental.	The Lorentz transformations are contingent.
Space is not real separately from time.	Space is real and it exists and changes in time.
Proper time is an invariant measure of processes that occur in space-time.	**Proper time reduces to a fundamental motion in a (higher-dimensional) space?**

The first line reflects a fundamental difference of opinion between *realists* and *relativists.* Although *relativism* dominates modern physics, most people recognise that there are fundamental differences between space and time. However, most physicists today would probably be confident of the Relativist viewpoint, and reject the Realist views. But it is not until the last line that we reach the starting point of the difference in physical theories that follow.

Now ordinary STR postulates *space-time* as a universal manifold for physics. It is a lot like God for physicists. Processes obey the general law of STR above, as if they are all in a single *space-time* manifold together. But there is no further explanation of this law in conventional physics. It is simply a fundamental property, nominalized as the *space-time interval,* a property of an abstract *space-time manifold.* It has no further explanation. It is just eternally how things are, in the modern view.

The TAU proposal is to replace space-time with a *real WXYZ* spatial manifold and give a reductionist mechanical explanation for STR instead. But this can only work if we can reduce *all the particles* to wave modes of *one geometric manifold* at once. When we develop the theory, we will start with an example of adding a single circular dimension to a 1D space – giving a cylinder in 3D. We have *w* curved in one dimension (meaning it is really rotating in two dimensions around the *YZ-plane*), with free motion in an open third *x* direction. We can develop this geometrically into a *space-proper-time diagram,* which we call a *WX diagram,* by unrolling the circular surface.

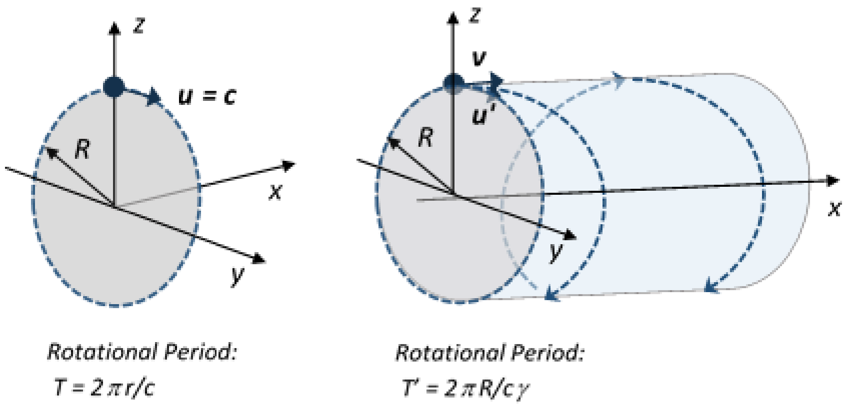


Figure 4. The "Compton-De Broglie Circular Light Clock". This is a *1+2 = 3D space.* If we set the radius to give the energy required to represent an electron mass with a single wave, we find it matches the fundamental relationships de Broglie and Compton found around 1923-24 by equating: $hf = mc^2$, and showing the equivalence of mass and light.

We can call this the *Compton-de Broglie CLC* because the relations we impose between the radius and the mass-energy are what Compton and de Broglie discovered around 1923-24. We see these shortly, but we continue with the concept of the geometric model for the moment.

- The STR metric equation applies precisely to describe the motion of particles or waves at the speed *c* on a cylindrical surface like this.

So the geometry has an essential equivalence to the STR "metric relation". But it describes a different model, because we interpret *proper time,* τ*,* as the motion in *w,* which is now a *motion in an underlying dimension in a real space.* This may seem a strange thing to do, of course, because proper time is defined and measured quite differently to space. But the point is that there is a good physical interpretation. And note that instead of postulating the STR metric as fundamental to describe this model geometry, it is now a contingent property of the model.

- The geometry will ensure we get relativistic relationships, the Lorentz transformations, etc.

The typical quantum properties generated by this *full-wave-length* model are:

Full wave-length particle.

$\lambda_x = Wc/v\gamma = h/mv$	Spatial wave-length = de Broglie.
$T = W/c\gamma = h/mc^2$	Period of wave-fronts at fixed *(w,x)* point.
$f = 1/T = mc^2/h$	Frequency of wave-fronts at fixed *(w,x)* point.
$E = hf = mc^2$	Relativistic QM energy.
$L = muR = \hbar$	Intrinsic angular momentum = spin-1.
$\mu = \hbar q/2m_0 = Lq/2m_0$	Magnetic moment.

The angular momentum is because: $L = muR = (\gamma m_0)(c/\gamma)(R) = (h/W)(W/2\pi) = \hbar$.

A rotating particle with charge q would generate the classical *loop current magnetic moment:* $\mu = IS$, where I is the current and S is surface area.

$I = \Delta q/\Delta t = q/T = q\gamma m_0 c^2/h$	Current.
. $S = \pi R^2 = \pi\hbar^2/m_0^2c^2$	Area.

Hence: $\mu = IS = (q\gamma m_0 c^2/h)(\pi\hbar^2/m_0^2c^2) = \hbar q/2m_0$

Considered from the 'outside' the system has a period, wavelength, rest-mass, relativistic mass, intrinsic angular momentum, and (for a charge) intrinsic magnetic moment, all conforming to an archetypal relativistic quantum system. We now use this to propose a *reductive explanation of fundamental quantum mechanical particles.* It obeys special relativity, and it gives a novel way of explaining why STR governed all processes except gravity.

We imagine that CLC systems existed on a tiny scale, and we could detect the proper-time periods T_A and T_B, and the spatial wave-length, and angular momentum, but could not see into the mechanical construction. We are aware of the motion of the system in *X,* but not the internal motion in the additional dimensions *YZ.* In this case, the CLC particles will appear to us like *relativistic quantum particles.*

This amounts to introducing an underlying *realist geometric model for "proper time", w.* Note that *w* is not taken as a "pseudo-spatial dimension", like time in ordinary relativity theory, which is given an "imaginary dimension", *ict,* in the tensor formalism. The new dimension *w* combines with *(x,y,z)* to give a space with a simple Euclidean distance metric. All the dimensions: *(w,x,y,z)* will be treated identically in respect of their intrinsic properties as *space*.

Now for the general connection to quantum mechanics, we will find that solutions for waves in this geometry obey this wave equation:

$$\pm(\nabla_w^2\Psi + \nabla_x^2)\Psi = \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\Psi$$ Wave equation for manifold.

This does not depend on any assumptions from quantum mechanics: it is simply obtained from the geometry. And when we put in a mass to determine the radius, we will find that this matches the relativistic QM Klein-Gordon equation – the most fundamental *relativistic wave equation in QM*

This solution occurs because of the *circular boundary condition on the w space.* This BC means we can give velocity boosts to a wave or trajectory in the *x* direction, but not in the *w* direction. The latter would involve spinning coordinates around the circle or pipe of *w.* But position is absolute in *w,* and in all valid coordinate transformations for this geometry, we have: $dw = dw'$.

- A physical model for "proper time" as a spatial motion is only realistically possible if *w* is cyclic, and on a tiny scale.

These are the boundary conditions on *w*. It must be cyclic to ensure that the new dimension has the same properties of *locality* as *XYZ* space. It must be tiny so we do not normally notice it.

Now the example above works for light on a cylinder. But we are going to do something radical, and propose that we can model *all physical processes* in a geometry of this kind. That is, we are going to try to *reduce proper time for all physical processes* to motions in a similar type of geometry. We will keep our normal *XYZ* space, and add some underlying *microscopic cyclic dimensions* for *w,* and call this *WXYZ space.* This will be the *space-proper-time manifold.*

For this to work, *w* has to have more than just one dimension (otherwise all we could get is a kind of simple boson, as in the example of light above). We will add two new *w-dimensions,* called w_e and w_p, and we will take these as the surface dimensions for a *torus*. These combine in a Euclidean metric: $dw^2 = dw_e^2 + dw_p^2$. The *torus* rather than the cylinder above will provide our fundamental geometry. This means there is a third dimension, through the torus volume. But that is all we will add!

- Our fundamental model of space will consist simply of a *torus embedded in XYZ space.*
- Any point in the 6D volume can be represented by 6 Cartesian coordinates:
- $(w_1, w_2, w_3, r_1, r_2, r_3)$.
- Points on the 5D torus surface can be represented by 5 surface coordinates:
- $(w_e, w_p, r_1, r_2, r_3)$.
- Because the surface points have a boundary constraint in 6D:
- $w_3 = f(w_1, w_2, r_1, r_2, r_3)$.

Now the idea is that motion in *w* in our theory will completely replace the normal variable τ, i.e. proper time, in STR – for all fundamental processes! We start with the *torus* because it is a unique manifold that can model the *electron,* which is the fundamental elementary mass particle, with the lowest rest mass (apart from the ghostly neutrinos, which we will see is a construction).

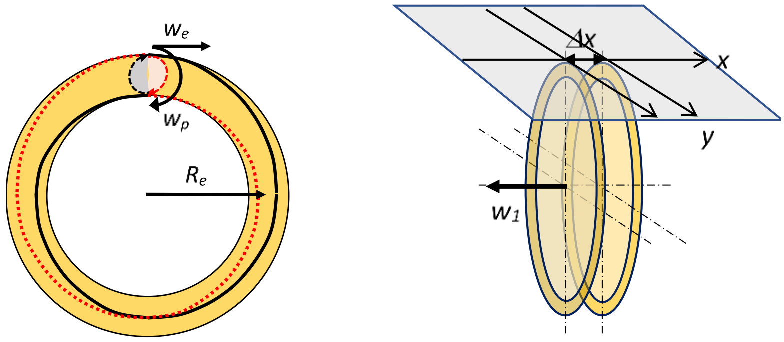


Figure 5. LHS. The *electron-proton torus.* The electron is identical to a light wave that rotates around a microscopic torus with a half-turn around the minor circumference. RHS. The torus is embedded continuously in 3D space.

Note that particles or charges can pass each other much closer in ordinary *XYZ-space* than the torus radius R_e, which we will find is about 10^{-13} *m.* But they cannot pass much closer than the minor torus radius, R_p, which is around 10^{-15} *m.* For the electron wave motion:

- The electron particle-wave does two rotations around the large circumference for a full wavelength, turning 180 degrees on the small circumference with each full rotation.

This is the essence of the fermion model. To clarify the variables:

- The capitalised terms: W_e and W_p are taken as the *circumferences,* and R_e and R_p are the radii. (Note R_e goes to the *center* of the torus pipe.)
- We take w_e and w_p as distance variables on the surface, so that: $dw = \sqrt{(dw_e^2+dw_p^2)}$ is distance on the surface.
- The full metric when we add motion in ordinary space is: $ds=\sqrt{(dw_e^2+dw_p^2+dx^2+dy^2+dz^2)}$.

Now before we examine the solutions, we emphasize a general point about the *explanation*.

The motions in *w* are going to completely replace *proper time,* and the fundamental metric equations will change like this.

STR View	TAU View
$c^2d\tau^2 = (c^2dt^2 - dx^2- dy^2- dz^2)$	$0 = c^2dt^2 – (dx^2 + dy^2 + dz^2) – (dw_e^2 + dw_p^2)$

(QM) → *(TAU)*

Plus the boundary condition on w_e, w_p.

We move *proper time* from the LHS in the STR equation to the RHS of the TAU equation. It becomes a description of a purely *spatial process* in the TAU equation – which no longer has a term for proper time at all! In fact, it is just the STR equation for *light* in the higher-dimensional space.

This change of the fundamental equation reflects the fact that it will have to be a very powerful reduction! Everything incorporated into proper time in physics will need to be reduced to a purely spatial process – in six dimensions. We must do this via the atomistic reduction that the Standard Model already represents. I.e. we only have to reduce the Standard Model particles and forces, and all other processes in conventional physics (except gravity) will reduce through this.

At first this may seem almost impossible: the geometric model we introduce looks far too simple to contain all the complexities and parameters of the quantum Standard Model! But surprisingly, when we try, it actually appears to work! To reproduce all the processes of physics means that there must be strong reductionist relationships inherent in nature, and this is what we have found.

Note that this way of *extending space dimensions* is quite different to the conventional concept, which simply adds more space dimensions to the *space-time metric.* I.e. we can add additional dimensions of space: $w_1, w_2 \ldots w_n$, to the STR metric like this:

$$c^2 d\tau^2 = (c^2dt^2 - dx^2 - dy^2 - dz^2 - dw_1^2 - dw_2^2 - \ldots - dw_n^2) \qquad \text{String theory extension of space.}$$

This retains the form of the STR *space-time* metric, but with more space dimensions. It has the normal pattern for a "covariant equation". It now defines a *space-time interval* in *4+n* space-time dimensions. This is the lesson normally taken from relativity theory: *since space-time is fundamental, a generalisation of the STR equation must retain this form.* But that is really just a guess based on thinking that we recognise a fundamental mathematical pattern – or a metaphysical assumption based on the belief in *space-time* as a kind of metaphysical reality.

TAU is fundamentally different, and it *is not based on retaining the space-time manifold* as the fundamental assumption. This is why TAU is radically different to string theory, or any other conventional theories based on taking the form of the space-time metric as the fundamental law.

So now we need to show how to derive key results from first principles of this geometric model. That is really all there is to it! To jump ahead to how to do this, our solutions must match with conventional equations of fundamental physics. They are normally written as *covariant equations.* This means they are written in a form like the *metric equation.* We briefly look at a few of these.

Role in equations for massive particles [edit]

The inverse reduced Compton wavelength is a natural representation for mass on the quantum scale, and as such, it appears in many of the fundamental equations of quantum mechanics. The reduced Compton wavelength appears in the relativistic Klein–Gordon equation for a free particle:

$$\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\psi = \left(\frac{mc}{\hbar}\right)^2\psi.$$

It appears in the Dirac equation (the following is an explicitly covariant form employing the Einstein summation convention):

$$-i\gamma^\mu\partial_\mu\psi + \left(\frac{mc}{\hbar}\right)\psi = 0.$$

The reduced Compton wavelength also appears in Schrödinger's equation, although its presence is obscured in traditional representations of the equation. The following is the traditional representation of Schrödinger's equation for an electron in a hydrogen-like atom:

$$i\hbar\frac{\partial}{\partial t}\psi = -\frac{\hbar^2}{2m}\nabla^2\psi - \frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r}\psi.$$

Dividing through by $\hbar c$, and rewriting in terms of the fine structure constant, one obtains:

$$\frac{i}{c}\frac{\partial}{\partial t}\psi = -\frac{1}{2}\left(\frac{\hbar}{mc}\right)\nabla^2\psi - \frac{\alpha Z}{r}\psi.$$

WIKIPEDIA 2021

Figure 6. The recurring role of *Compton's wavelength* in some of the most fundamental equations of modern physics. Compton Wavelength. WIKIPEDIA 2021.

To orient ourselves, what are these conventional equations going to look like in our new model, with space, time and proper time rearranged? Just like the STR metric, these have three parts, with space and time differentials and an invariant. E.g. the Klein-Gordon has *space and time* on the left and *an invariant quantity* of momentum squared on the RHS. We can briefly illustrate what happens with the Klein-Gordon equation, as the paradigmatic example. This is one of most fundamental equations in QM: component waves of particles in relativistic quantum mechanics are always K-G waves. Just as we rearranged the STR metric, we can first rearrange this to separate the spatial and temporal terms:

$$\frac{1}{R_e^2}\Psi + \nabla_x^2\,\Psi = \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\Psi$$

(Different combinations of signs may be allowed in complex valued solutions, and they correspond to particles and anti-particles, so we do not worry about the sign of $1/R_e^2$ here).

- The length $R_e = \hbar/m_e c$ is the Compton wavelength.

This plays the critical role: it converts from *mass* to *length.* The LHS in our rearranged equation now has both operators dimensionally equivalent to: *($1/Length^2$)*. But we have to unify these into one operator, which will be a 4-dimensional Laplacian for a *four dimensional space*. The basic *complex valued wave solutions* look like this:

$$\Psi(w,x,t) = Ae^{(\frac{i}{\hbar})(p_w w + p_x x - E_w t - E_x t)} \qquad \text{Prototype K-G solution.}$$

with: $p_w = m_e c$ and $E_w = m_e c^2$ for a particle with mass m_e. These are the solution for a kind of K-G equation arranged like this:

$$\pm(\nabla_w^2\Psi + \nabla_x^2)\Psi = \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\Psi \qquad \text{K-G equation for manifold.}$$

We will obtain these K-G solutions purely from the geometry – not from any quantum mechanics. They hold *whatever we take the function Ψ to represent.* We can take the real parts of the solutions alone and these must provide solutions for *real-valued waves in our geometry* (like EM waves).

We generally interpret Ψ as a complex-valued wave function in QM, but we do not have to define any *interpretation* for it yet. We return to the physical interpretation later.

This works if w is a cyclic dimension of space, with a cyclic length of: $W = h/mc$, which is just the Compton wavelength: $R = W/2\pi = \hbar/mc$. This is a result of equating: $E = hf = mc^2$. The term hf is the energy for light, and mc^2 is the relativistic energy for mass. By taking the wave to move at speed c, with *one full wavelength around the circumference,* we immediately get: $f = c/W$, so: $hc/W = mc^2$. Hence: $W = h/mc$, or: $R = \hbar/mc$. In this way we can treat the term w as a *spatial variable,* like x,y,z, but it must repeat in a cycle: $w + W_0 \equiv w$, where W_0 is the appropriate *cyclic wave-length.* This is the additional boundary condition that lets us derive a K-G equation, and makes the model *Lorentz invariant*.

So this is the basic idea. Now the first main result is to show that we can realistically model the *electron, photon, and electromagnetic field.*

The torus geometry and electron model.

In the torus model above, the large radius is determined by the fundamental principle:

$$E = m_e c^2 = hf_e \qquad \text{Energy principle.}$$

This identifies the *rest-mass energy* for the electron in two ways, through STR ($E = m_e c^2$) and through the energy of light ($E = hf_e$). The reason for identifying them is that we are going to model an electron as *literally consisting of light trapped in the cyclic geometry of the torus.*

But because in the torus model, the electron wavelength is *twice the circumference,* (giving the lowest-energy wave), the *frequency* is: $f = c/2W_e = c/2\pi R_e$. Hence: $m_e c^2 = hc/2\pi R_e$, and this gives:

$$R_e = \hbar/2m_e c \qquad \text{Fundamental length.}$$

This is half the *reduced Compton wavelength* for the electron. The factor ½ is because of the double-wave. So this length R_e has to be the radius of the torus in our model. We can then solve for wave functions on the surface.

Remarkably, the properties of frequency, angular momenta, magnetic moment, etc, calculated from this model correspond to the QM properties of the real electron – i.e. QM wave frequency, intrinsic spin, intrinsic magnetic moment, etc. When we work it out in detail, the general solutions are Klein-Gordon waves, and when the spin components are interpreted, they correspond to the Dirac wave functions for an electron.

- The torus geometry works for spin-½ fermions like the electron.
- The simple circular geometry works for *mass bosons,* if we take one full wavelength in the circumference: $\lambda = W = 2\pi R = h/mc$.

This is a general result of using this geometry – we get constructions essentially identical to *fermions and bosons*. The double-rotation is the essential feature to give the fermionic behaviour, with the correct spin-½, and SU(2) symmetry. If we represent the electron as a wave, it is like a double wave moving around on a mobius strip.

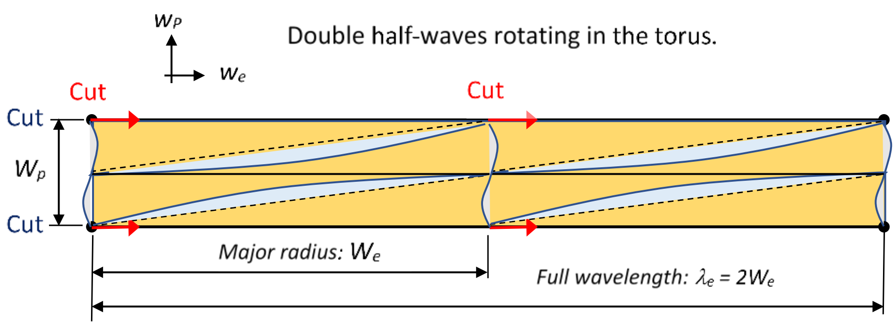


Figure 7. *W_eW_p-diagram* (no *XYZ* dimensions shown here). The torus is developed as a flat surface. The electron forms a double wave around the torus.

This predicts the intrinsic angular momentum correctly as $\hbar/2$, and the magnetic dipole moments accurately, and other features. It is the double-wave (or half-wave) geometry that produces the properties of the real electron. The phenomenal properties of mass, spin, magnetic moment, etc, can be calculated quite simply. It is generalised by solving the electron wave function. The solution is separated into three parts, corresponding to the motion in the three different dimensions of motion (with *r* the direction of motion in *XYZ* space):

$$\Psi\left(w_e, w_p, r, t\right) = A\ e^{(\frac{i}{\hbar})(p_r r\ -\ E_r t)} e^{(\frac{i}{\hbar})(p_e w_e -\ E_e t)} e^{(\frac{i}{\hbar})(p_p w_p -\ E_p t)} \text{ Electron wave.}$$

The first two components represent the kinetic and rest-mass energy and momenta. But the second component contains a *spin* of *ħ/2*, and the third component contains a small mass-energy with a second tiny *spin* component. But the relationships are not completely represented in this equation alone because the second and third terms are cyclic, they represent angular momentum, so they are the additional boundary conditions. These are extra linear relationships that match the Dirac equation, and give rise to the spinor properties of the electron. In the Dirac equation, which is the foundational equation of QED, they are imposed by adding the *matrix terms* to the SG equation. This correspondence is what makes the model feasible as a *relativistic theory of the electron and EM interaction*.

Space-proper time diagrams and Lorentz rotations.

Physics is normally visualized in *space-time diagrams,* and all the modern physicist's intuitions are tuned around this representation – which also corresponds to using covariant equations. But we have seen how we can transform an equation from the usual covariant expression to an expression suited to our *space-proper-time* model. And the corresponding use of *space-proper-time diagrams* (or *WXYZ* diagrams) becomes the natural alternative tool for visualization. This involves quite a change from the conventional visualizations. It may be difficult to adjust our intuitions, for those of us brought up on *space-time* and the relativistic tensor calculus. We review *WXYZ diagrams* in the early Chapters, because they are essential to visualize the physical relationships. In this section, we briefly illustrate some of these.

To start with, what do Lorentz transformations look like in *space-proper-time*? If we give the plane wave we saw above a velocity boost in some direction in *XYZ* space, there is no effect on the torus dimension, *w*, because it is orthogonal.

- We cannot give velocity boosts in *w,* because motion in *w* is a *rotation,* and rotation is absolute.

The invariance of proper time is usually referred to the instrumental definition of its measurement (i.e. counting processes) in ordinary STR. In our model, it is referred to the absolute nature of rotation. But it is similar: *rotations in w can be counted in an absolute sense.*

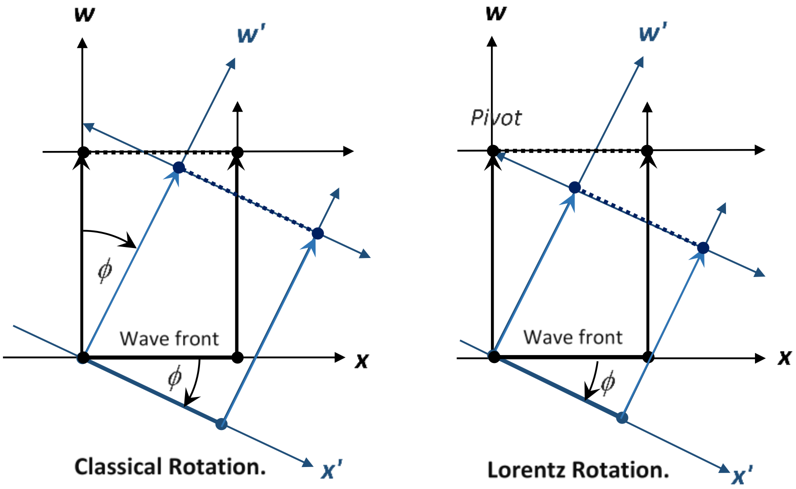


Figure 8. The Lorentz transformation induces a rotation-and-shear transformation of the *WXYZ* space that we can call the *Lorentz rotation*. A purely classical rotation, left, would change *w'* in the new coordinates, but this contradicts the boundary conditions. The Lorentz rotation corresponds to tilting the axes while retaining the *w* coordinates.

For instance, on a Lorentz transformation, the trajectory of the moving electron tilts into a spiral, with component motions tilting into *XYZ.* Note that the *Lorentz transformations* do not change their *definitions* at all – they are defined to make the STR metric invariant, and they make our rearranged version of the metric as the *speed function* invariant in precisely the same way.

When this is applied to electromagnetic fields we see they transform exactly like the classical EM field, with *4-vectors* for momentum, current, etc. Except now we define 4-vectors in the *4D space manifold,* not in the usual *space-time* manifold.

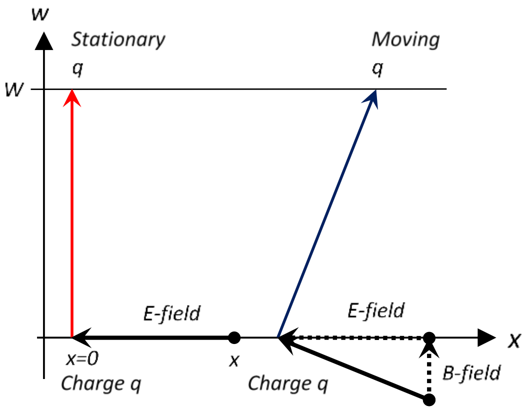


Figure 9. The Lorentz transformation of the EM in the *WX.* The red and blue lines show the *current vector,* for a charge rotating in *w.* The resultant force of the field of a source charge *q* on a 'test charge' at field point *x* is always *orthogonal to the 4D current vector.* All conventional 4-vectors, for momentum, current, etc, correspond to similar diagrams.

The *WX-diagrams* are especially useful to visualize the momentum and energy relationships in our model. We briefly illustrate these without much explanation here.

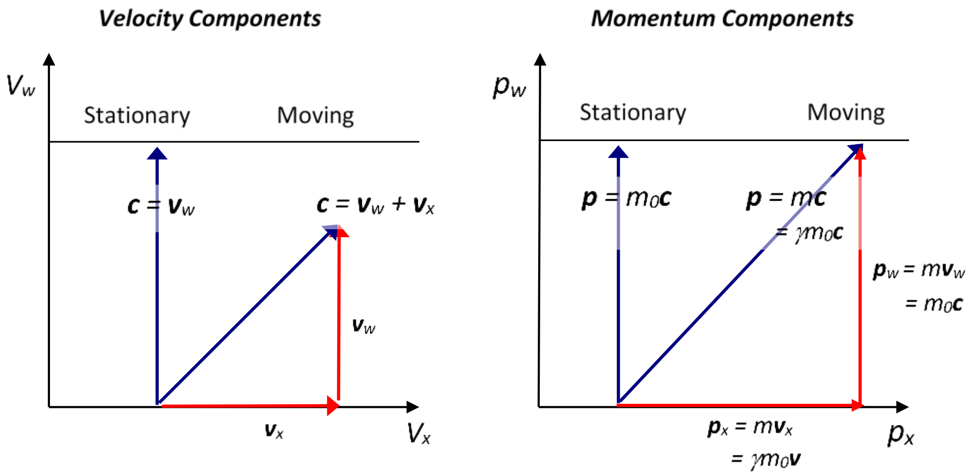


Figure 10. Left. A stationary and moving particle (blue) with the same rest mass in the *WX* velocity diagram. They both move at the speed of light, *c,* in *WX.* Components of velocity are red vectors. Right. The momentum components in the *WX* momentum diagram.

The components in *w* represent the rest-mass and rest-momenta *($p_0 = m_0c$),* while the components in *x* represent the ordinary momenta. This is our version of the momentum 4-vector, with the 4-vectors now in 4D space (*WXYZ)* instead of space-time. Transfer of momenta must balance in each direction. But we now see we have *conservation of momentum in w just like x,y,z.*

Note that a single particle cannot simply split into two particles with the two momentum components – this contradicts the energy law. This is illustrated by the transformation of a stationary particle to a moving state, through a 'collision' with another particle.

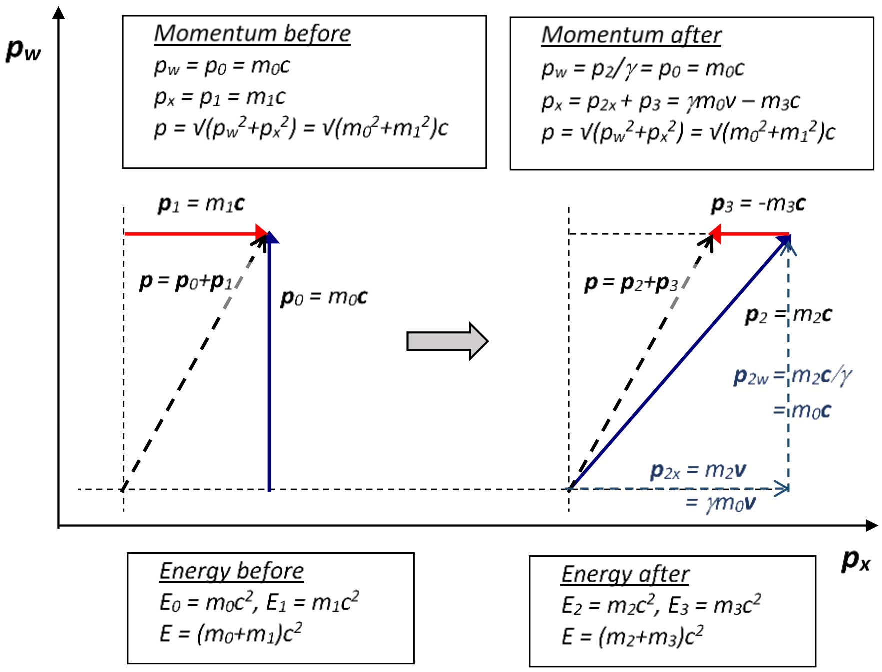


Figure 11. Two particles interact on the left, and there is a transfer energy and momentum, resulting in two altered particles on the right. This illustrates the *photo-electric effect.*

A light particle with all its momentum in *x* strikes a stationary mass particle, and imparts some momentum to it. But it cannot be simply *absorbed into one particle* - the solution requires a reflected light particle. We need to assign a *momentum and mass to light,* written here as: p_1 and p_3.

- These momentum-energy diagrams apply to all interactions – including the EM, strong and weak interactions, which are all orthogonal.

This illustrates that STR interactions are like classical interactions between particles with motions in orthogonal directions. This is perfectly valid to describe conventional STR processes, but the *orthogonality of rest-mass momentum with linear momentum* cannot be illustrated in conventional *space-time diagrams.*

The physical interpretation.

Although we generally have the same relationships in TAU as in conventional STR, the difference comes when we look at the physical interpretation.

- In TAU, all fields and particles must correspond to vibrational modes or distortions of the underlying manifold.

The electric field corresponds to a rotating (tilting) vibration of the electron ring into *XYZ space*. This behaviour corresponds to the usual 4-vector transformations of the EM field, where moving electric charges have their electric fields tilted partially into magnetic fields. But it is caused by a rotating mass-charge affecting the space.

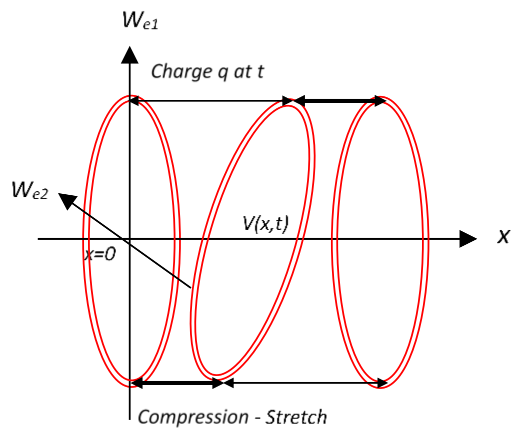


Figure 12. This illustrates the electron torus tilting into ordinary space. The electric field is a vibration of this kind, with the electron ring vibrating longitudinally w.r.t. ordinary space.

The rotating electron mass vibrates the torus, and creates the electric potential wave of a charge (and later, a strain effect creates gravity.) This shows the fundamental problem of solving the model: solving the vibrational modes of the 6D *WXYZ space.*

Vibrational modes in 6D may be rather difficult to analyse in general. But we know what the effects must be in this case, from standard theory EM theory, so we can match the solutions to conventional physics, and pick out the specific modes that correspond to the EM force. The model needs to effectively reproduce the conventional electrodynamic model. Next is a short summary of some of the relevant concepts of classical EM theory that we must link our model to.

Classical Electromagnetism.

For a phenomenological theory, matching with classical electrodynamics, we can assume the electron has an elementary electric charge, *-q,* rotating with the wave, and this gives rise to the classical EM field. (The electron charge matches literally to a *classical photon* trapped in the torus geometry. We later take this rotation to be the source of the charge.) The *proton* has the opposite charge, *+q.*

The EM force in the real world essentially comes back to the fields produced by just these two "point-like" charged particles, *e-* and *p+,* electrons and protons, as they move around in space. Their charges produce electric potential fields. There are also "free EM fields", photons, containing energy but no charge. The motion produces magnetic fields, but there are no magnetic charges.

In TAU there is really just one elementary electric charge, produced by the *electron/positron wave.* This is wave is duplicated in the proton, spinning in reverse, giving an elementary positive charge. So we really only need to produce this. In the Standard Model, protons are composed of three quarks with fractional 0 in the Standard Model (+2/3, -1/3, +2/3), but there is no physical observation of these charges, and no explanation of why they come in fractions of the same elementary charge of the electron. In TAU, the electron and proton charges are produced by an identical mechanism.

Charges produce potential fields, and these produce EM fields, *E* and *B,* which are classically described by Maxwell's equations. The latter are often taken as the fundamental equations, but they are not really. The *force fields* are not fundamental: they are constructed from the *potential field.*

- Charges produce a spherical *scalar potential field,* ϕ.
- Changes of ϕ, produced by accelerations of charges, produce *vector potentials,* ***A***.

The potential field, ϕ (or *V*) at a point in space, represents the electrical energy per charge. The spatial gradient gives the *electric (force) field,* ***E****.* This has a direction. The *potential fields* from multiple charges superpose linearly. The potential field spreads out dynamically, as a spherical wave travelling at speed *c* from the central point of a charge. (Note we will limit the charge radius to be larger than R_p *or* αR_e*.)*

- In EM theory, the potential field is governed by a *retarded wave equation.* The wave travels outwards from the point-like central particle.
- The solution in three dimensions is the spherical harmonic function: *1/r*.

This is illustrated using light-cones in space-time diagrams. (Here we switch to *V* instead of ϕ - we use *V* in TAU and ϕ in ordinary EM theory.)

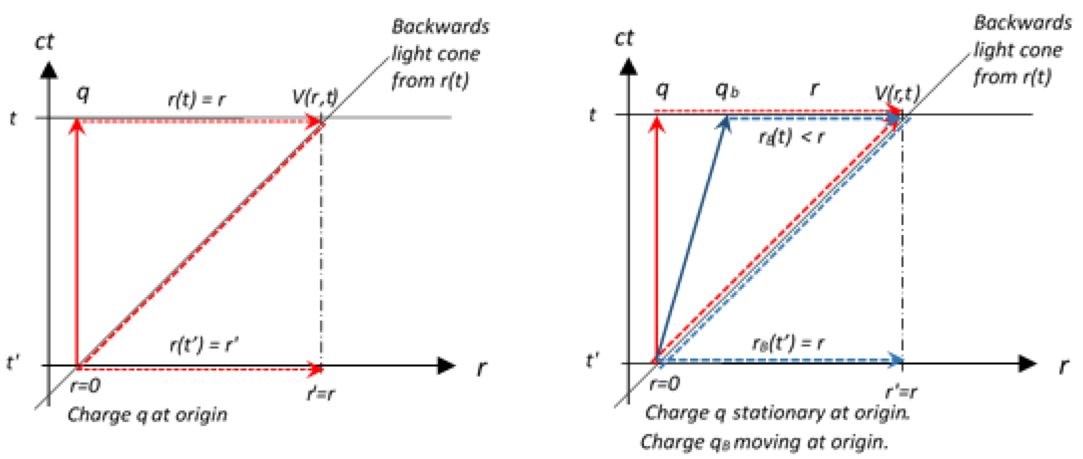


Figure 13. LHS. Space-time diagram of charge stationary at *r = 0.* The potential *V(r,t)* at field point *r* at *t* results from *the potential field* of the charge *q* at *t'.* The potential field travelled at speed *c* spherically outwards from the charge. RHS. A second charge, q_b, blue, is moving towards the field point *V(r,t)* when it crosses the first charge. The retarded distance r_B' is the same as for the stationary charge it crosses.

In the second diagram, the moving charge q_b is closer to the field point *r* by the time *t.* But its electric field at *(r,t)* turns out to be equal to that of a stationary charge remaining at $r_b(t)$. Although the *potentials* contributed from both charges originate from the same retarded source point, the *electric field* produced at the field point *(r,t)* by the moving charge is larger, because the gradient of the potential at the field point is greater for the charge B, because of its motion.

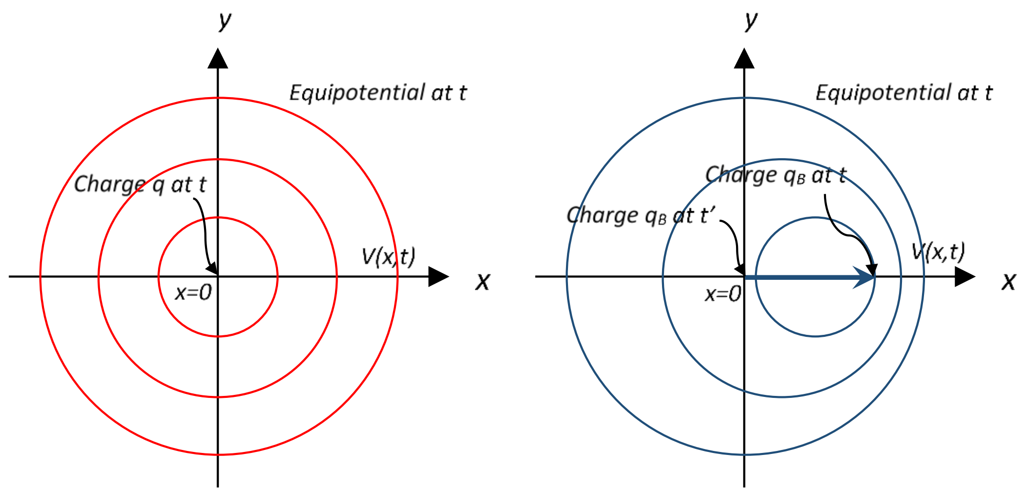


Figure 14. Lines of equipotential *V* in a space diagram *(x,y).* These are all at one moment, *t.* Left, stationary charge. Right, moving charge. The equipotential are circles (spheres in 3D) spreading out from the central charge.

The potential wave spreads out spherically at the speed of light, whatever the particle motion. Note that the equipotentials remain circles (spheres) on a Lorentz transform. But the equipotential circles for the moving particle become bunched up ahead, giving larger ***E***-field from: ∇V at field-point *(x,t).*

V at *(r,t)* depends on the *retarded position of the charge,* when it produced the field that travels to *(r,t).* This is the intersection of the backwards light cone from the field point to the charge.

This is represented by *retarded potentials*:

$$\emptyset(x,y,z,t) = \frac{1}{4\pi\epsilon_0}\int_{v'} \frac{\rho(x',y',z',t-r/c}{r} dv'$$ Scalar retarded potential.

$$\boldsymbol{A}(x,y,z,t) = \frac{\epsilon_0}{4\pi}\int_{v'} \frac{\boldsymbol{J}(x',y',z',t-r/c}{r} dv'$$ Vector retarded potential.

(E.g. Lorrain, Corson, Lorrain, 1988, p.680-81). Note this has the *retarded time variable, t-r/c.* Note that the intersection point of the *world-line of the charge with the backwards light cone* is invariant w.r.t. frame of reference.

- The terms in *t* are asymmetric – the retarded equations are *not time symmetric*.
- This means electrodynamics *with source charges* is *irreversible* at a fundamental level.

Only the retarded solutions are physically real. There is a second set of mathematical solutions to the *wave equations*, called the "advanced wave solutions", but these are not physically possible. They would describe the time reversal of normal physics. But time reversed physics does not work in reality. Advanced wave solutions are not physically possible.[1]

This is the point where retarded fields enter into conventional electrodynamics, and similarly into TAU. This retardation is equivalent to the causal principle, that *physical effects (waves) spread outwards from central causes (charges)*.

To illustrate how this leads to the Maxwell equations for ***E*** and ***B***, we start with the classical non-homogenous wave equation in the scalar potential function: $\phi = \phi(r,t)$. This is the fundamental wave equation, with the space-time operator on the LHS, and an invariant, the *charge-density,* on the *RHS.* We will derive the Maxwell equation for *E.*

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} = -\frac{\rho}{\epsilon_0}$$ Wave equation in $\phi(x,y,z,t)$.

$$\nabla.\boldsymbol{A} = -\frac{1}{c^2}\frac{\partial\phi}{\partial t}$$ Definition of *A*.

Note that the first equation is the fundamental relation to the source charge, the second defines the *vector potential, A*. We can see how this connects to the Maxwell field equations.

$$\frac{\partial\,\boldsymbol{\nabla.A}}{\partial t} = -\frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2}$$ Rearrange definition of *A*.

$$\nabla^2\phi + \frac{\boldsymbol{\nabla.A}}{\partial t} = -\frac{\rho}{\epsilon_0}$$ Substitute ***A*** in wave equation.

$$\nabla.(\nabla\phi + \frac{\partial\boldsymbol{A}}{\partial t}) = -\frac{\rho}{\epsilon_0}$$ Rearrange.

$$\boldsymbol{E} = -\nabla\phi - \frac{\partial A}{\partial t}$$ Definition of E.

$$\nabla.\boldsymbol{E} = \frac{\rho}{\epsilon_0}$$ Substitute to get Maxwell's 1st equation.

[1] So why is electrodynamics usually claimed to be *time reversible?* Because we can write a *general wave equation* that does not specify the time direction. However the *actual law of physics* is the retarded equation. It is irreversible. The fact that we can write a *mathematical equation* to describe the time reversal of processes does not mean those processes are physically possible.

The *electric field* is thus constructed from the scalar and vector potential fields – and the vector potential is constructed from the scalar potential. This illustrates that the field ϕ (or its four partial differentials, in 3D space and time) is what is fundamental. The field is produced by source charges, which is the fundamental connection between *charges connected to point particles* and *fields across space produced by charges*. The vector potential ***A*** is defined from the differentials of ϕ, and the electric field ***E*** is determined from these.[2]

In TAU, we similarly take the charges, but now with an underlying motion in 4D (or actually, in 5D, but we start with the 4D model). In our 4D space, we can rearrange the equations like this (we will replace ϕ with V in the context of TAU):

$\nabla_r{}^2\phi + \frac{\rho}{\epsilon_0} = \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2}$	Wave equation in 3D space-time.
$\nabla_w{}^2\phi = \frac{\rho}{\epsilon_0}$	Postulate. The rest charge density.
$\nabla_r{}^2\phi + \nabla_w{}^2\phi = \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2}$	Rearranged.
$c^2 \boxdot^2 \phi = \frac{\partial^2\phi}{\partial t^2}$	Laplacian in 4D.

Note that our 4D-Laplacian (box operator) here is not the d'Alembertian from special relativity. We have rearranged the construction to represent our 4D spatial model (as with the K-G equation and STR metric equation). The *postulate* now states that the rest charge is equivalent to the Laplacian component in *w.* The source charge term now appears as a component of the total 4D field. In 4D, 5D, and in constrained spaces, there are different harmonic functions to the 3D harmonics. But since there is no overall dispersion in our circular dimensions, they integrate to finite classical spherical wave functions, once we are outside small atomic distances: > R_e/α. This integration can be done, and we can reproduce something almost the same as the classical laws – except now we have a difference: multiple light-paths (potentials) connect the same events. We must integrate and renormalise the electric potentials. We expect the same behaviour as in QED.

This illustrates how we can connect our model end-to-end with EM theory and QED at fundamental points, and obtain the equations from an underlying physical mechanism. And the mass-wave in the torus essentially duplicates the Dirac equation, and conforms to QM properties.
So now: what about all the other particles?

[2] Of course there are non-trivial solutions without source charges, viz. free EM fields, or photons. But they are also defined by *solutions for the potential field equation with zero charge density,* i.e. for the homogeneous wave equation.

The particle geometry.

So far so good. This defines two nice particles, the electron and photon (which we get as the free EM field as usual). But the idea is to use *this single manifold to model all the particles!* It is now it is a matter of looking to see if other particles can fit. The next particle we construct is the *proton.*

There is a second dimension in the torus, the small radius, with wave solutions similar to the electron solution. This must correspond to a second larger stable mass particle, and the only possible candidate is the proton. So we postulate that the small torus dimension has the radius: $R_p = \hbar/2m_pc$ to match the proton mass. Now this length is about 1/1836 of the electron-ring radius, R_e, so the torus is very skinny. (Because: $R_p/R_e = (\hbar/2m_pc)/(\hbar/2m_ec) = m_e/m_p = 1/1836$).

The proton has a short wave-length, hence a large mass-energy, and it will contain an electron-like wave function as a component wave. It will require this lower energy level to be filled to be energetically stable. The *positive charge of the proton* is produced by its electron-wave component, but it must be rotating in the opposite direction to the electron, i.e. a positron.

> "Because protons are not fundamental particles, they possess a measurable size; the root mean square charge radius of a proton is about 0.84 - 0.87 fm (or 0.84×10^{-15} to 0.87×10^{-15} m.)[3] In 2019, two different studies, using different techniques, have found the radius of the proton to be 0.833 fm, with an uncertainty of ±0.010 fm.[4]" Proton. Wikipedia.

Hence the charge radius and physical radius are very similar to the ½ Compton radius.

Table 4. Energies and Compton wavelengths for four main long-lived particles.

Energy-Mass-W-R-T	Model γ photon	Neutrino ν TAU Model	Electron e- $R_e = h/2\pi m_e$	Proton p+ $R_P = h/2\pi m_P$	Neutron N $R_N = h/2\pi m_N$
e- masses	E/m_ec^2	1.48E-07	1.00	1,836.15	1,838.68
Energy (GeV)	E = hf	7.58E-08	0.511	938.3	939.6
Mass (Kg)	$m = E/c^2$	1.35E-37	9.11E-31	1.67E-27	1.67E-27
W (meters)	W = c/f	8.18E-06	1.21E-12	6.61E-16	6.60E-16
R (meters)	$R = W/2\pi$	1.30E-06	1.93E-13	1.05E-16	1.05E-16
T (seconds)	T = W/c = 1/f	4.34E-15	6.44E-22	3.51E-25	3.50E-25

We see that the ½ Compton wavelength that we adopt for R_p is very close to (20% smaller than) the measured average charge radius and physical radius. This match makes the model possible. Essentially, the electromagnetic force and gravity operate outside the radius of about 10^{-16} m, while the strong and weak forces only operate within this distance, which corresponds to the physical boundaries of the torus. Note also the proton ring can be *rotated into ordinary space* at this scale – forming a 3-sphere.

But we also need a third particle, the *neutron,* which is universal in nature, like the electron and proton. It is similar to the proton, also a spin-½ fermion, but slightly heavier, and has no charge. But there is simply nowhere for a wave representing this in the simple solid torus. It requires another dimension, with the radius: $R_N = \hbar/2m_Nc$. It must be slightly smaller than the proton. And because of

[3] Shearer, Paul. 2013. Antognini, Aldo, et al. 2013.

[4] Bezginov, N. et al. 2019. Xiong, W. et al. 2019.

the similarities with the proton, it should be *parallel with the proton motion.* There is only one apparent choice, which is to make the torus hollow inside. Thus we arrive at the basic TAU torus model, which looks like this.

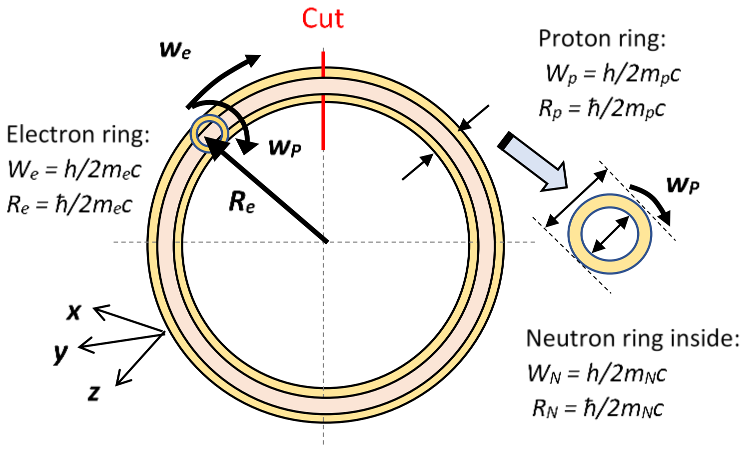


Figure 15. The micro-torus geometry. It has three parameters, the radii, which are fixed by the masses of the electron, proton and neutron, m_e, m_p, m_N. It is embedded in *XYZ* space. We use *W's* for circumferences and *R's* for radii.

The *neutron* is modelled as a wave on the inside of the pipe. It has a mass about 2.5 electrons more than the proton. The neutron must contain two electron-wave components – an electron inside the pipe, a positron outside – moving in opposite directions, so the electric charges cancel.

The neutron can therefore decay to a proton, as a lower energy state – because its mass energy is slightly larger, and its momentum is in the same direction - but to do so, it must have some way of transferring its momentum through the pipe, and the result must be to split into an electron and a proton. When we work out the details, this corresponds nicely to properties of the neutron and to neutron decay. But for this process there must be an *electron neutrino,* to balance momenta. And we find the perfect candidate for the neutrino is in the electron model already!

The main electron spin is around the large circumference, W_e. But there is a secondary spin, around the pipe, W_p. The wave (which may be initially imagined as carrying a point-like mass-charge around the torus) completes one rotation of W_p for every two rotations of W_e, and so the momentum vector in W_p is tiny. This means the electron has *two dimensions of motion in w* (not counting its *XYZ* motion). Again, *WX* diagrams are useful to work out geometric relationships.

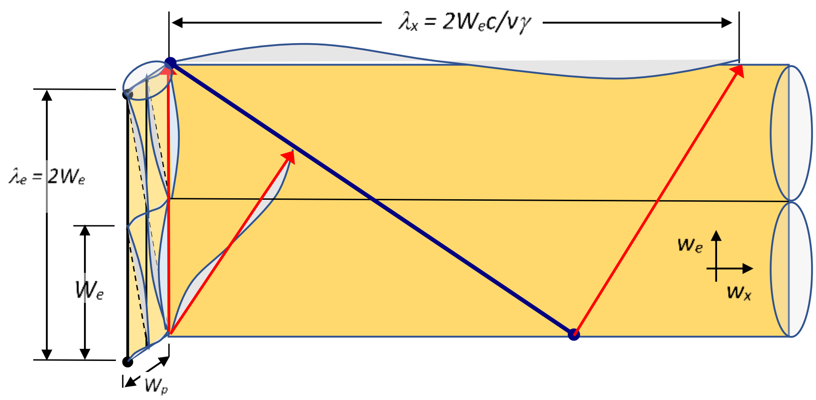


Figure 16. The 1-D electron as a wave motion in *x*, w_e and w_p. The double-wave motion of the electron gives strong relationships between the motions in the different dimensions.

These motions correspond to two wave components, and two orthogonal components of the electron rest mass. The spin-wave in W_p has a very tiny mass-energy compared to the main electron mass-energy in W_e. (This secondary spin momentum also weakly connects the electron with the main proton mass wave.)

- This tiny spin-energy component is identified with the *electron neutrino.*

This is a novel prediction (and electrons do *not* contain neutrinos in the Standard Model). Perhaps it is not absolutely certain that this has to be the interpretation of the neutrino. But it is very hard to avoid. When we calculate the extra tiny spin-mass, it turns out to be 0.075 eV (or twice that, 0.15 eV). This is consistent with current empirical estimates, although they are not determined to better than a scale of magnitude yet. Only the *sum of the three neutrino masses* is known with any degree of accuracy, and is currently estimated between about 0.1 – 3 eV (opinions vary a little). Three electron neutrinos on our model would be about 0.22 eV (or 0.45 eV). We cannot predict the masses for the muon and tau neutrinos yet, but expect them to be comparable.[5]

So while this prediction cannot be empirically confirmed to better than an order of magnitude yet, it is consistent, and this is quite a coincidence. The coincidence lies in the large difference of scale between the neutrino mass, and the electron and proton masses that it is calculated from: they differ in scale by about $10^{-6} – 10^{-9}$, but the result conforms to within a scale of about 10.

In summary, the TAU torus provides a remarkably good model to host the five major long-lived particles to start with: *the photon, electron, proton, neutron, and electron neutrino.* (And their anti-particles, which are reversed wavefunctions).

But is there room for the full set of particles in the Standard Model?

[5] A guess based on dimensions is that the muon neutrino is about 12.25 times the electron neutrino mass.

Standard Model mass particles.

The model so far may seem far too simple. Yet we propose that it is *all we need for all the Standard Model particles and forces!*[6] Is this possible!? The Standard Model has about 24 particles, with their own parameters, while so far we have only three or four independent parameters, and five or six particle types. So how could such a simplistic reduction be possible?

Only by powerful coincidences between the geometry and the physics.

The geometry contains several further types of mass-waves. We cannot work these all out yet, but we can match general features and scales.

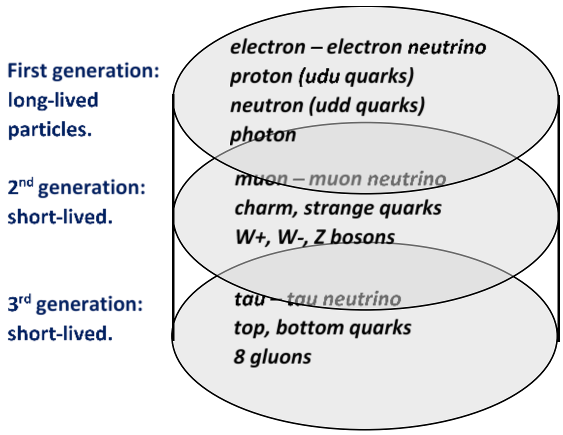


Figure 17. Three particle generations in the standard model. We can model the first generation using the simple torus geometry, and then consider the 2nd and 3rd generations.

We have only so far only considered surface waves, travelling at *c,* in 5D (the W_eW_p surface plus 3D *XYZ space*). The odd dimensionality is important, as it allows coherent waves. But there are also waves possible within the volume, such as waves reflecting between the W_N and W_p surfaces. These *volume waves* will behave differently to surface waves. We do not know what speed they will travel at without some additional principle. But they can only have very short wavelengths and high energies and short life-times. They will not form stable particles, because there are many lower-energy modes to decay to. So we expect very brief transitory particles. And there are also wave combinations and masses plausible for mesons and other composite particles.

The torus pipe has a thickness, given by the difference: $R_p – R_N$, between the neutron and proton radii. This is the smallest physical length in the model so far, corresponding to a large mass. On the assumption that waves in this dimension also travel at speed *c*, the energies and times are on the scale of the transitory *W+,W-,* and *Z bosons.* These are close to the heaviest particles in the Standard Model. (In fact waves in: $W_p – W_N$ correspond quite closely to the vector boson energies, while the radius: $R_p – R_N$ is about six times too large. This is only an estimate until wave functions are properly solved, but this is a good match to scale.)

Note also that there are two distinguished directions: in the plane of the torus, and parallel to the axis of the torus. These give rise to two slightly different components in the proton and neutron

[6] When I first developed the model, I assumed there must be more dimensions (probably 9), or more structure in the geometry. And there may still be. But everything now seems to point to just this simple structure.

waves. *Up and down quarks* will have to be identified with components in these two directions. But *up* and *down* quarks are still pretty fuzzy in the Standard Model, their individual masses are barely known to within 20% (only their difference is known precisely), and they can never be individually observed. They also make up only one percent of the total proton mass in the standard model, the remaining energy is attributed to a flux of *gluons*, which we will associate with internal energy that strains the torus.

We see here the division of two realms of particles – which matches between the Standard Model and TAU. Long-lasting stable particles like electrons and protons have to match directly to real stable particles in TAU, and they do. But quarks can only match with *wave components* in TAU, and vector bosons can only match with transitory particles.

But there is a fundamental difference between TAU and the Standard Model in this respect. The scheme of TAU particles is more like the construction of complex atoms made by filling in electron orbits from the bottom up with increasing energies, rather than a mathematical construction from combining algebraic groups of elementary particle properties. To illustrate:

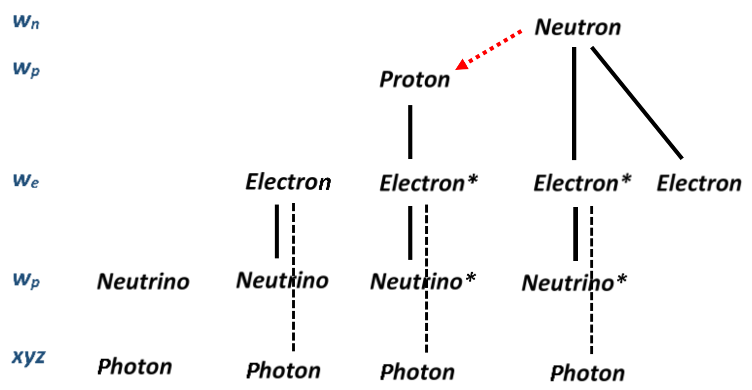


Figure 18. Illustration of TAU particle components. The neutrinos are *electron neutrinos.* The *electron** is a *positron,* and is a *T**-reversed electron. As we go up, the rest masses (energy) increase, and the *w* dimension changes.

The electron, proton and neutron thus all contain lower-energy wave components. Energy levels must be filled from the bottom up for the particles to be stable. The neutron can decay to a proton, creating an electron and anti-neutrino in addition. This means some particle constructions are reorganised compared to the Standard Model. But there is a basic correspondence with *mass, length and time scales* of the Standard Model particles.

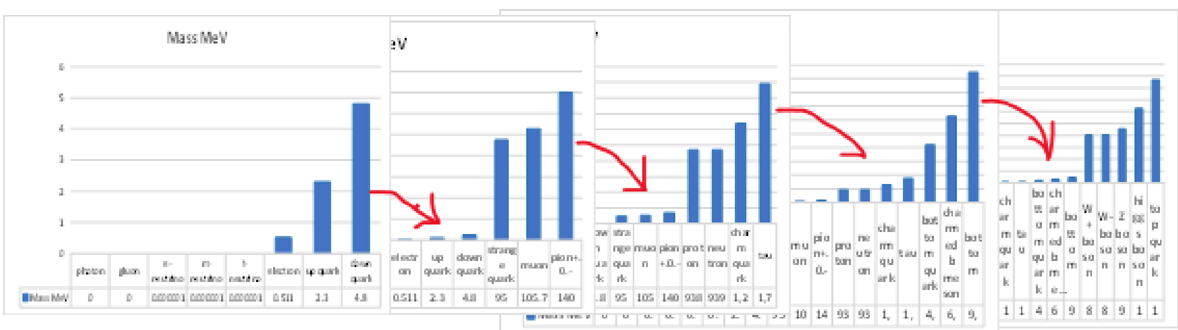


Figure 19. The particle mass series, from electron to the top quark. Subsequent mass groups are like 20-story sky-scrapers next to the previous group.

Table 5. Particle mass groups.

Particles	Mass MeV	Ratios between groups	Distance/Gaps
electron	0.511		
up quark	2.3		
down quark	4.8	185.9	Distance
strange quark	95	19.8	Gap
muon	105.7		
pion+.0.-	139.6	9.9	Distance
proton	938.3	6.7	Gap
neutron	939.6		
charm quark	1275		
tau	1777	4.5	Distance
bottom quark	4180	2.4	Gap
charmed b meso	6276		
bottom	9460	19.2	Distance
W+ boson	80380	8.5	Gap
higgs boson	125,100		
top quark	173,210		

The mass range for a group generally spans about the mass of the lightest particle, from *m* to about *2m*. The gaps between groups are much larger than the variance within groups.

There are a four elementary but composite particles included: *pion (lightest meson*), *proton, neutron*. Then the *charmed b meson,* as the heaviest meson. The *W- and Z bosons* are left out. They are both about the same as the W+. All the other fundamental particles are shown, except photons and gluons, which have no rest-mass.

Physicists would normally consider these in terms of their particle group types. But note that there is a regular series of steps in the rest-mass groups. What causes this? A physical geometry that allows multiple wave function components, and can make stable particles. As a whole, the Standard Model mass particles reflect about 5 distinct mass scales, separated by about 5 orders of magnitude. This is a strong pattern. And there is an excellent correspondence with these scales in TAU. This makes the model possible.

The torus dimensionality also corresponds to the number of forces. The forces must transfer momentum from *W* directions into *XYZ*. The EM force must connect W_e and *XYZ* (with the photon being a vibration tilting the W_e ring into *XYZ.)* The weak force connects W_p and *XYZ.* The strong force connects: $W_Q = W_e \, X \, W_p$ and *XYZ.* There can only be three independent quantum forces in TAU. The relative strengths are also consistent.

So overall, the torus has the right structure to reproduce the *first generation* of the Standard Model, and about the minimal complexity and dimensionality and mass-energy scales for the whole range. But the main feature missing so far are the *three generations of leptons and quarks.*

Particle generations.

This triple structure of generations is the key pattern of the Standard Model. The structure for the first generation (electron, proton, neutron) is duplicated at a higher energy level (electron → muon), and then a third time (muon → tau). We can first look for the *muon* to solve the problem of modelling generations in TAU. This single additional particle should give us the fundamental mechanism for understanding *generations*, and should conclusively determine the interpretation. On the other hand, mesons and quarks could also be modelled, and the W+,W- and Z-bosons can also be modelled, so there are several lines of investigation, with strongly determined data and limited modelling possibilities.

This means the full theory must be very solvable – all the clues must be there to solve it *if it is solvable*. Other theories have investigated geometric properties in different ways, e.g. GUTs, seeking to unify the forces, and although these have not quite worked as thought, they show strong patterns of a similar kind to TAU.[7] However, the question is how *flexible* TAU is to incorporate new features, such as the multiple generations. Although the simple TAU model is very constrained by its fixed geometry, it has more flexibility when we consider the dynamics of the geometry.

The muon is essentially an exact copy of the electron, but with about 207 times the mass. But there is simply no place for the muon in the fixed electron-proton torus, without some new feature of the geometry. The electron already occupies the lowest energy for the electric charge. We can try higher-energy superposition states for higher-masses, but we get higher charges, and this does not seem to work at all.

The key alternative is the *dynamic distortion of the torus.* There are local effects of energy on the *spatial geometry.* The torus is not an inert entity – it already vibrates in EM fields, and strains in gravitational fields. But another type of distortion is possible: a change of length ratios, from the ratio: $R_e/R_p = 1836$. This can plausibly change in high-energy collisions, because particle energies are contained in the stretching of the torus space. The distinctive mode of change is as follows.

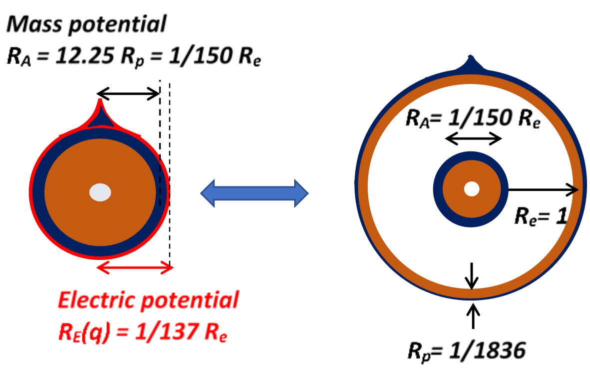


Figure 20. The TAU torus may change its length ratios while retaining its volume. The minimum is a *1/150-ratio to R_e,* when all the radii are made equal.

[7] There are some parallels with GUTs (Grand Unified Theories), which appeared tantalisingly close in the 1970's, but did not quite work. They also identify particles and forces in terms of a small number of symmetry groups. However they are patterns in abstract geometries, and based on gauge symmetries, while we propose the symmetry groups will be found to correspond to our specific concrete geometry in 6D, and we will eventually see that we must adopt a definite gauge.

The torus is elastic, but obeys a law of conservation of 6D volume. To conserve the *volume,* we must conserve the quantity: $R_eR_p^2$, because the torus volume is: $2\pi^2R_eR_p^2$.

- Actually, strictly speaking our hollow torus is: $2\pi^2R_eR_p^2 - 2\pi^2R_eR_N^2 = 2\pi^2R_e(R_p^2 - R_N^2)$, but we will assume the ratio of the *proton to neutron radius* is fixed as a constant, call it *a,* so: *Volume =* $2\pi^2R_eR_p^2(1-a^2)$, and we can work with $R_eR_p^2$ as the simple invariant.

Hence we introduce an *average radius:* $R_A = (R_eR_p^2)^{1/3}$ as an invariant length characterising the torus. I.e. no matter how the radii change relative to each other, locally we always have the same value for R_A. But note in the expanding universe, the real conservation law is:

- R_UR_A *= constant,* with R_U the universe radius.

We will get back to this, and it is the reason the particle theory has to be consistent with the cosmology and gravitational theory, which both involve dynamically stretching space.

In terms of a ratio to the electron radius, this *average radius* is:

$$R_A = (R_eR_p^2)^{1/3} = R_e(R_p/R_e)^{2/3} = R_e(1/1836)^{2/3} \approx R_e/150 \qquad \text{Average radius.}$$

This ratio: $(R_p/R_e)^{2/3} = 1/150$ is a kind of magic number in the model, because it is the *invariant volume-average under (local) distortions of the torus*.

- R_A is the *minimal radius of the torus,* when the hole in the centre disappears, and the two radii become equal: $R_A = R_e' = R_p'$.

This distortion of the torus, expanding the proton radius to: $R_p' \rightarrow 12.25R_p$, and shrinking the electron radius to: $R_e' \rightarrow R_e/150$, gives a wave-function solution like a very heavy electron, with 150 times the mass, and still one negative electric charge. The real muon is 207 times the electron mass, so this is in the right mass scale. But the muon a bit heavy for the simple model. But we may wonder: how much energy does this distortion really take?

This is also close to another "magic number" of electrodynamics: the *fine structure constant,* $\alpha = 1/137$. This suggests: $(R_p/R_e)^{2/3} \approx \alpha = q^2/4\pi\varepsilon_0hc$, which we also propose as a lawlike relation. Another coincidence is that we must integrate the electric field energy down to exactly: $R_e\alpha$ to get the *mass energy:* $mc^2 = hc/r_e$ *to match the electrical self-assembly energy:* $\alpha hc/r_E = hc/r_e$ or: $r_E = \alpha r_e = r_e/137$.

Note the torus radii could only be made smaller than this minimum value (with the same volume) by also changing the ratio of R_p to R_N. This is possible too, so there are in fact several ways the torus could distort to host muon or tau particles without altering the general topology.

There is another variable also: the speed of light changes when the surface tension changes, and this modifies the simple mass-length relationships. These relationships merge in cosmology, where the expanding universe also distorts the torus.

So to make further progress, we need to analyse all the dynamic quantities of the torus together. But before proceeding further, we need to see how further properties are determined by considering gravity and cosmology. So we will leave the Standard Model now, and move on to gravity, which gives a new set of relationships. We return to particles subsequently, when we return to apply the gravitational-cosmological model, and examine the features of *wave function collapse, non-local connections, entanglement* and the interpretation of the wave functions.

To summarise, the particle model has very strong features for the first generation of particles and the EM force, it makes strong predictions and none have broken down yet, and with the torus stretch and other features, *there is just about exactly the right complexity* to get all the particles and forces. At first it looks too simple, but if we make it any more complex we will probably get too many particles and forces. There is ample data and several clear paths to continue the modelling. However, the results of the TAU particle model will have to be consistent with standard particle physics, as this has such strong data, and we should not expect novel predictions here.

Gravity.

The main areas where predictions of TAU do diverge from standard theory are in *gravity and cosmology.* And this is where the most direct tests are found. The TAU theory for gravity is fairly simple, and its main features have been worked out. There is not much choice in this. It departs slightly from conventional GTR, and is empirically very testable. Gravity is produced by mass-energy *straining* the manifold. The strain function uniformly expands the torus. This is how energy is stored in the manifold.

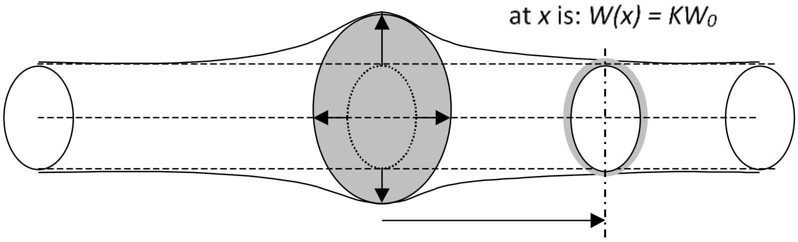


Figure 21. Curvature in a simple pipe. The theory of gravity is determined by the strain induced by a given mass-energy and the effect on the wave-speed, *c*.

Note the *strain function* does not really flatten out when we get close to a *point mass*. The main solution is an exponential function, and produces a singularity, and this has to be modified at very small distances. But in our solution, it does not simply flatten out. We return to this later. Here we deal with the solution at significant distances from the mass centre.

Energy in this model is stored in the elastic strain of space, and the curvature this produces gives rise to gravitational attractions. This strain represents *potential energy* – note that space itself is now a *source for storing energy.* In conventional gravitational theory (or potential theory), we distinguish between *potential and kinetic energy.* E.g. a test-particle *m* at a distance, falling towards a gravitating mass *M,* gains kinetic energy, and to keep *energy conservation,* it is said to lose *potential energy.*

Thus in a classical gravitational field, the potential energy is: $E_P = - mMG/r$, and this trades off with kinetic energy of: $\frac{1}{2}mv^2$. The potential energy is set at zero for a particle "at infinity", and energy conservation as it falls means: $\frac{1}{2}mv^2 - mMG/r = 0$, and the velocity is solved by: $v = \sqrt{(2MG/r)}$. The field potential is written as: $\phi = -MG/r$, representing the *classical gravitational potential field.*

Thus gravity (and other forces) involve a real exchange of *potential and kinetic energy.*

There is no equivalent representation of *potential energy* in conventional physics, where it is just taken as a mathematical definition. It may be called the "field energy", but the field has no physical model. How is it "stored" *physically?* There is no mechanism.

In TAU, the *potential energy* for gravity is physically stored in the strain of space. The individual particle mass-energies are also stored in their strains. When *m* falls into *M,* the combined strain as they approach each other is reduced slightly, as the superposed wave-functions have a slightly non-linear effect on strain. Thus the combined particle mass-energy when two mass particles approach each other is reduced, and this is the *reduction in gravitational potential energy.* It must be transferred to the kinetic energy. Thus we are able to have a fully realist model and realist mechanism for energy.

Energy is stored in the strain of space, and the underlying strain of "empty space" represents the *background energy of space itself.* Something keeps the giant inflated. We end up with an absolute energy content for space. This is only possible because we have a *realist model for space.* It corresponds to a cosmological constant in conventional GTR. It also means we do not have *gauge symmetry,* except as a local approximation (instead we will have a strong scale symmetry). This is a major point of departure from the conventional theories.

This also means that the energy "of space" can have local variations, e.g. clumping of internal energy, on a galactic scale. This appears as "free energy" in space, which acts like a gravitational attractor. This is proposed as the primary mechanism for "dark matter" in TAU. As galaxies evolve in the expanding universe, they retain a larger background spatial energy (*gravitational potential energy*) than the "cold" intergalactic space they are set in (due to the dynamic of transferral of energy between space and matter in the expansion process). Such local distortions of the manifold are like a kind of inhomogeneous fluid, flowing between regions, and self-attracting, and attracting particle masses. This model for dark matter *has no associated discrete quantum particle,* it is free energy of space.

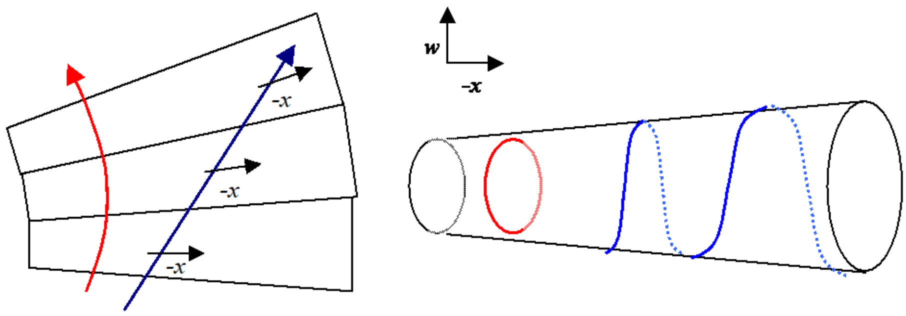


Figure 22. LHS. This shows the development of the torus surface, as we approach a mass on the right. Trajectories from left to right are moving towards the mass center. Straight-line-motion on the cone development (blue) is a geodesic (almost). Rotation at constant x (red line) is an accelerating path. RHS. The trajectories around *w.* For the straight-line path, the increment Δx in the x-direction is not constant with each rotation. It accelerates into *x.* The resulting geodesic is not actually a straight line, because the speed of light also changes.

This is a visualisation of the physical mechanism for gravity. Such a mechanism is only possible because we have a realist model of space as an aether, with real properties of strain and energy. To specify the theory of gravity, we just need to specify the *strain function,* and its effect on curvature and the local speed of light in the surface. This turns out to be surprisingly simple, and gives a theory matching GTR very closely – but with smooth solutions.

The *strain* produces two effects: an acceleration towards the centre from both the spatial distortion (because the curved surface now acts like a funnel for particles or waves), and a change in the speed of light. We now summarise the key equations of the theory. Particles are localised in *XYZ,* and the *strain function* is a spherical function around the mass centre. This is a simple exponential function:

$$R(M,r) = R_0 e^{\frac{MG}{c^2 r}} \qquad \text{Torus strain function.}$$

Here *R* is any dimension of the torus (such as R_e), R_0 is the value of *R* in empty space (or at infinity), and *r* is the radial distance from a central source mass *M.* We define the function as *K(M,r)*:

$$K(M,r) = e^{\frac{MG}{c^2 r}} \qquad \text{Definition of } K.$$

This strain function is determined by more fundamental considerations, reflecting the manifold properties. It has the *linear superposition property.* If we take *M* to be composed of two masses: $M = M_1 + M_2$, the function gives the linear superposition: $R(M,r) = \left(R_0 e^{\frac{M_1 G}{c^2 r}} \right) \left(e^{\frac{M_2 G}{c^2 r}} \right)$, and is identical to imposing the two masses in sequence. Note that this equation is valid when *r* is substantially larger than the torus radius, but when *r* becomes comparable to the torus radius it is no longer valid.

The result of the strain is this *metric-speed equation* at the field point:

$$\frac{ds}{dt} = \frac{\sqrt{(dw^2 + dy^2 + dz^2 + dr^2/K^2)}}{dt} = Kc \qquad \text{TAU metric.}$$

Here *r* is the radial vector to the field point, and *y, z* are orthogonal directions at the field point. Again, this is derived from more fundamental properties of the continuum. This means that:

- The *speed of light* in the orthogonal directions *w,x,y* reduces from *c* to *Kc.*
- The *speed of light* in the radial direction *r* reduces from *c* to K^2c.

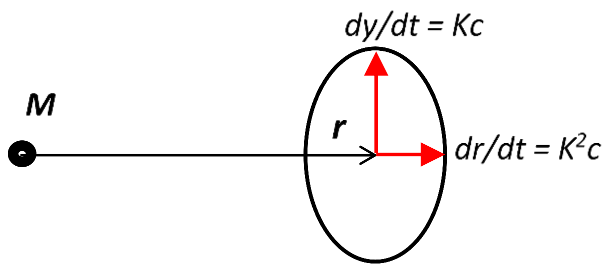


Figure 23. The field point ***r*** is a distance *r* away from mass *M.* The ellipse around ***r*** shows the *surface speed, c(r),* generated by the central mass *M* at the field point. The speed of light is now different in the directions parallel and orthogonal to the radial vector.

The *speed-metric* is required by continuum properties. It corresponds to *surface tension* and to *speed anisotropy* of light in an inhomogeneous medium. More generally, the solutions are represented by 4X4 matrices representing *speed tensors:* c_{ij}. These correspond to the usual metric tensor, $g_{\mu\nu}$. The central mass solution is symmetric so it can have a diagonal form. We now compare this with the usual Schwarzschild solution for GTR.

If we rearrange our speed metric, above, into the usual type of GTR line metric formulation, using: $d\tau = cdw$, it is:

$$d\tau^2 = dt^2/K^2 - dr^2K^2/c^2 - dy^2/c^2 - dz^2/c^2 \qquad \text{TAU Line Metric}$$

We call this *K-gravity.* This is exactly the form of the GTR *Schwarzschild line metric*, except we have used *K* ("big *K*") whereas GTR uses this "little *k*" function:

$$k = 1/\sqrt{(1-2MG/c^2r)} \qquad \text{Definition of } \textit{little-k}$$

$$d\tau^2 = dt^2/k^2 - dr^2k^2/c^2 - dy^2/c^2 - dz^2/c^2 \qquad \text{GTR Line Metric}$$

(This is normally written in spherical coordinates, we have defined: $dy = rd\theta$ and: $dz = r\sin\theta d\phi$ as local orthogonal coordinates *at the field point.*) The difference between the TAU metric and the GTR metric is determined by the differences between *K* and *k.* If we expand *K* as a Taylor series, we see that *k* is really the first two terms of *K.* It is easiest to see as:

$$1/k^2 = 1\text{-}2MG/c^2r \qquad \text{Definition of } k.$$

$$1/K^2 = 1 - 2MG/c^2r + (2MG/c^2r)^2(1/2!) - (2MG/c^2r)^3(1/3!) + \ldots. \quad \text{Taylor expansion.}$$

They differ in the second-order terms: $(MG/c^2r)^2$ and higher. $1/K^2$ is the *analytic continuation of* $1/k^2$. For the direct comparison of *k* and *K*:

$$k = 1 + MG/c^2r + (3/2)(MG/c^2r)^2 + \ldots$$

$$K = 1 + MG/c^2r + (1/2)(MG/c^2r)^2 + \ldots$$

Now the factor: MG/c^2r is small in weak gravitational fields. Hence: $k \approx K + (MG/c^2r)^2$ for large *r,* and *k* is slightly larger than *K.* Hence the Schwarzschild solution will predict slightly stronger accelerations than our K-gravity, for the same source mass. But note that for experiments in the solar system, we estimate the value of *GM* for the sun from measured accelerations *and the assumed theory*, and using *K-gravity* we must recalculate *GM* as slightly larger, and there is a kind of reversal of the effect at larger radial distances. In terms of empirical tests:

- Current measurements of solar system gravity are not precise enough to distinguish between the two predictions.
- But the differences can be tested with a practicable experiment in the solar system.

The difference will probably not be noticed accidentally by astronomers without a dedicated experiment, because it requires an experiment designed around the specific effect. An experiment to test this is explained in (Holster, 2017).

In fact, the TAU prediction initially appeared to be confirmed by the anomaly in the Pioneer spacecraft data, which was in free-fall over 20-30 years.[8] But it subsequently turned out that the Pioneer data is too dirty to detect such fine anomalies. The Pioneer trajectory data initially showed anomalies on exactly the scale predicted by TAU. And this was a problem for NASA for about 15 years. But through a decade-long effort to reestablish consistency with conventional GTR, the NASA theorists searched for and found some extra small uncontrolled factors that were overlooked in the

[8] Musser 1998; Bertolami et al 2003; Mbelek et al 2003; Nieto, Martin, Turyshev et al, 2003; Palle, 2004; Ranada, 2004; Turyshev, et al, 2012.

original analysis and design.[9] However it is not particularly convincing. Given there were several factors overlooked, and the theorists were looking for a factor to reconcile the data to a preferred model (GTR), and the key factor found (a tiny heat asymmetry in the spacecraft) is based on a complex theoretical analysis (not confirmed empirically), the Pioneer experiment cannot be taken as a reliable test of such fine-scale effects.

It was just an accident that the Pioneer data turned out to be just sensitive enough to pick up this scale of difference between TAU and GTR. Conventional tests of "alternative gravity" are limited to testing a narrow range of variations of GTR, but these do not test K-gravity. (We discuss this in more detail in the context of the Lunar Laser Ranging experiments, which are similarly claimed as strong confirmation of GTR, but where the experiments also fail to distinguish GTR from TAU.)

To calculate the effects of gravity in TAU, we need a principle governing the motion of particles in the "curved space". This can be derived from first principles of the continuum mechanics, but because principles of energy and momentum conservation hold, this turns out to be equivalent to the usual *geodesic principle* in GTR, at least to an extremely good approximation. Applying this we then find that:

- The K-gravity solution corresponds precisely to the *GTR solution* for a mass-density that is slightly smeared out in space (to infinity), not a mass concentrated entirely in a central region in empty space, as assumed in the normal Schwarzschild solution.

Smearing a mass out beyond a given radial shell reduces gravitational effects within that shell.

The substitution of *K* for *k* defines the K-gravity *solution* for $g_{\mu\nu}$. But we can now reverse the usual GTR derivation (from: $T_{\mu\nu} \rightarrow g_{\mu\nu}$), and instead derive the stress-energy tensor $T_{\mu\nu}$ required to produce this $g_{\mu\nu}$ (i.e. $g_{\mu\nu} \rightarrow T_{\mu\nu}$). This is analytically solvable. We consequently obtain the pressure-density distribution required to produce K-gravity in conventional GTR. The calculation shows the mass-density $\rho(r)$ required to produce $g_{\mu\nu}$ for K-gravity varies primarily with $1/r^4$ for large r. The series expansion in terms of $1/r$ is found to be:

$$\rho = (M^2G/4\pi r^4K^2) + (c^4/8\pi Gr^2K^2)((2MG/c^2r)^3/3! + (2MG/c^2r)^4/4! + \ldots)$$

This solution shows something interesting about GTR. The defining equation is:

$$G_{\mu\nu} = R_{\mu\nu} + \tfrac{1}{2}g_{\mu\nu}R = (8\pi G/c^4)T_{\mu\nu} \qquad \text{Einstein's Equation.}$$

This equates the *space-time metric* $G_{\mu\nu}$ on the LHS to a function of the *stress tensor* $T_{\mu\nu}$ on the RHS. Now $G_{\mu\nu}$ represents a geometric description in Riemannian geometry, and *this purely geometric description still holds for K-gravity*. But the application of the equation requires the *physical interpretation of* $T_{\mu\nu}$, the empirical term on the RHS. This is calculated from mass-energy distributions, requiring another theory. TAU forces us to reinterpret *this* term – as we must expect because it changes the physical interpretation of mass.

TAU means that *mass is never concentrated at a point,* it is always continuously distributed to infinity! The reason is illustrated in the strain diagram above. The presence of a mass continuously strains space, the strain function is continuous and positive to infinity, and this is responsible for

[9] Turyshev, et al, 2012.

gravity. Hence it is impossible to have $T_{\mu\nu}$ or ρ with "sharp boundaries" or a discontinuity in space – and so it can never go to zero.

Imposing: $T_{\mu\nu} = 0$ outside a region, and: $T_{\mu\nu} \neq 0$ inside a region, as assumed in the derivation of the Schwarzschild solution, means that $T_{\mu\nu}$ *cannot be an analytic function across all space,* and contains a singularity or analytic discontinuity. (Indeed this discontinuity in the conventional *mass distribution* is what really produces the usual black hole event horizon singularity.)

- K-gravity removes this singularity, and thus removes the black hole event horizon, normally assumed to be a surface at: $r = 2MG/c^2$ where quantities become infinite.
- But the curvature in K-gravity starts to become large around this distance, and it is still effectively the "black hole radius".

Hence the nature of "black holes" changes dramatically in TAU. Strictly speaking there are no black holes as understood in GTR. But the curvature of space becomes large around the Schwarzschild radius so that particles and radiation effectively can become trapped. Dense concentrations of matter are still appropriately called "black holes", and they occur when there is sufficient mass density that the Schwarzschild radius extends beyond the normal physical radius of a very dense object. But K-gravity predicts that "black holes" will behave quite differently in some respects to those predicted by GTR. E.g. they can leak radiation, and proper time does not slow to zero and quantities no longer become infinite.

The TAU alternative the GTR black holes remains consistent with observation. Although "black holes" at the centres of galaxies are assumed to be GTR black holes in physics, a GTR event horizon has never been observed, and its specific properties have never been confirmed. TAU would remove one of the main conceptual anomalies of modern physics, and it makes "black holes" simpler.

This close match with GTR means TAU predicts a viable theory of gravity on a local scale, and it is consistent with GTR at significant distance from the mass, but also has distinctive differences. However we see another fundamental effect: *straining space changes the speed of light, c.* This is evident in conventional GTR, as we already saw above. But in conventional GTR there is no physical explanation or mechanism – it is just a result of the formal equations. In TAU, there is a physical explanation.

The fundamental constant *c* characterises a property of space. It is continuum property, related to the *surface tension.* When space is distorted, as under the gravitational strain, this changes. We will soon see that all the "fundamental constants", c, h, G, ε_0, as well as the elementary masses and charge: m_e, m_p, m_N, q, must be taken to characterize *properties of space* in TAU. And they are *dynamic* and can change with changing properties of space. Their values are not set in stone, for all time, as magical values determined at the "creation" of "space-time" in a mystical "big bang" event.

But this gravity theory now raises two distinct problems:

- What happens at the central singularity, when we approach $r \rightarrow 0$? Can we extend the K-gravity solution to the centres of individual particles?
- Is K-gravity consistent for infinite space?

We will continue on with the second question, and we now return to our larger model of space.

Global space.

Our model means that at every point of ordinary 3D *XYZ*-space there are three more hidden dimensions. So the whole space is a six dimensional space, with a five dimensional hyper-surface on which ordinary long-lived particles are stable wave modes. But what is the topology of the large space? The main problem with the basic K-gravity solution above is that in infinite "flat" space, the *volume integral* of the strain function goes to infinity. I.e. a finite mass will produce an *infinite volume increase,* in terms of the 6D volume. This is not physically feasible.

Instead we have to make space finite, and using the model we know from cosmology, i.e. the expanding universe, we make *XYZ* space into a 3-sphere. It is extrinsically curved in a fourth dimension, which is one of the torus dimensions. So we return to consider the combination of the torus with ordinary space.

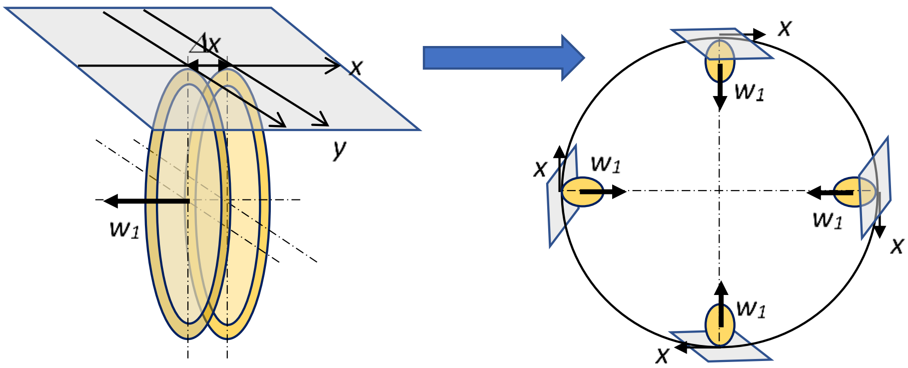


Figure 24. LHS. The torus embedded at points in a locally flat *XY* plane. RHS. On the cosmological scale, *XYZ* is a 3-sphere, and the *XYZ* directions rotate into the w_1 direction as we move in a fixed direction on the surface. W_1 is the axial direction of the torus.

Note first that the diagram on the LHS shows the torus at two points very close together in *x.* This illustrates that two particle trajectories can interact at much closer distances in *x* than the large radius R_e. But the R_p is the natural limit. The electric charge spirals around the proton radius, R_p, and cannot be localized more precisely in *XYZ* space.

Now *Lorentz symmetry* holds locally around a point, and space is "locally flat". If the *XYZ* space extended flat in all directions, as indicated by the LHS diagram, it would correspond to a globally flat STR metric over infinite space. But this is not possible in TAU, because it would make the volume integral of the strain function infinite (and it is incompatible with an expanding universe). Instead, we make space a 3-sphere, a finite closed universe, and the volume integral becomes finite.

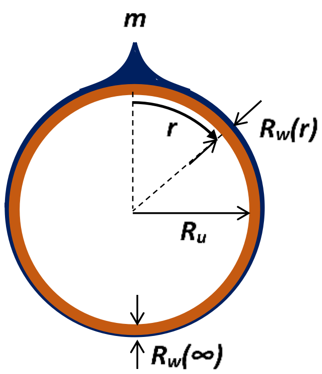


Figure 25. A particle imposed on an empty TAU universe strains the torus and increases the 6D volume of space. For a closed hyper-spherical universe, we can integrate around the whole universe, and the extra 6D volume is finite.

The finite radius changes the *strain equation* and gravity equations we saw earlier to a slightly modified form:

$$K(M,r) = e^{\frac{MG}{c^2}\left(\frac{1}{r}+\frac{1}{\pi R_U}\right)}$$ Strain function in finite universe.

The additional factor of $1/\pi R_U$ comes from integrating the strain around the finite hypervolume. It is extremely tiny and can be ignored in all local gravity. But it is essential for the global consistency, and in the very early universe. And we see the strange feature that *the radius of the universe* enters into the local equation for gravity!

(Note also that *G* and *c* are constants for "background space", without mass present. Once we get into the full theory we have to start distinguishing dynamic values for the constants).

Our first concern here is with the curvature, and construction of the hyper-space. The expanding universe is described in standard cosmology by the Friedman equation, and curvature is treated as *intrinsic curvature,* in the formalism of Riemannian geometry. We can generally translate our solutions back into these conventional terms. But our underlying model is very different. We define space as an *extrinsically curved hyper-surface.* This is not possible in conventional physics, with only three spatial dimensions. Note also that we disentangle *time from space* by splitting the effects into the *spatial curvature,* combined with the *modification of the speed of light*.

The striking point of difference is that *space* in TAU is an *extrinsically curved 5D surface*, bounding a 6D volume. Conventional physics treats 4D *space-time* as an *intrinsically curved* Riemannian manifold. The formal possibility of switching to *extrinsic curvature* is ensured by *Whitney's theorem (1933).* But we do not just make a formal reinterpretation. We physically disentangle *space from time*. Space and time are thought to be quite inseparable in GTR; but they are separable in our slightly modified theory.

Space as a whole is then a kind of 6D *aether.* We should stress that our ordinary 3D space alone is not an "aether" as C19th physicists thought of it: it is a "surface" of larger manifold. The 6D space as a whole is a concrete manifold, with a finite surface, which can be distorted, vibrate, change shape. It has real properties, such as a *surface wave speed (*the speed of light, *c),* an *elasticity* (related to *G),* a 6D *volume* and a 5D *surface area.* A fundamental principle is that the total 6D volume of the manifold is conserved under distortions. Such a property cannot even be conceived in conventional theories. But it is natural and inevitable in TAU, and it is the source of very powerful theoretical and empirical relationships and predictions.

Treating curvature as *extrinsic* may seem impossible to relativity theorists, but it is perfectly valid. It is guaranteed that we can do this by a foundational theorem of differential geometry: Whitney's theorem (1933), which states that an intrinsically curved space in N dimensions can always be modelled as an extrinsically curved hyper-surface in at most 2N dimensions – and if N is odd, at most 2N-1 dimensions. Any intrinsically curved 3D Riemannian space can be modelled as extrinsically curved in 5D. The global curvature in our model is simple, and it can be modelled in 4D, with ordinary space as the 3D hyper-surface of a 3-sphere.

This means that if we travel in a "straight line" in space, say in the x direction, the *x-vector* really rotates. It does not rotate in the y or z directions, but in *one of our w directions.* By the time we are a quarter of the way around the universe, the *x-vector* will point completely into the original w direction. By half-way around, it will point in the opposite of the original x direction. It is precisely analogous to travelling around on the surface of a sphere.

This also means that the fourth direction of curvature must be in a specific w direction. To make this consistent and to match with the *spin asymmetry* of the electron, it proposed that this is the direction of the torus axis. We will call this direction w_1. It is always orthogonal to the w_e direction at any point on the surface of the torus. It is parallel to w_p from points on the outer or inner circumference. (The direction of w_p of course rotates as we go around the small proton circumference on the torus). The direction of w_1 rotates into x as we travel in any *x direction* around the universe.

W_1 also provides an asymmetric direction for the *spin direction* of the electron and proton waves in the torus, and the asymmetric spin of the EM field. We use a "left-hand rule" to associate spin direction of the electron with motion, just like spin direction of the magnetic field produced by motion of electrons in a current. This is a major *time asymmetry* in particle physics. If the physics was time reversed, we would have "right handed electrons". This should not be confused with the merely "conventional" labels for electric charges or magnetic fields. The physical asymmetry is that *only one direction of spin is allowed.* The asymmetry is apparent in ordinary quantum mechanics. It is often claimed that quantum mechanics the ordinary Schrodinger equation is *time reversible,* but this is not correct, as *only half the possible wave function solutions are allowed*. (See Holster 2003(a)).

Physicists get around this by defining *time reversal for quantum wave functions* as the combination of true time reversal, *T* (which reverses both trajectory motions and spin direction), plus complex conjugation, **,* to restore the spin direction, and this is called the *Wigner time reversal operator*, *T*.* This is adopted because *T** is a real physical symmetry. But it is misleading about the symmetries. The physical solutions are time asymmetric. This corresponds to the asymmetry of spin rotation in our model.

We can now take spins to be "± *into the w_1 direction".* This spatial asymmetry – *towards and away from the cosmological center* – also allows a physical basis for the asymmetry of the weak force. In conventional theory, there is no underlying physical basis for a distinction of spatial directions.

- This model means that *on a global scale, there is a unique frame of reference for space.*

Locally, space is flat (STR metric), and we can transform between moving frames of reference, using the Lorentz transformations. This holds for ordinary physics on a local scale. But there can be only *one consistent global frame* in our model. This is essentially because rotation or angular momentum is absolute. This is obvious in our model because we have *extrinsic curvature,* introduced through additional dimensions of space.

This is seen if we consider sending light signals around a symmetric static universe. An experimenter could send two light signals in orthogonal directions, *x* and *y*. They will eventually circle the universe, and come back, and cross at the point they originated from. If the experimenter is in the true *stationary global frame,* the light beams will cross where they started, back at the original position of the experimenter. If a second experimenter is moving w.r.t. first experimenter, and sends two similar light beams (when the two experimenters coincide in space), those light beams will follow exactly the same paths, and meet back at the same point. But the moving experimenter will now have moved to a different position, and will not be at the point where the light beams meet. The experimenters will be able to tell whether they are really stationary w.r.t. the global frame.

We cannot expect that *local covariance* rules out a unique global frame of reference for the universe as a whole. It is empirically evident in the unique "stationary frame" for the cosmic micro-wave background radiation (CMBR). This is the frame in which the CMBR is isotropic. This special frame is adopted in cosmology as stationary. The Big Bang cosmology makes no sense in other frames. E.g. the "cosmological principle", which claims *homogeneity and isotropy* on the large scale, can only possibly hold in (at most) one frame. A moving frame induces relatively different concentrations of matter and light in the direction of motion. This requires *a global frame of simultaneity, and an absolute frame of space.* It contradicts the usual space-time metaphysics. But remember, we are changing the number of spatial dimensions. That is the major change in the way we see space.

This brings us to the TAU *cosmology.*

Cosmology.

The global topology in TAU matches general features of standard cosmology, i.e. Robertson-Walker models for an expanding universe, but only up to a point. It departs for the very early universe, where conventional cosmology is a purely theoretical extrapolation. It similarly departs for long-term future predictions. And it departs in the interpretation of dark matter, dark energy, the Hubble tension, and gravitational constant, that are not explained by conventional cosmology.

At present the universe is expanding. The simplest solution from TAU predicts that the radius follows a simple cyclic function, it will reach a maximum radius after a certain time, and contract again. When it reaches a minimum radius, it will "bounce", and go into new expansion phase. This solution may be modified, but it is good to illustrate the mechanics. However the big difference in the theory is that TAU requires that *fundamental constants are dynamic,* as they characterize properties of space, and as space expands and contracts, constants change and processes will run faster or slower as a consequence.

Now our *conventional measured variables* (for space, time, mass, charge) are fixed instrumentally to physical (atomic) processes that are governed by the constants: $c, h, \varepsilon_0, q, m_e, m_p, m_N$, and we do not normally notice this change – because all the local electromagnetic and quantum processes change in unison. But gravity behaves separately, and we can measure changes in its relative strength to the EM force, and predict discrepancies in measurements taken across large time periods. However more generally, the fact that instrumental variables may appear unchanging to us does *not* mean that these variables are adequate to write the laws of physics.

When we write the laws of physics in TAU, we have to adopt "true variables" for the laws to be invariant over time. This *time translation invariance* is the most fundamental assumption of physics – it is the assumption that *there are unchanging laws of nature.* We can have changing constants without breaking this assumption, but they must be changing in a larger framework of simple invariant laws. However the laws of TAU are not *time translation invariant* in our conventional variables.

This gives the two key problems of the TAU cosmology.

- Constants *c, h, G,* etc, change values with expansion, and can be solved as functions of the universe radius, R_u.
- R_u changes with time, and can be written as a function of time: $R_u(t)$. This is the *expansion function,* and it describes the history of the universe.

The first problem we can solve exactly – or at least, we propose an exact solution, which is consistent with our larger theory. Whether it is the only plausible solution is really still an open question. But this is a question that is simply not considered in conventional physics, and showing how a solution works is important as a concrete example. For the second, I put forward the simplest realistic solution I can think of, which has a strong logical consistency in the model. This is bound to be modified, but again having a concrete solution is important to illustrate fundamental features of the model.

This solution assumes a homogenous 3-sphere for space, characterized by one variable, $R_U(t)$. (I.e. we ignore cosmological inhomogeneities – and the possibility of a spatially distorted universe. The universe might also have an alternative topology, e.g. a 3-torus rather than a 3-sphere. We ignore this here, and only consider the simplest possible solutions.

The problem is to model the expansion of the universe consistently with the effect on the local micro-physics that happens in the torus.

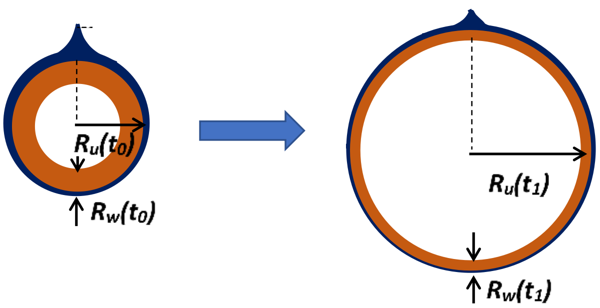


Figure 26. Left, the universe at earlier time, t_0. Right. At a later time t_1, the hyper-sphere has expanded, the torus has contracted. A particle (blue) strains space, and as the universe expands the strain decreases. The solution must ensure conservation of total volume.

The fundamental principle is *conservation of the 6D spatial volume.* The aether acts like an incompressible fluid, with a surface tension. The volume is essentially the product of the *torus* *volume X 3-sphere volume.* The fundamental effect is that as the 3-sphere expands, the torus shrinks to maintain the volume.

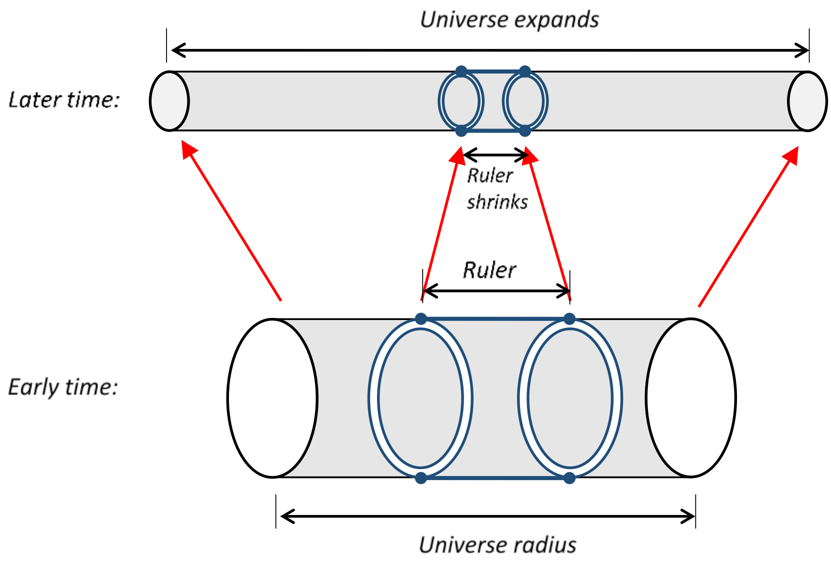


Figure 27. The expanding universe has two opposite effects. Local objects bound together by EM forces, e.g. atoms, molecules, rulers, etc, shrink – as the torus dimension shrinks. The universe as a whole expands – and unbound objects like galaxies separate.

As the universe expands and the torus shrinks, the *real dimensions* of atoms shrink, the *real speed of light* increases, the *real particle masses* decrease, the *fine structure constant* is constant, the real linear momentum is constant. Because of the scale symmetry, as the torus shrinks, all the objects shrink with it. Rulers, clocks, us, etc. We are turning into shrinking people! Yikes! But we don't seem to notice. Locally, all the material objects locked together in strong energy relations are shrinking together. But the opposite effect is happening on the astronomical-intergalactic scale: the distance between galaxies (or objects not bound by local forces) increases, as they are separated by the global expansion of space. This is the Hubble expansion. But to interpret it now, don't we have to take into account that light was travelling slower in the past? ... and what about gravity? If the distance to the moon increases because of weaker gravity but the speed of light increases … or the rate of supernova production was different in the part … or the luminosity of stars in the distance ladder … our inferences about measurements are have to be recalculated.

The upshot is that we need to find transformations from conventional *instrumental variables*, which are actually changing, into *true model variables,* which are not changing. These will be dashed variables. Note that this only applies to the *base units for: r', t', m', q',* or their *differential quantities: dr', dt', dm', dq'.* This coordinate system is *not changing*. The instrumentally-defined quantities or coordinates use the mass of atoms and periods of atomic processes to define space and time measurements, and they *are changing*. This means fixing: m_e, m_p, c, h, q_e *as constant.* This defines everything as constant by definition, except *G.*

It is quite well confirmed this works empirically: and the TAU model matches this result. Only *G* appears to change, in instrumental coordinates. But what really changes? The TAU model starts with the 6D volume conservation.

Transformations and evolution equations.

The exact 6D volume is: $Vol = (\pi/2)R_U^3R_W^3$, but ignoring the small constant of integration $(\pi/2)$ the essential invariant is the *invariant length, L*:

$$L^6 = R_U^3R_W^3 = Constant \qquad \text{Volume conservation.}$$

But note that this equation only holds generally in the *true variables,* as we see. By the end of this section we will switch to using dashed variables for the true variables, when we need to use them. So we can continue to use our normal variables as they are.

We identify: $R_W = R_A = (R_eR_p^2)^{1/3}$ from particle physics: the *average torus volume-radius* that we obtained in the particle theory. For a simple model we assume this is an average over a fairly homogenous universe.

Note we use R_W in the cosmology theory as a generic variable, and identify it with R_A, as the specific amount determined by the two masses in the particle theory. It is essential the radii are in this combination, which corresponds to the combination of masses: $m_A = (m_em_p^2)^{1/3}$.

This is the topology the *torus model for particles* determines: the *torus volume* is the combination: $R_eR_p^2$. The invariance of this is the source of key relationships between *local constants,* that R_A depends on, and the global universe radius, R_U.

Now: $R_A = \hbar/m_Ac = \hbar/c(m_em_p^2)^{1/3}$. (Again, we ignore the small factors of ½ for fermions here.) The true quantities for: m_e, m_p, c and $\hbar$ may all be expected to vary with expansion in our theory. To solve the cosmology we must take into account changing constants, with changing basis units (our instruments are shrinking), and use the special role of *the present moment* as the reference point in the measurement of constants. It requires a set of transformed variables to represent, because it means that the values of constants measured at the *present moment* change, and this means that *the basis units for space, time, mass and charge* must change magnitude, in our normal system.

- So we define a transformed coordinate system with dashed variables, and their relationships with the universe radius, R'.

A critical concept for this was recognised by Dirac (1969), who developed a cosmology in which the constants may change: *G, h, c, m, q*. He started with a simpler theory (in 1937), but the first version failed.[10] It does not take into account that a *transformation of variables* is required. In the 1960s, Dirac realised that a transformation makes more general solutions possible. If fundamental constants change, *basis units for quantities may also change,* and we must transform from our conventional system of "measured quantities" to a system of "true quantities" in which the laws are written.

Dirac showed in principle how this can be done as a differential transformation. His own theory was motivated by what he called the *Large Number Hypothesis (LNH).* Certain dimensionless numbers can be constructed from fundamental constants and global variables: $c, h, G, m_e, m_p, q^2/\varepsilon_0$, the age T, radius R, and the number N of mass particles. The values of the dimensionless numbers have several distinct coincidences. Although his theories were rejected, Dirac remained convinced that these

[10] Dicke, 1961; Dyson, 1977.

"large number coincidences" reflect physical relationships for the rest of his life. The problem was he had no model to determine how the constants should change, *except to determine the Large Number relationships*. He just made an educated guess to get a theory going. It was slightly wrong but a good idea. TAU gives a second version, but based on a more determined model.

Dirac's theory relates the *age of the universe (time)* to the value of changing constants. However TAU relates everything to the *universe radius.* We do not relate constants directly to time.

We first provide the *variable transformations and evolution of the constants in terms of R.* And then solve the *universe radius* as a function of time, as seen in our own measuring system. We give functions for the *values of constants like c, h, G, etc,* in terms of a *normalised radius of the universe, R-hat:*

$$\hat{R}(t) = R_U(t)/R_0 \qquad \text{Normalised radius.}$$

Here: $R_0 \equiv R_U(t_0) \equiv R_U(Now)$ is the present radius, and $t_0 = Now$ is the present time for us. We must recognise in the formalism that our measurements and observations are made *at our present time,* when the universe radius and the constants have their particular values *Now*. We use the special time variable: T with the origin: $T = 0$ set at the time of minimal expansion in the past (the Big Bang). So T effectively represents the *time since the Big Bang,* which is what physicists generally call the *age of the universe.* It has the same metric: $dT = dt$.

We can imagine physicists at a different cosmological time to us, say a billion years ago, who measure quantities the same way as us *instrumentally*. Some of the constants will be changed, and their *basis units for time, space, mass and charge* will be in a different system of physical units to ours. E.g.

- If we both define mass using the *mass of the electron or proton* as a standard unit, the *basis unit for mass* is reducing.
- If we both define length using the *Compton radius of the electron:* $r = \hbar/m_e c$ as a standard unit, the *basis unit for length* is reducing.

This means there is a difference between *true variables,* and *measured variables.*

- The laws of physics must be written in the *true variables* to have their correct form to match the model, which makes them *time translation invariant.*

Only in the true variables will the laws be simple and invariant and correspond to the model.[11]

So we assume that there is a system of *true variables for space, time, mass, charge* in which the laws have their simplest form, and are *time translation invariant*.

- We will take: (x,t,m,q) as our conventional *measured variables,* and (x',t',m',q') as the *true variables,* and establish transformations: $(x,t,m,q) \Leftrightarrow (x',t',m',q')$.
- Similarly we take: $(c,h,G,m_e,m_p,q,\varepsilon_0)$ as our *measured constants,* and $(c',h',G',m_e',m_p',q',\varepsilon_0')$ as the true constants, and establish transformations between them.

[11] If we insist that comparison with some standard mass like the electron mass is *the definition of mass,* that would make the electron mass constant throughout time by definition..

The same issue arises for our *radius* variable: R_u and "age of the universe" *variable: T.* We must use the true variables, R_u', and T', to define the fundamental laws, and subsequently transform them back into our conventional variables, R and T to interpret ordinary measurements. We use *normalised variables* for these as the key parameters in evolution functions.

Normalised variables.

$\hat{R}' = R'/R_0'$ and: $\hat{R} = R/R_0$	Definition of normalised radius universe.
$\check{T}' = T'/T_0'$ and: $\check{T} = T/T_0$	Definition of normalised age.

The *true normalised radius variable*: $\hat{R}'(T') = R_U'(T')/R_0'$ is used as the parameter in our functions.

Note below we often write: R or R' for the universe radius, R_U or R_U', where it is unambiguous. We generally use a subscripted 0 to represent *present values.* The basis unit transformations are defined as differential transformations like: $dt = f'dt'$, where $f's$ are all *simple functions of the normalised radius,* $\hat{R}' = R'/R_0'$. The solutions for variables and constants in TAU are proposed as follows. We simply state these here, and explain their rationale in more detail in a Chapter.

The variable transformations.

$dx = \hat{R}'dx'$	Space metric transformation
$dt = \hat{R}'^2dt'$	Time metric transformation
$dm = \hat{R}'dm'$	Mass metric transformation
$dq = \hat{R}'dq'$	Electric charge metric transformation

The evolution equations for the constants in true variables.

$c' = c_0\hat{R}'$	Evolution of speed of light constant.
$h' = h_0/\hat{R}'$	Evolution of Planck constant.
$G' = G_0$	**True gravitational constant is constant.**
$m_e' = m_{e0}/\hat{R}'$	Evolution of electron mass.
$m_p' = m_{p0}/\hat{R}'$	Evolution of proton mass.
$q_e' = q_{e0}/\hat{R}'$	Evolution of elementary electron charge.
$\varepsilon' = \varepsilon_0/\hat{R}'^2$	Evolution of electric force constant.
$\mu' = \mu_0$	Evolution of magnetic force constant.

(These must be determined and justified from the underlying mechanics of the manifold.)

The transformations are completed by specifying boundary conditions at the origin:

Boundary conditions.

$R \rightarrow 0$ as $R' \rightarrow 0$	Zero radius of the universe.
$T \rightarrow 0$ as $T' \rightarrow 0$	Zero age of the universe.

And boundary conditions matching true and conventional values at the present time:

$dx_0' = dx_0$ $\quad dt_0' = dt_0$ $\quad dm_0' = dm_0$ $\quad dq_0' = dq_0$

$c_0' = c_0$ $\quad h_0' = h_0$ $\quad G_0' = G_0$

$m_{e0}' = m_{e0}$ $\quad m_{p0}' = m_{p0}$ $\quad q_{e0}' = q_{e0}$ $\quad \varepsilon_0' = \varepsilon_0$ $\quad \mu_0' = \mu_0$

This defines the general system of dynamic constants proposed in TAU, and we can now solve the evolution of conventional variables in terms of true variables.

Inverse evolution equations.

$c = c'/\hat{R}' = c_0$	c is constant.
$h = h'\hat{R}' = h_0$	h is constant.
$G = G'/\hat{R}'^2 = G_0/\hat{R}'^2$	**G is decreasing.**
$m_e = m_e'\hat{R}' = m_{e0}$	m_e is constant.
$m_p = m_p'\hat{R}' = m_{p0}$	m_p is constant.
$q_e = q_e'\hat{R}' = q_{e0}$	q_e is constant.
$\varepsilon = \varepsilon'\hat{R}'^2 = \varepsilon_0$	ε_0 is constant.
$\mu = \mu' = \mu_0$	μ_0 is constant.

Note that all the conventional variables *except G* are constant. This is expected as they are defined instrumentally. Conversely, all the constants *except G* vary with $\hat{R}'$ in the true variables.

Evolution of special quantities.

Note that our *conservation of 6D volume* law holds in *true variables,* by substitution from above:

$$R_U'R_A' = R_U'\hbar'/c'(m_e'm_p'^2)^{1/3} = R_U\hbar/\hat{R}'c(m_e m_p^2)^{1/3} = R_0R_{A0} = constant$$

But the 6D volume in conventional variables is not constant:

$R_UR_A = (R_0R_{A0})\hat{R}$ Volume in conventional variables varies with *R*.

This is an example of the fact that *the laws of nature only appear correctly in true variables.*

In true variables, constants change, to reflect properties of space, e.g. the *speed of light* reflects surface tension, and it changes with expansion. But in conventional variables, the speed of all our processes increases, including our clocks, so our measurement of time increases speed with light, and our measuring instruments shrink, but the speed of light appears to remain the same. A quantity may be constant in one system and variable in the other.

However *dimensionless quantities* have the same values in either system. There are only about four independent dimensionless quantities.

- The *fine structure constant, α,* is predicted to be constant:

$\alpha = q^2/4\pi\varepsilon_0 hc = q_0^2/4\pi\varepsilon_0 h_0 c_0 = constant = 1/137$ Fine structure is constant.

This holds in either set of variables (because it is *dimensionless)*, and it follows by substituting from the equations above.

- The dimensionless ratio of electron to proton mass is also constant:

$m_e/m_p = m_{e0}/m_{p0} = constant = 1/1836$ Mass ratio is constant.

And this means the *average mass ratio* is constant:

$m_e/m_A = m_{e0}/m_{A0} = (1/1836)^{2/3} = 1/150$ Average mass ratio is constant.

This is why it is possible to identify: $\alpha \approx m_e/m_A$ in our model. There is also a dimensionless constant defined from *c, h, G, m,* which we call the Dirac constant.

- The dimensionless *Dirac constant, D,* changes with $\hat{R}'^2$.

$D = \hbar c/m_A{}^2G$ Definition Dirac constant.

Substituting values from above:

$$D = \hbar c/(m_e m_p{}^2)^{2/3}G = D_0\hat{R}'^2$$

We must use the mass combination: $(m_e m_p{}^2)^{2/3}$ in the theory, because this is the *invariant average mass* corresponding to volume. Because *D* is dimensionless it has the same value in any variables:

$D' = D$ Identity.

And there is one more: the dimensionless cosmological ratio:

- The universe – torus ratio changes with $\hat{R}'^2$.

$R_U/R_A = (R_{U0}/R_{A0})\hat{R}'^2$ Universe/Torus ratio.

We then state the fundamental relation, that was predicted in a different form by Dirac, by equating these two dimensionless constants:

$R_U'/R_A' = D' = D$ Dirac-TAU relation.

But we can just take it as an empirical postulate for now. Substituting for the definitions, with: $R_A = h/c(m_e m_p{}^2)^{1/3}$ (ignoring the factor of ½) this predicts the *radius of the universe* from purely local constants in its simplest form as:

$$R_U' = R_A'D = \hbar'^2/(m_e' m_p'^2)G'$$

This relation holds at all times, and we can substitute the present values: $\hbar_0{}^2/(m_{e0}m_{p0}{}^2)G_0$, and we get the value as (the simplest possible combination, without geometric factors, except in $\hbar^2$:

$$R_{U0}' = \hbar^2/(m_e m_p{}^2)G = 6.91 \text{ billion light years.}$$

- Coincidentally, this is exactly half the measured *age: 13.82 billion light years, times the speed of light.*

It seems a strong coincidence that this coincides with *precisely half the measured age of the universe times the speed of light.* There are two main current methods used to estimate the age (time since the Big Bang), which give measured values of about 13.77 - 13.81 billion years.

Now the age predicted by these methods is really giving us estimates, one way or another, of the time it has taken light to travel across the universe from events, starting soon after the Big Bang.

So we have to predict the *co-moving coordinates in TAU* of this light, and this is what the result seems to represent: the age times the speed of light. We are measuring how far the light has come, and this seems to be what the TAU radius means, at first. The measurement of age from the CMBR also measures how far the light has come from its production in the primordial universe, divided by *c* to get the time.

Note that this result is the first Large Number Coincidence, that inspired Dirac to formulate his theory. But he did not know exactly what to use for mass in the constant *D*, and he defines: $D^* = \hbar c/m_e m_p G$ (giving the electron and proton equal weight). Also he took the ratio as between the *universe age* and the characteristic *electron time:* $T_U/T_e = D^*$, which corresponds to: $T_U=\hbar^2/(m_e^2 m_p)Gc.$ This is empirically wrong by about a factor of 100. He still thought this was a strong coincidence – because we are combining multiple constants with large powers, on the scale of 10^{-30}, to produce a result within 10^3. But our torus model forces us theoretically to adopt a different combination of masses: $(m_e m_p^2)$, and this gives an even more freakish coincidence!

Now our prediction almost looks like it is pointing to an *exact relationship with the age of the universe* – in which case, where does the factor of ½ come from? Well, factors of ½ and 2π are floating around in our geometry, and in the choice of *h* or *ħ.* E.g. we should strictly define R_w as half the value taken above to conform to our electron-proton model. But we may also expect the relation to predict a comoving-distance around the *circumference,* the comoving distance from the light source, not the radius or total circumference of the universe. (The latter will turn out to be more like 30 - 100 bly.) But we should not worry about the factor of ½ initially, or conclude that it points to an exact relation yet. The close match to the *exact measured age of the universe* within a factor of *2* can be considered the very coincidental result. But to interpret it, there are two more questions.

First, our prediction is for the "*radius" of the universe,* in the *true distance variable,* R_{U0}'. But:

- How does this prediction of a value for R_{U0}' relate to the *conventional variable,* R_{U0}*?*

Second, the "coincidence" is that the *predicted radius* is related to the measured *age,* T_0, by the speed of light: $R_{U0}' = ½T_0 c.$

- But how does this predicted radius relate to the conventionally measured age in our theory? (And what is the relation between T_0 in conventional variables and the true age, T_0'?)

We will next determine the transformations: $R' \rightarrow R$, which is also necessary to determine the predicted rate of change of *G in conventional variables.* Then we return to the second question.

Predicted rate of change of *G.*

Note that our evolution equations above predict that:

- All the constants appear *invariant* in conventional variables *except G* (which actually just conforms to the instrumentalist definitions of conventional variables), but:
- All the constants actually *change* in true variables *except G*.

Hence the primary measurable prediction is that:

- *G* in conventional variables is decreasing with $1/\hat{R}'^2$ (in true variables).

This predicts the rate of change of *G* w.r.t. the *true variable,* $\hat{R}'$*.* But what we measure in experiments to determine the rate of expansion (the Hubble constant) is the rate of change w.r.t. the *conventional variable,* $\hat{R}$*.* And this is determined from measurements made *at the present time* – but referring back (through light sources from various types of stars) to distant events in the past. We have to translate the prediction for G into $\hat{R}$.

We can relate R and R', using the differential transformations above. We integrate using: $dR/dR' = dx/dx' = \hat{R}'$, and use the boundary condition that: $R \rightarrow 0$ *when* $R' \rightarrow 0$. (We will not assume a singularity in R' or R at the temporal origin, just a very small minimal value of R' and R close to the time origin we set for T.) For an arbitrary radius, R_1, we take the definite integral:

$$R_1 = \int_{0,R1} dR = \int_{0,R1'} (dR/dR')\, dR'$$
$$= \int_{0,R1'} \hat{R}'\, dR' = \int_{0,R1'} R'/R_0'\, dR'$$
$$= [R'^2/2R_0']_{0,R1'} = R_1'^2/2R_0'$$

This gives the key relationships, for an arbitrary radius R:

$R = R'^2/2R_0' = R'\hat{R}'/2$ General solution for R.

$\hat{R} = R/R_0 = \hat{R}'^2$ Solution for normalised radii.

$R_0 = R_0'/2$ Solution for present radius.

And the corresponding inverse relations:

$R' = 2R/\sqrt{\hat{R}}$

$\hat{R}' = \sqrt{\hat{R}}$

$R_0' = 2R_0$

The relation between R and R' is quadratic, not linear, but at the *present moment* the values are given by the simple linear relationship: $R_0 = R_0'/2$ or: $R_0' = 2R_0$.

Now substituting in the relation: $G = G_0/\hat{R}'^2$

$G(R) = G_0/\hat{R}$ Change of G in conventional variables.

So the rate of change is only the *linear inverse of* $\hat{R}$, not the squared-inverse, as on Dirac's original (1937) theory. Hence: $dG/dt = d(G_0/\hat{R})/dt$ at the present time, when: $R = R_0$. So:

$$\dot{G} = dG/dt = d(G_0/\hat{R})/dt$$
$$= -(G_0R_0/R^2)(dR/dt) = -G_0(dR/dt)/R_0$$
$$= -G_0(d\hat{R}/dt)$$

Hence the *normalised rate of change of G* is predicted to be just:

$\dot{G}/G = -d\hat{R}/dt$ Normalised rate of change of G.

Hence TAU predicts that the normalised rate of decrease of G at the present time is precisely the normalised rate of change of R in conventional variables. This escapes the fatal problem of the simpler theories, which make the rate of change of G the squared-inverse.

Hence the predicted rate of change in G is simply determined by the *present rate of expansion.* This is measured by the Hubble constant. Estimates of the Hubble constant derive from cosmological periods in the past, and the interpretation has to be checked in the context of the new model.

Strictly we need to know the radius expansion function, and our point in the expansion cycle (next section). But the simplest assumption is that the Hubble constant is fairly stable, and its measured value is about: $H = 70$ *(km/sec)/Mps.* In units of sec^{-1} it is:

$$d\hat{R}/dt = H = (70\ km/sec)/(3.09 \times 10^{19}\ km) = 2.3 \times 10^{-18}\ s^{-1}$$

We convert this to a rate per year, and the normalised rate of change in *G per year* over the last few billion years should be about:

$$\dot{G}/G_0 \approx -7.14 \times 10^{-11}\ year^{-1} \qquad \text{Simplest predicted change of } G.$$

(It may be a little smaller, depending on the point of the expansion cycle we are at, but probably no less than about half this value.) Note the inverse is the *Hubble time,* which would represent the time for R to increase from 0 to its present size at this rate of change, and by another coincidence, this is very close to the measured age of the universe: $1/H \approx 14$ *billion years.*

Also, this prediction for the change in G depends on the present expansion rate, and as we will see subsequently when we solve the expansion function, it must be slowing in our model, but we take the value above as the higher realistic limit, and accurate over the past several billion years. So we must now examine whether this is consistent with measured values.

Several attempts have been made to measure the value of $\dot{G}/G_0$ directly. Note first that measurement of G alone is very problematic, and measurements vary between different studies at different times, well outside the standard errors estimated for the studies! Anderson *et al* (2015) finds a cyclic pattern of variation, with a period of about 5.9 years (which coincides quite strikingly with a variation in the Length of Day).[12]

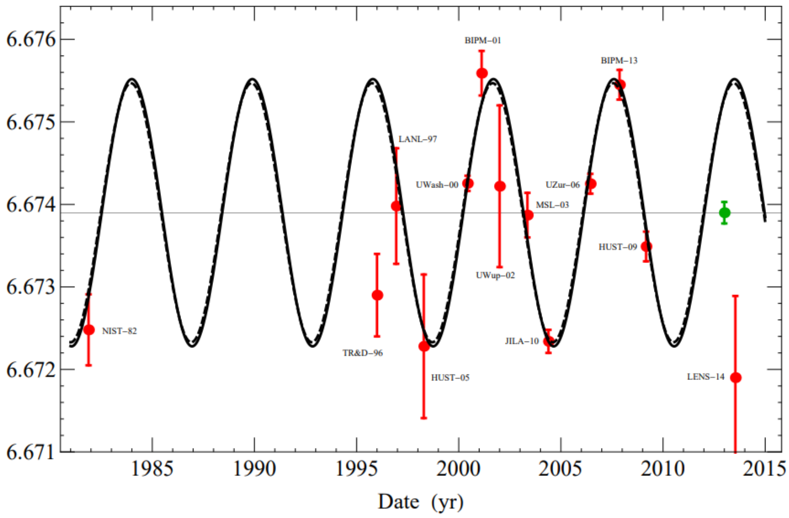


Figure 28. From: Anderson *et al* 2015, *p.2*. "*Comparison of the CODATA set of G measurements with a fitted sine wave (solid curve) and the 5.9 year oscillation in LOD daily measurements (dashed curve)*".

These are essentially the best (laboratory-based) estimates of G over the three decades up to 2015. This is a great illustration of how poorly we really know the value of G. The standard errors are much smaller than cyclic variations, and measurements of G vary dramatically, in a 5.9 year cycle. These would represent $\dot{G}/G_0$ varying cyclically by about 10^{-4} parts per year! This would swamp any variation

[12] Anderson *et al* 2015. Note that variations in G are possible in TAU if the solar system passes through clumps of dark matter. But that is not proposed as the cause of these cyclic variations.

on the order of 10^{-11} in the short term. Since it is thought that *G* itself cannot vary so much, it is expected that there is some local physical (e.g. mass flows in the Earth) variation, associated by Anderson *et al* with a similar oscillation in the terrestrial Length of Day. This is an interesting problem in itself, and it raises some questions over experiments.

However the *average rate of change:* $\dot{G}/G_0$ over longer periods can be measured much more precisely than *G* itself. There are two main types of measurements:

- Estimates from cosmological data, mainly supernovae and pulsars, determining *average change over billions of years*, and:
- Estimates from lunar laser ranging, determining *current rates of change*, from data over several decades.

The most robust estimates from the point of view of TAU are from studies of supernovae and pulsars[13]. The simplest (most robust) cosmological studies limit the rate of change of *G* to less than about $\pm 10^{-10}$ *parts per year,* as an average over about the last 9 billion years. Researchers then try to fit better models to take into account many cosmological features, to improve precisions. E.g. a recent analysis (Zhao et al 2018) claims the strongest precision so far from this kind of study, of around 3×10^{-12} year^{-1}, but this is the result from some complicated modelling assumptions, including in this case an assumption about the dependence of *G on t*: $G \propto t^{-\alpha}$. But this assumption and others do not hold in TAU.

> "As examples to compare our results with other constraints, we adopt z = 0.4 (z = 0.9) and assume a power-law cosmic time dependence, $G \propto t^{-\alpha}$, then the constraint $\Delta G(z)/G < 0.015$ is equivalent to a constraint on the index of $|\alpha|$. 0.04 (0.02), which can be translated into $|(dG/dt)/G|_{t=t0}$. 3×10^{-12} year^{-1} (1.5×10−12 year−1). This is of the same order as constraints from pulsars [4], lunar laser ranging [3] and BBN [5] (|(dG/dt)/G|t=t0 . 10^{-12} year−1). Most importantly, the new method offers a novel and independent way to constrain Newton's constant G over a wide redshift range 0 < z < 1.3, which could also be extended to 0 < z < 2 by future SNIa observations [37]." Zhao et al 2018.

If we look at the modelling in this paper and others that claim very high precisions, we get a sense of how complicated it is to get from about a precision of about 10^{-10} (which is robust), to 10^{-11} to 10^{-12} …10^{-15}? These claims of high precision involve modelling a lot of very fine effects. Some models are really being optimised to render the rate of change as close to zero as possible (i.e. using it as a condition, not a test). And most important, there is a major systematic problem with the method, as we see with the Lunar Laser Ranging analysis next. But we conclude initially that:

- The most robust cosmological studies show $\dot{G}/G_0$ is changing by less than $\pm 10^{-10}$ y^{-1}.
- This is consistent with the variation predicted by TAU, but close to the predicted variation.

However the strongest precisions are reported in *lunar laser ranging* (LLR) studies. These claim to set phenomenally accurate limits on *the current average rate of change in G ,* measuring its change over the last few decades (with data from the 1970s – 2010s). Precisions were improved by about three orders of magnitude over 10 years, from around 10^{-12} *parts per year* (Turyshev *et al* 2007, Müller *et al* 2007), to around [-5×10^{-15} to 1.5×10^{-13}] (Hofmann, F. and Müller, J. 2018). This involves

[13] Mould et al 2014. Zhao et al 2019.

measuring the distance to the moon within a millimeter and estimating multiple parameters to fit the models. (Pavlov et al, 2016; Boggs et al, 2016).

- These studies have ruled out changing *G* in the context of conventional *GTR*.

At first this appears to rule out the TAU prediction. But when we examine the LLR method carefully, we find it is not a valid test of TAU. The analysis in TAU actually predicts the same empirical result!

- The LLR experiments do not test TAU, and do not measure change in *G* according to TAU.

We now explain this in some detail. First we may observe that:

- The LLR analysis is based on looking for changes in *G in the context of conventional GTR.*

We may accept this analysis. But when we introduce the TAU variable transformations, we get a different analysis. The LLR analysis starts from Kepler's Third Law, for the period: $P^2 = 4\pi^2 r^3/Gm$. The time derivative gives: $\frac{\dot{G}}{G} = \frac{3\dot{r}}{r} - \frac{2\dot{P}}{P} - \frac{\dot{m}}{m}$. The method then depends on determining the values on the RHS empirically – primarily the *distance term* and the *period term, as* the mass term is regarded as effectively constant. If *G* is changing, it is inferred that this will be reflected in changes of: $\frac{3\dot{r}}{r} - \frac{2\dot{P}}{P} - \frac{\dot{m}}{m}$. This holds in conventional GTR. The question is: *how should these (conventional) quantities be related in TAU?* TAU gravity is very similar to GTR in this domain, and it predicts the same relationship – but *in true variables, not in conventional variables.*

We can work this out by considering an idealised experiment, with an orbiting mass, subject to the expansion of space. In the true variables, we obtain these relationships in TAU:

$$G' = G_0; \qquad \frac{dG\prime}{dt\prime} = 0; \qquad \frac{\dot{G}\prime}{G\prime} = 0$$

$$m' = \frac{m_0}{\widehat{R'}}; \qquad \frac{dm\prime}{dt\prime} = -\frac{m_0}{\widehat{R'}^2}\frac{d\widehat{R'}}{dt\prime}; \qquad \frac{\dot{m}\prime}{m\prime} = -\frac{1}{\widehat{R'}}\frac{d\widehat{R'}}{dt\prime}$$

$$r' = r_0\widehat{R}'; \qquad \frac{dr\prime}{dt\prime} = r_0\frac{d\widehat{R'}}{dt\prime}; \qquad \frac{\dot{r}\prime}{r\prime} = -\frac{1}{\widehat{R'}}\frac{d\widehat{R'}}{dt\prime}$$

$$P' = P_0\widehat{R}'^2; \qquad \frac{dP\prime}{dt\prime} = 2P_0\widehat{R'}\frac{d\widehat{R'}}{dt\prime}; \qquad \frac{\dot{P}\prime}{P\prime} = \frac{2}{\widehat{R'}}\frac{d\widehat{R'}}{dt\prime}$$

Setting the boundary condition: ${P_0}^2 = \left(\frac{4\pi^2{r_0}^3}{G_0 m_0}\right)$ we have:

$$P'^2 = {P_0}^2\widehat{R}'^4 = \frac{4\pi^2{r'}^3}{G'm'} = \left(\frac{4\pi^2{r_0}^3}{G_0 m_0}\right)\widehat{R}'^4 \qquad \text{Kepler's Law in TAU}$$

$$\frac{\dot{G}\prime}{G\prime} = \frac{3\dot{r}\prime}{r\prime} - \frac{2\dot{P}\prime}{P\prime} - \frac{\dot{m}\prime}{m\prime} = 0 \qquad \text{Differential in TAU}$$

So Kepler's law does hold in true variables in TAU. But now we must transform the relationships into *conventional variables,* to see what this predicts for the LLR experiments. These are:

$$\frac{\dot{G}}{G} = -\frac{d\hat{R}}{dt}$$

$$m = m_0; \qquad \frac{\dot{m}\prime}{m\prime} = 0$$

$$r = r_0\hat{R}^2; \qquad \frac{dr}{dt} = 2r_0\hat{R}\frac{d\hat{R}}{dt}; \qquad \frac{\dot{r}}{r} = \frac{2}{\hat{R}}\frac{d\hat{R}}{dt}$$

$$P = P_0\hat{R}^3; \qquad \frac{dP}{dt} = 3P_0\hat{R}^2\frac{d\hat{R}}{dt} \qquad \frac{\dot{P}}{P} = \frac{3}{\hat{R}}\frac{d\hat{R}}{dt}$$

And adding these up we get:

$$\frac{3\dot{r}}{r} - \frac{2\dot{P}}{P} - \frac{\dot{m}}{m} = 0$$ TAU prediction for LLR.

$$\frac{\dot{G}}{G} = \frac{3\dot{r}}{r} - \frac{2\dot{P}}{P} - \frac{\dot{m}}{m} - \frac{d\hat{R}}{dt}$$ TAU Kepler relation in conventional variables.

The first equation predicts the result measured in the LLR experiments.

The second equation gives the TAU relation in conventional variables.

- This means the LLR experiment *confirms TAU* just as much as it confirms GTR.

Hence the LLR experiment is not testing TAU against GTR. To test a theory you normally need to design specific experiments that distinguish its predictions from alternative hypotheses.

But this is not the only prediction of TAU. E.g. we get another empirical prediction from TAU using its relation: $\frac{dr}{dt} = 2r_0\hat{R}\frac{d\hat{R}}{dt}$ for the moon. This integrates to: $r = r_0\hat{R}^2$. This should give the moon's present radial spiral away from the earth *from the effects of cosmic expansion and weakening G combined* (but not from tidal forces). The factor of *2* adds the two equal components: the *speed from cosmic expansion* and *the speed from changing basis vectors*. Putting in the numbers:

$$r_0 = 380\ x\ 10^6 \qquad \hat{R} = 1 \qquad \frac{d\hat{R}}{dt} = 7.1\ x\ 10^{-11}$$

We get: $\frac{dr}{dt} = 2\ x\ 380\ x\ 10^6\ \ x\ 7.1\ x\ 10^{-11} = 5.3$ cm/year

This is *twice* the rate of separation of two *unbound objects* due to the Hubble expansion of the universe:

$$\frac{dr}{dt} = 380\ x\ 10^6\ \ x\ 7.1\ x\ 10^{-11} = 2.7 \text{ cm/year}$$

However, in *gravitationally bound systems* like the sun, earth, moon, it is normally assumed that orbital distances are locked, and the cosmological expansion does not come into play. I.e. the expansion is not usually added in the analysis. (Although it is 1,000 times larger than precisions being claimed in some LLR studies).

In TAU, it is not immediately clear what effects to expect. We should still expect the locking of gravitationally bound systems against the cosmological expansion. But the situation is more complex. The galaxy provides a bubble of higher-energy space in a colder inter-galactic background, and this bubble reduces the local effect of global expansion. (This acts like dark matter). But the relative change in basis units should still show up, reflecting the changed value of *G* imposed from the larger outside space.

If we adopt this assumption, we should subtract the expansion effect for bound orbits, as in the normal analysis. The remainder is a natural component of 2.6 *cm/year* increase in the moon orbit. This is change is from the changing basis/weakening G, independent of the expansion effect (and before other effects like tidal friction, etc, are taken into account.) Tidal friction effects then only need to account for 1.1 cm/yr to make up the observed value of 3.8 cm/yr.

This appears to allow a consistent history for the moon's orbit without any special hypotheses. In the present theory, it is a mystery why the moon is moving away so fast, at 3.8 cm/yr. When this speed is projected back into the past, we find the moon would have been close to the Earth only about 1 billion years ago, whereas we know it is about 4.5 billion years old. So it is believed that the moon's speed away from earth must have increased recently – within the last few hundreds of million years. The anomaly has been attributed to changing tidal patterns, but that is still hypothetical. In TAU, the distances to the moon appear realistic, back to 4.5 billion years ago, without these special hypotheses. There are other similar types of solar-system phenomenon that could be tested. So TAU is very testable.

What is concerning is that the LLR experiments do not actually test if gravity is weakening on *alternatives to GTR* – but they are taken as conclusive tests. Note that all the other LLR experiments, that are claimed as strong confirmation of GTR (e.g. tests of the equivalence principle) also confirm TAU just as strongly! They are taken as strong tests of GTR taken alone - but in fact they are only weak *tests of GTR against TAU.* The theorists have forgotten a cardinal principle of experimental testing: we must test *alternative hypotheses* against each other. For a well-known example used in the philosophy of science, the predictions of planetary movements and eclipses in C16th Ptolemaic astronomy were very accurate (and could be made more accurate with *ad hoc* additions of epi-cycles, etc), but they were really only weak tests of the Ptolemaic theory against Copernicus. Similarly, a solar system test of the *acceleration* predicted in TAU gravity versus GTR requires a specifically designed experiment *based on differentiating TAU from GTR*. This has not been done. The whole class of theories like TAU that incorporate changing constants is currently overlooked by NASA and the ESA and other high-profile experiments.

We should also beware that the interpretation of the LLR data models fine adjustments for multiple effects, such as tidal friction of the moon, solar perturbations, seasonal variations in orbits, changed speed of light in gravity and in the atmosphere, flow of molten cores within the Earth or moon, thermal expansions, etc. To get a sense of the sensitivity, the claimed LLR precision requires measuring the distance from the earth to the moon to within a *millimetre!* There is some intricate modelling involved, with practical ongoing calculations of lunar flow boundaries and other properties. We must be sceptical that these really set precisions of $\pm 10^{-15}$ for $\dot{G}/G_0$. Rather, they show that models can be fitted to match this idealised accuracy, but that is different from testing $\dot{G}/G_0$ at this precision.[14]

In any case, the LLR does not test TAU directly, but improved cosmological data can. Besides these tests, the general prediction is that gravity should appear to be substantially stronger in the very early universe. And this should result in some substantially different dynamics to conventional cosmology – e.g. galaxies or stars forming faster than expected. A variety of such anomalies is known. They have not yet been analysed in the context of TAU.

[14] Another question is why these results do not reflect anything like the large variations found in *G* measured directly in other studies, as illustrated above? There may be real cyclic variations in *G* locally, due to unknown factors, such as mass flows with the earth. But then it seems strange that no sign shows up in the LLR experiments – or are they compatible with the claimed precisions? It can be difficult to know what to take seriously when scientists are primarily intent on proving their standard theories (GTR) are correct and experimental designs take this as a premise.

The time integration.

We saw the space integration is quite easy, but now we have to do the same kind of integration for time, to relate the true time variable to the conventional time variable. We must integrate using: $dT/dT' = dt/dt' = \hat{R}'^2$, and the boundary condition: $T \rightarrow 0$ *when* $T' \rightarrow 0$.

$$T = \int_{0,T} dt = \int_{0,T'} (dt/dt')\, dt' = \int_{0,T'} \hat{R}'^2\, dt' = \int_{0,T'} (R'^2/R_0'^2)\, dt' \qquad \text{Time integral.}$$

However (unlike the spatial integration) we cannot do the time integration until we have an evolution equation for R' in terms of T', i.e. the function for $R'(T')$. We propose a full solution next. But to illustrate what happens generally, an approximate solution can be obtained, for a period of approximately linear expansion in the recent past. For this, we can take R' as a linear function of time, e.g. $dR'/dt' = H_0$, between the present time: $t_0' = T_0'$ and an earlier time, $t_1' = t_0' - \Delta t'$. We get:

$$\Delta T = T_0 - T_1 = \int_{[T_0'-\Delta t, T_0']} (H_0^2 t'^2/R_0'^2)dt' = H_0^2 T_0'^3/3R_0'^2 - H_0^2(T_0'-\Delta T')^3/3R_0'^2$$

$$= 3H_0^2 T_0'^2 \Delta T'/3R_0'^2 - 3H_0^2 T_0' \Delta T'^2/3R_0'^2 + H_0^2 \Delta T'^3/3R_0'^2$$

$$= \Delta T' - \Delta T'^2/T_0' + \Delta T'^3/3T_0'^2$$

If $\Delta T' << T_0'$, the third term is small, and we have: $\Delta T \approx \Delta T' - \Delta T'^2/T_0'$. So an expansion may appear quadratic or cubic in T while it is really linear in T'.

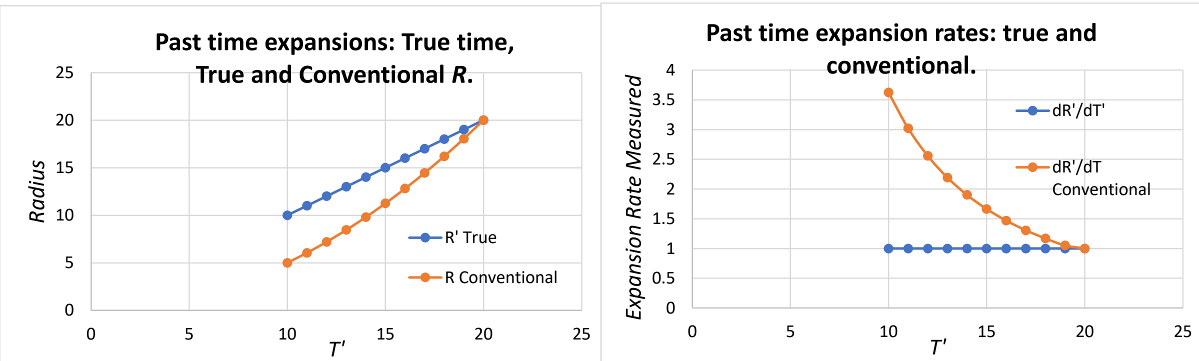


Figure 29. Looking back from a present time (at $T' = 20$ here), we see the linear expansion in true variables is distorted in conventional variables. On the RHS, the conventional expansion rate appears to be reducing.

This shows a general phenomenon, which we may call the *perspectival effect.* If we mix up true and conventional variables, we will get the appearance of changing rates of expansion and non-linear time intervals, due to variable transformations, not real physics.

However a purely linear expansion is of limited use, and not realistic over several billion years (the period in which *dark energy* appears). The more realistic solution is a smooth cyclic one, as shown next. This demonstrates the more essential effects of changing expansion speeds.

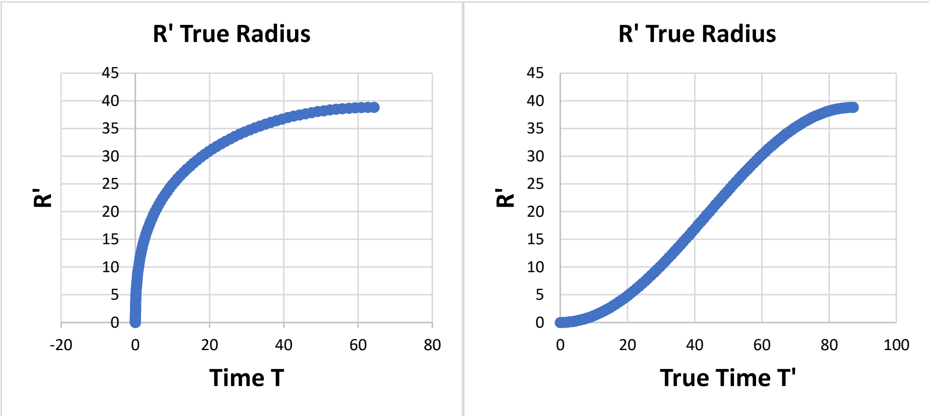


Figure 30. Cycloid solution to the expansion *R'* against conventional time and true time. The expansion in true time matches observations of the Hubble constants in the medium-past.

These are graphs of the *cardiod solution,* obtained next as a real solution to TAU. The solution looks totally different in the two different variables. What do the measured expansions corrospond to? We cannot assume that the cosmological measurements we actually make correspond to either diagram. Instead we must work out the measurement proceedures in detail for different types of meaurements. Different empirical methods determine these through their measurement assumptions. And they can be mixed up. However the RHS diagram is what we think the key measurements really reflect.

Note that if measurements of the rate of expansion reflect true expansion against true time (RHS graph above), then in the period in the early-mid expansion (where we appear to be), we will see the expansion accelerating. But it will eventually slow. This shows how a *dark energy effect* may arise, so the universe appears to have an accelerating expansion although it is really in a cycle.

This also illustrates how the so-called *Hubble tension* may arise: different measurement procedures that have the same expected results in GTR have different results expected in TAU.

We now obtain the precise solution graphed above. It is not known if it is accurate when analysed against cosmological data in full detail, but it is at least broadly realistic and plausible, and it has such simple and powerful properties that it is ideal as one type of prototype solution.

The Cardioid solution for expansion.

We get the *cardioid solution* by imposing a simple conservation of energy principle. The evolution of our constants already means that the *local momentum of particles in the manifold* is conserved:

$$mc = (m_0/\hat{R}')(c_0\hat{R}') = m_0c_0 = constant \qquad \text{Momentum conservation.}$$

Momentum is conserved on any expansion function. But the mass-energy is different:

$$mc^2 = (m_0/\hat{R}')(c_0^2\hat{R}'^2) = m_0c_0^2\hat{R} \qquad \text{Mass-energy increases.}$$

This is *increasing with expansion!* Particles are increasing their mass-energy as the universe expands! Where does this energy come from? It must come from the spatial manifold, one way or another.

We propose the simple hypothesis that the total kinetic energy in the global frame of the universe is conserved. The mass has a *surface speed c,* but also an "expansion speed" in *R',* with a total energy:

$E' = m'V'^2 = m'c'^2 + m'(dR'/dt')^2 = constant$ 6D Energy Conservation Principle.

(This is on the assumption that the speed c is orthogonal to the expansion, dR'/dt. Particles have a cyclic component in R', but this is true on average). Note also that this takes: $E = mV^2$ generally as energy. This is consistent with STR. When we add up momentum diagrams, *momenta* in the different directions add up as vectors, and their squares add up like energies.

$P = mc = \gamma m_0 c$ Relativistic momentum.

When we add the momenta-squared, it gives the sum of velocity-components-squared, and we get the energy times mass. Using: $u = dw/dt = c/\gamma$, and: $v = dr/dt$:

$$P^2 = m^2c^2 = \gamma^2 m_0^2(u^2+v^2) = Em$$

$$P^2/m = mc^2 = (\gamma m_0)(u^2+v^2) = mu^2+mv^2 = mc^2 = E$$

And this is generalised in TAU, to all component velocities, including speed of expansion (which is really in the direction w_1), as well as the normal surface speed, c. Note that these two components are not the *rest mass energy and kinetic energy* in STR, which add up like this:

$\gamma m_0 c^2 \quad = \quad m_0c^2 + E_{kinetic}$ Total Energy = Rest Mass + Kinetic.

This is a different way of separating the energy components. $m_0c^2 + E_{kinetic} = m(u^2+v^2)$. The $E_{kinetic}$ is the extra energy we have to add to stationary m_0 to give it a speed v. But the *orthogonal energy components* in the resulting system are: $mu^2 + mv^2$, and do not match $m_0c^2 + E_{kinetic}$.

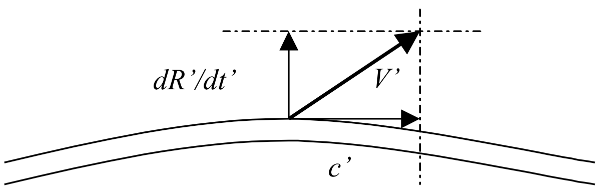


Figure 31. Total resultant velocity, V', for a free particle in the expanding manifold.

So this takes the kinetic energy from both the motion in the space manifold and the motion of the space manifold into account. The present total kinetic energy is then:

$m_0'c_0'^2 + m_0'(dR_0'/dt')^2 = m_0'V_0'^2 = E_0'$ Present 6D kinetic energy.

From the conservation principle and the evolution of m' we have:

$$V'^2 = E_0'/(m_0'/\hat{R}') = V_0'^2\hat{R}'$$

And then from the evolution of c' we have:

$$(dR'(t')/dt')^2 = V_0'^2\hat{R}' - c_0'^2\hat{R}'^2$$

$= (V_0'^2/R_0')R'(t') - (c_0'^2/R_0'^2)\, R'(t')^2$ Equation of motion.

This is an equation of motion for R', and it has a simple solution:

$$R'(t) = (R'_{MAX}/2)(1-\cos(\pi T'/T'_{MAX})) \qquad \text{Evolution equation.}$$

Where R'_{MAX} is the maximum expansion (in true variables). This is a simple cardioid function.

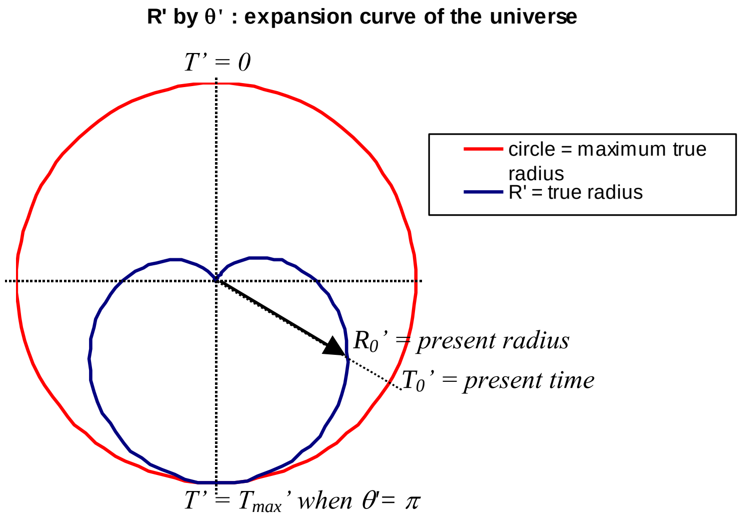


Figure 32. The cardioid solution for the universe expansion, blue. Time T' is the angle around the circle. The radius R' is a cardioid function, the length (black arrow) from the centre.

This is in *true (dashed) variables,* so must be converted to conventional variables.

The result for conventional time, T, is:

$$T = (R'_{MAX}/R_0')^2(3T'/8 - \sin(AT')\cos(AT')/2A + \sin(2AT')\cos(2AT')/16A)$$

where: $A = (\pi/2T_{MAX}')$ and: $T_{MAX}' = \pi R_0'/c_0'$, so that: $A = (c_0'/2R_0')$.

There is one more essential result for interpreting the cycloid model, the *comoving distance* for photons. This tells us how far apart the origin and detections points for a photon are.

The co-moving distance of a photon moving between two moments of time is easily defined in terms of the radial angle θ', as defined in the diagram above. A change in the radial angle of $\Delta\theta'$ in a period $\Delta T'$ corresponds to a co-moving distance $\Delta L'$:

$$\Delta L' = \Delta\theta' R' \qquad \text{Comoving distance.}$$

where R' is the radius at the final time (time of detection). This gives:

$$\Delta L' = \Delta T' c_0 R'/R_0' = \Delta T' c_0 \hat{R}' = \Delta T' c' \qquad \text{Comoving distance.}$$

where c' is the speed of light at end of the period (time of detection). In the special case where we detect light at the present time from the origin of the universe (approximately the last scattering surface for the CMBR), we define $\Delta L' = L_0'$, and $\Delta T' = T_0'$, and $c' = c_0'$, giving:

$$L_0' = T_0' c_0'$$

Hence the present *co-moving distance of light from the origin* (the Big Bang, or shortly thereafter) is simply the *present age of the universe times the present speed of light!*

- This is what appears to be reflected in the TAU relationship: $DR_A = R_u = L_0' = T_0'c_0'$.

The peculiar problem with interpreting the Dirac Large Number relationship we obtained earlier was that it predicts a *distance, Ru,* that should reflect the radius of the universe; but it actually corresponds to the *measured age, T,* times the present speed of light, *c.* The reason these are closely connected now turns out to be through the special form of the radial expansion function in time.

Note in the special case of light from the origin of the universe detected at the time of maximum expansion, L_{MAX}' is half the maximum circumference:

$$L_{MAX}' = \pi R_{MAX}' = T_{MAX}'c_{MAX}' = T_{MAX}'c_0\hat{R}_{MAX}' = T_{MAX}'c_0R_{MAX}'/R_0'$$

This means that: $T_{MAX}' = \pi R_0'/c_0$. Thus we can determine the eventual expansion, and subsequently our position in the cycle, from R_0' and c_0. This solution obviously makes the cosmology highly deterministic. We now return to the problem of interpreting the predictions.

Interpreting the cosmological predictions.

The main general feature is that expansion rates can look very different in different variables. E.g.

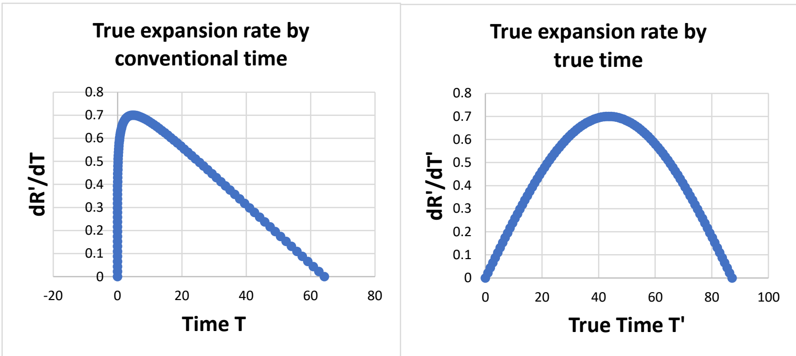


Figure 33. The cycloid expansion rates against conventional and true time.

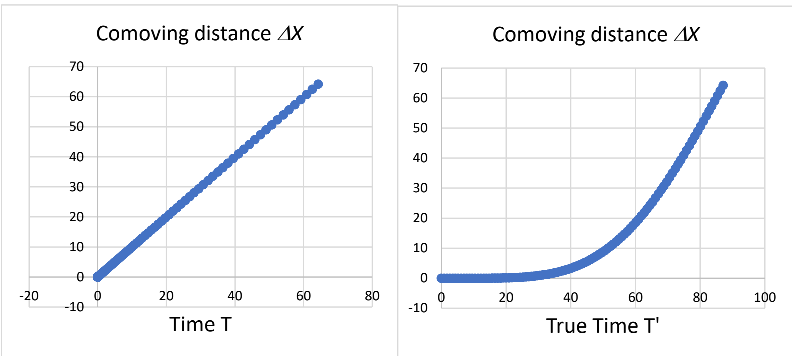


Figure 34. Co-moving distance between light origin point (Big Bang) and detection point (CMBR), against conventional time and true time.

Two distinctive effects we find from the model are:

- In the early-middle period the measured expansion should be accelerating – but it will slow, and is really cyclic. The inference of *dark energy* in the conventional model is just a way of reconciling it with GTR, but it is probably mistaken.
- Conventional measurements of the Hubble constant estimated from different periods in the past, and by using different methods, should be inconsistent.

The first predicts a “dark energy” effect should appear but the cause is not “energy”, while the second predicts that a “Hubble tension” should appear. These effects have been confirmed over the last 10-30 years, and represent serious anomalies in conventional cosmology.

However the application of this model depends upon a re-analysis of measurements of the Hubble constant, expansion acceleration rates, etc, to determine what they are measuring *in the context of TAU*. Hence our problem comes back to determining the TAU analysis of measurements. Note there are two main methods for determining the Hubble constant: the *distance ladder,* and the *CMBR*.

- The *distance ladder* at its simplest involves identifying “standard” types of stars, supernovae, pulsars, etc, and determining (i) their distance from their brightness (luminosity), (ii) their recessional velocity from their red-shift.
- The *CMBR* method involves measuring the CMBR very precisely, which comes from a period quite soon after the Big Bang, and determining wave-length expansions or red shifts.[15]

Both methods are theory-laden.

> “The figure astronomers derive for the Hubble Constant using a wide variety of cutting-edge observations, including some from Hubble's namesake observatory, the NASA/ESA Hubble Space Telescope, and most recently from ESA's Gaia mission, is 73.5 km/s/Mpc, with an uncertainty of only two percent. … A second way to estimate the Hubble Constant is to use the cosmological model that fits the cosmic microwave background image, which represents the very young Universe, and calculate a prediction for what the Hubble Constant should be today. When applied to Planck data, this method gives a lower value of 67.4 km/s/Mpc, with a tiny uncertainty of less than a percent.” Jan Tauber, Markus Bauer 2019. European Space Agency.

Hubble Constant	Estimate
Distance ladder	73.5
CMBR (Planck)	67.4
Ratio:	109%

> “ ‘*The CMB is a portrait of the young Universe, and the picture delivered by Planck is so precise that we can use it to scrutinise in painstaking detail all possible models for the origin and evolution of the cosmos*,’ comments Jan Tauber, Planck Project Scientist at ESA. ‘*After this close examination, the standard model of cosmology is still standing tall, but at the same time evidence of anomalous features in the CMB is more serious than previously thought, suggesting that something fundamental may be missing from the standard framework*,’ he adds. ESA Science & Technology - Simple but challenging: the Universe according to Planck.

The Planck project is a great experimental achievement, as are other leading experiments. But the comment that “*we can use it (Planck data) to scrutinise in painstaking detail all possible models for the origin and evolution of the cosmos”* is an overstatement, and shows the naivety of physicists

[15] A third method was found in 2018, “gravitational lensing” of merging neutron stars using gravitational wave detectors. There is little data yet, but this should give an independent method over the next few years.

committed to GTR and the standard models. We cannot test all the “possible models” *unless we know all the possible models*, and this is a fatal flaw. Just as with the LLR data, no one has worked out a model with changing constants and changing basis variables, as in TAU. The focus on *proving GTR and the conventional cosmology are true* can detract from the goal of *testing the theories.*

To interpret conventional cosmology in TAU, we must interpret all the physical processes underlying the measurements, and their subsequent modelling. First there are *rates of stellar processes and formation of stars, and radioactive and chemical radiation processes* affecting formation and brightness of stars and their expected spectra. These are affected by changes in fundamental constants and gravity. Then in the conventional modelling, there are estimates of different *material components of the universe,* which includes ordinary matter (fermions/baryons, photons, neutrinos, etc), and dark matter (a large component), and finally dark energy (or cosmological constant) – another large component that has become essential to make the conventional models work. These ingredients are normally combined using GTR and the Friedmann model. Modelling the *acceleration of the Hubble constant* is a good example of how theory-laden the measurements are.

> “The accelerated expansion of the universe is thought to have begun since the universe entered its dark-energy-dominated era roughly 4 billion years ago. Within the framework of general relativity, an accelerated expansion can be accounted for by a positive value of the cosmological constant Λ, equivalent to the presence of a positive vacuum energy, dubbed "dark energy". While there are alternative possible explanations, the description assuming dark energy (positive Λ) is used in the current standard model of cosmology, which also includes cold dark matter (CDM) and is known as the Lambda-CDM model.” Accelerating Expansion of the Universe. WIKIPEDIA.

The *cosmological constant* (or dark energy) and other parameters in conventional models take some real effects of the TAU model into account. It appears from this point of view that cosmologists have measured a real Hubble acceleration effect, but the cause is not “dark energy”. But ultimately, in a TAU-type universe (any universe with changing constants), the conventional theory cannot work properly. It will just end up fitting more and more *ad hoc* parameters to cover discrepancies – like Ptolemaic astronomy. In developing TAU we need to be careful not to make the same mistake of making *ad hoc* adaptations to fit the theory to the data.

The conclusion we reach is that the TAU model with even the simplest cardioid solution fits surprisingly well, and it gives alternative explanations of several major effects, including Hubble tension and large number relations.

This type of alternative theory should be considered. It reveals physical mechanisms and explanations that cannot be represented in conventional cosmological theory. It emphasises the fact that:

- The *entire class of theories with changing constants* is presently ignored in cosmology.
- There are no realistic tests of such theories in cosmology or gravitational studies.

We now conclude with a brief discussion of *dark matter,* for which TAU also provides a mechanism that is not possible in ordinary cosmology.

Dark Matter.

In the TAU model of expansion, mass particles lose some component of energy from: dR_U'/dt' to increase their mass-energy: $d(mc^2)/dt$. This creates a force slowing the expansion. In a truly homogenous universe it should average out for a smooth expansion. But with large clumps of matter (galaxies or galaxy clusters), it should result instead an uneven expansion rate, and clumping of energy.

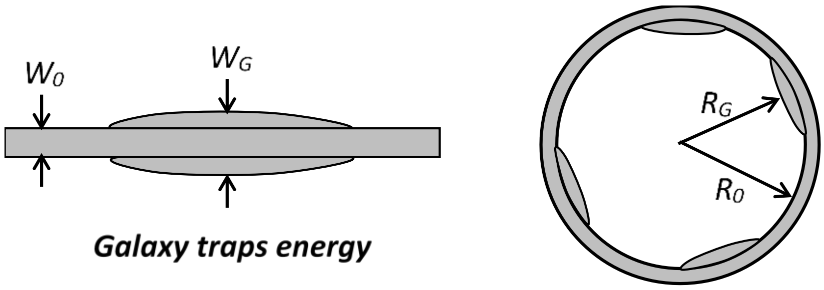


Figure 35. LHS. In large clumps of matter (galaxy clusters), the extra gravitational strain increases the torus dimension from W_0 (in empty space) to W_G. RHS. As the universe expands, regions with clumps of matter expand more slowly than empty space, so: $R_G < R_0$. This further increases the difference in: $W_0 < W_G$. This appears to us as *dark matter.*

In the expanding universe, the clumping of matter does not just increase the local strain as in a flat space in equilibrium. Rather it is part of a dynamic effect. The presence of matter is expected to *retard the local expansion,* doing some work against it, so that the space within the galaxy retains a larger general strain than the "cold" background of intergalactic space: $W_G > W_0$ and: $R_G < R_0$. We propose that this is responsible for dark matter. It appears to be the only clear and obvious explanation in TAU. It works qualitatively at least, and corresponds to several features.

- Dark matter is present throughout practically all galaxies.[16] This is important because in TAU, dark matter is created by concentrations of mass, as well as being gravitationally trapped with them.
- It makes up about 85% of the *mass-energy*, and is in a roughly constant proportion with ordinary matter in large stable galaxies. But there is a substantial range, with high ratios in some small dwarf galaxies. The conventional mechanisms proposed for this work much the same in TAU: the ejection of mass from small galaxies, and local galactic interactions.
- Dark matter concentrations are not known to form outside galaxies or clusters, i.e. it is not concentrating in intergalactic space (as far as we know).

[16] A small number of diffuse dwarf galaxies have now been found (starting in 2018) without dark matter. (Two strongly confirmed, up to about 20 others detected). The TAU explanation must be similar to the conventional explanation: their dark matter has been stolen! By larger neighbouring galaxies. [At Last: Galaxy Without Dark Matter Confirmed, Explained With New Hubble Data (forbes.com)].

- Also it forms halos and does not concentrate in the galactic centres (like ordinary matter). As in conventional theory, this is because it is relatively hot, and does not cool, like ordinary matter, by transferring kinetic energy.

Generally speaking, the behaviour of dark matter in TAU is similar to the conventional theory. But the key difference is that in TAU, dark matter has been created over time.

- In TAU it is expected the dark matter creation process started when stars and galaxies began to form (around 400 million years after the Big Bang).
- In TAU, gravity was stronger then, and kept galaxies stable.

It is commonly assumed that dark matter is required in the early universe to stabilise galaxies, just as it is now. So it is assumed there was about the same ratio (15% baryonic matter to 85% dark matter) throughout the history of the universe. But in TAU, gravity was substantially stronger in the early universe, and this off-sets the need for dark matter to stabilise galaxies. In fact, the two trade off in tandem: G decreases with expansion, and dark matter increases.[17]

This is the key difference with the conventional theory, and it also helps explain why observational effects of stronger G may not be immediately apparent as might be expected. (The main effects are just as apparent as the effects of dark matter.) Otherwise, dark matter in TAU has generally similar behaviours to the conventional theory. It produces gravitational strain within galaxies. Once clumps are formed, they will gravitate like matter, and it appears they form stable boundaries. It primarily affects the rotational dynamics of galaxies, keeping them from flying apart, and giving a common rotation speed for stars at different distances. But in TAU, the mystery of dark matter is resolved: it is not associated with particles, instead being "free energy" trapped in the vacuum.

In terms of quantitative predictions for this model, the first main point to estimate the rate of dark matter creation required, and check if it is consistent. The universe has expanded roughly about 20 times (from red-shift data) since the start of galaxy creation, at about 500 million years.[18] Now if all the extra mass-energy had gone to dark matter, this would give about a 5%-95% ratio of baryonic mass to dark matter. So the observed ratio of 15%-85% corresponds to about a 1/3 energy conversion into dark matter. This may be expected to be about ½ on simple dynamics (*potential-kinetic energy* exchanges), so this ratio is consistent as a general observation. It may become a prediction with a more complete model, but at present it is just a consistency check.

Now we can develop more exact models for the TAU cosmology, and try to apply them to predict the evolution of the cosmos, but it is quite a tricky exercise. *Strong predictions* of the theory arise when we can isolate individual effects (as with gravity), but predictions for the TAU cosmology really needs full models of the whole shebang. Everything is interdependent, and the long-time processes of cosmology can be sensitive to initial conditions. The modelling also needs good feedback from observational data, as well as theoretical enhancement.

---

[17] We should also expect that the constants G, c, h, etc, measured within galaxies do not reflect the general values for "cold space" outside, which is the majority of the universe. This difference is not that great, but it may have significant effects in long-term processes.

[18] About 2/3's of the simple estimate of: 14by/0.5by = 28 on a simple linear expansion at the present Hubble constant.

This has not been done beyond elementary models, but it is now very feasible. Observations of dark matter, gravitational waves, the Hubble constant, very early galaxies, etc, are now gaining much greater precision, sufficient to test cosmological theories much better. This is quite recent. The first gravitational waves were only detected in 2015-16. The first estimate of the Hubble constant from gravitational lensing was in 2018. Dark matter maps and CBR maps have improved dramatically in the last ten years. The data is becoming available for much more precise tests of cosmological theories. But a substantial modelling exercise is required to test the TAU cosmology properly.

I conclude with a few general comments. The dynamics of the TAU manifold is much like a system in continuum mechanics, with an asymmetric thermodynamic process, and may be quite solvable in a general form. But it is in six dimensions, so it is not as simple as just plugging in ordinary continuum mechanics. A related feature is the existence of strong global properties, such as the energy balance between gravitational energy (in the strain of space) and the total mass-energy. These add to similar amounts when we integrate the strain equation, and consider the total matter in the universe. This also gives rise to relationships between the *particle numbers* and the global parameters, with the Dirac Large Number relation: $N \sim D^2$ between particle numbers and expansion. These kinds of global properties do not exist in the conventional theory.

The global particle number, *N,* is one of the most interesting points. In Dirac's theory, *N* is expected to increase with expansion, requiring spontaneous particle creation – and allowing the possibility of a stable constant-state universe. But this does not appear to be the case. Instead, *N* appears to be set in the early universe, from *D* at an early time. It seems the main particle creation occurred around 10^{-6} - 10^{-5} of the current radius. On a rough estimate the Dirac relation gives: $N \sim 10^{82}/10^{5} = 10^{77}$ *particles.* This is a feasible number, and lends support to a relationship of this kind. But the transition from the extremely high compression state to the era of individual particles is not understood in detail. The simple solutions (like the cardiod function) that apply to the smooth expansion period will probably break down in this period.

In the extreme compression state ("Big Crunch"), there were no particles as we know them, and space was just a large vibrational state. In the "inflationary expansion" period, space was not under the same constraints as in the post-inflation period after particle creation, because it was not retarded by mass-energy exchanges among particles – surface tension became very low. The *mass-particles* appeared when it expanded and cooled enough to form individual particles, much as in ordinary cosmology. This should give rise to a high level of homogeneity but also a non-homogenous scale, as observed in the CMBR. Once most of the stable mass particles (electrons, protons, neutrons) were created, it appears the main particle creation process ceased, and the *fine structure constant,* which is fixed to the *proton-electron ratio*, also froze out.

The TAU version of early dynamics requires more complete modelling of the process. But it highlights the weakest part of the conventional theory, which extrapolates the universe back to the recombination era (which is a sensible extrapolation) to the unification era (more speculative) to the tiny radius-inflationary era (completely speculative), and even back to an initial singularity, at which point physics turns into theoretical fantasy. Popular speculations in "quantum gravity" theory about our universe appearing magically out of a "quantum vacuum fluctuation" before time began (what vacuum?) should be regarded as fantasy. Such ideas and extrapolations do need to be worked out – it is a part of finding the limits of current theories – and we should not be too critical of theorists for pursuing strange ideas. But it is a matter of putting these speculative models in context. The theories on this outer edge of the twilight zone are *not real physics*. They cannot be compared with the real physics of electrodynamics or quantum mechanics or astronomy or cosmology. And they cannot be taken as any kind of guide to judging other theories.

In TAU, at any rate, the minimum compaction radius cannot be less than the *average volume radius* value: $L \approx \sqrt{(R_U R_A)}$, on the scale of *10,000 km.* It means the ordinary physics of GTR and QM cannot be applied with any real confidence before the recombination period – when the universe reached thousands of light-years radius. The theory of *cosmic inflation* is perhaps the one theory in this realm that does have substantial evidence, based on the simple observation of *homogeneity and anisotropy* in the CBR. TAU has something similar: there was a period of extremely rapid expansion (very fast in conventional variables – much slower in true variables). But theories of underlying processes causing inflation based on GTR and quantum fields are extrapolations to a realm where only a *unified theory* could be expected to have any validity. TAU contradicts this whole field of early-universe cosmological speculation. And because it *is* a unified theory, it should be possible to extrapolate it more robustly, and to provide a realistic alternative to the very early dynamics.

We conclude this survey of the TAU cosmology here. It appears plausible and consistent with current observations, has a few striking points of confirmation, and is very testable in the future. We have seen strong relationships appear in the theory of gravity and cosmology, and we now return to the particle theory, and consider how gravity merges with particles close up.

Gravity and particle identity.

We now return to the gravitational strain close at the particle centre, and the merging of gravity and quantum mechanics. Here we make one more fundamental proposal. This final proposal is more speculative than the particle, gravity and cosmology theories, and has not been worked out in as much detail, in terms of equations of motion and testable predictions. But it is a very specific mechanism, and is coherent with other theories (there is a lot of work in this field). And it is really the most fascinating aspect of the whole problem, the mystery of *non-local connections and wave function collapse*. The theory proposed here appears as the natural extension of TAU. It is interesting in any case because it specifies a fully realist causal mechanism, something no other theories do, and something that many theorists think is impossible.

As we saw, the general *strain function* required for gravity is: $R(M,r) = R_0 e^{\frac{MG}{c^2 r}}$. Here M is a gravitating mass, r is distance in *XYZ-space* to the mass, and R_0 is the torus dimension without the gravitating mass present. This gives the variable strain of the micro-dimension created by a mass M. (Note $R(M,r)$ may be used for R_A, or R_e or R_p). This function holds at significant distances $r > R_0$. But the function has a central singularity.

- What happens physically as we go to the centre of a single particle, with mass m_A?

As: $r \rightarrow 0$, the function becomes infinite. This *singularity* is rejected as non-physical, and the strain function must be modified at small r. But we propose to allow r to become extremely small. We will allow the gravitational strain to become very large, and to produce a thin *filament*. This filament extends R in the w_1 direction of space. It begins to appear when: $R(M,r)$ becomes comparable to R_0.

- We propose to identify this *gravitational filament* as the *particle identity*.

We first briefly discuss the dimensions. With the normal strain function above, this filament would appear when the factor: mG/c^2r becomes comparable to 1, so that the strain function becomes like: $R(m,r) \approx R_0 e^1 \approx 2R_0$. At this point R has essentially doubled, so the gravitational strain starts to radically distort the torus. We can define this as the "black hole radius" for the particle:

$L_B = m_A G/c^2$ Definition. Black hole radius.

(This is half the conventional GTR event horizon). Using: $R_{A0} = \hbar/m_A c$ and: $D = \hbar c/m_A^2 G$, this means:

$L_B = R_{A0}/D$ Rearranged.

This is about 10^{-55}m. So this is one natural choice for the radius of the filaments. However it is not the only choice. Note that the *Planck length* commonly used in physics is defined as:

$L_{Planck} = L_P = \sqrt{(\hbar G/c^3)} = R_{A0}/\sqrt{D}$ Definition. Planck length.

This is equal to: $L_B\sqrt{D}$, and is about 10^{-35}m. We propose that this is the more likely length scale for the filament radius. Note that these are two lengths in a spectrum of *length scales* defined around one fundamental length, R_A, and multiples of $\sqrt{D} \approx 10^{20}$. These are given in the following table.[19]

Table 6. Length scale (reduced lengths).

Dirac constant	*Value*	*Formulae*
Dirac constant (reduced)	*2.54E+40*	$\hbar c/m_A^2 G$
Square root Dirac	*1.59E+20*	$\sqrt{D}$
Name	*Length (m)*	*Formulae*
R_U *universe radius*	*6.54E+25*	DR_A
L invariant length	*4.10E+05*	$\sqrt{D}R_A$
R_A *Torus radius*	*2.58E-15*	$\hbar/m_A c$
L_P *Planck length*	*1.62E-35*	$R_A/\sqrt{D}$
R_B *particle black hole*	*1.01E-55*	R_A/D

Note that only *the Planck length:* $L_P = \sqrt{(\hbar G/c^3)}$ is independent of the particle mass. So it is identical for all particles. The idea is that at this distance, the particle turns into a very thin "filament of space", extending into the w_1 dimension. This is literally an extrusion of space, in 6D.

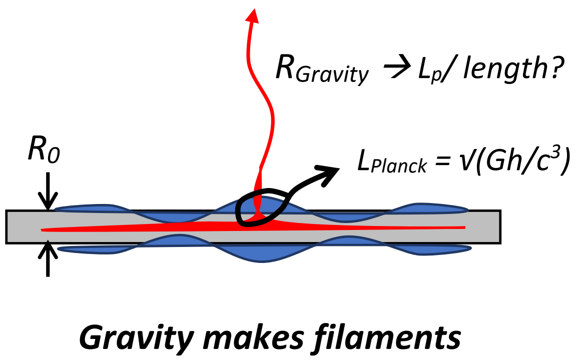


Figure 36. The quantum waves are in the surface (blue). The strain produces a *filament* with a radius, proposed to be the reduced Planck length.

The normal gravitational strain function becomes significant in relation to the torus radius only around the black hole radius, which is phenomenally tiny. But we propose this happens at the Planck length, which becomes a general filament radius. Fundamental particles will then appear like tiny spherical "holes" (like "*worm-holes"*) with Planck-length radius. We must modify the normal gravitational strain function close to the particle for this. We know the strain function must be modified anyway, once *r* becomes much smaller than R_A, because the geometry turns fully into six dimensions.

[19] Note we can use either $\hbar$ or h in the following definitions, to give *reduced lengths,* or *full lengths*, which correspond in the geometry to *radii* or *circumferences*. The black hole radius is the only one that does not depend on *h,* since: $R_B = m_A G/c^2$, so the *reduced value* is the same as the *full value*.

At the Planck length, the factor in the normal strain function is: $mG/c^2L_P = m\surd(G/c\hbar)$. In the normal strain equation, this is still a tiny expansion: $R(m, L_P) = R_0 e^{m\sqrt{\frac{G}{c\hbar}}}$, which is about $10^{-20}R_0$. It requires the additional factor of $1/\surd D \approx 10^{-20}$ to get to the black hole radius, and become comparable to 1. In any case, we must modify the strain function to get filaments appearing at L_p.

E.g. we could modify the normal 3D strain function: $R_0 e^{\frac{mG}{c^2 r}}$ to: $R_0 e^{\left(\frac{mG}{c^2(r-L_p)}\right)}$ and then letting: $\left(\frac{mG}{c^2(r-L_p)}\right) = 1$ we get: $r = \left(\frac{mG}{c^2}\right) + L_p = \frac{hG}{c^3 R_m} + \sqrt{\frac{hG}{c^3}} = L_p(1 + \frac{L_p}{R_m})$. So at this radius: $R = R_0 e^1$, and this is where the filament appears. The Planck length acts like an event horizon for particles.

So we simply propose for the moment that the Planck length is the scale at which an individual mass creates a filament. We can then take filaments to have a common radius. This scale is attractive because the Planck length is invariant for all particles, and it matches properties found in certain *discrete theories* that emphasise the significance of the Planck length.

One main effect of this choice is on the 6D-volume integrals. The 6D volume of a *filament* is like: $V_f \approx L_p^5 L_f$, where L_f is the filament length. The filaments are proposed to extend *inside the universe hypersphere.* Hence they have a maximum length (if they were extended across the whole universe) of: $L_f < R_U = DR_A$. Hence the filament volume for one particle may be as much as: $V_f \approx L_p^5 L_f \approx (R_A/\surd D)^5 (DR_A) = R_A^6/D^{3/2}$. For a consistency check we can compare this with the 6D volume of the full space, which is like: $V_u \approx R_U^3 R_A^3 \approx R_A^6 D^3$. Thus the ratio is: $V_u/V_f \approx D^{4.5} \approx 10^{200}$. This means the volume of space is enough for some 10^{200} individual particle filaments. If this number was comparable to the number of mass particles, much of 6D space of the universe would be in filaments, and they would play a major role in the expansion dynamics. However there are only around 10^{80} mass particles (electrons, quarks) and even if there were billions of neutrinos or photons per particle (assuming neutrinos and photons also have filaments), the filament volume is still vastly smaller than the main universe volume.

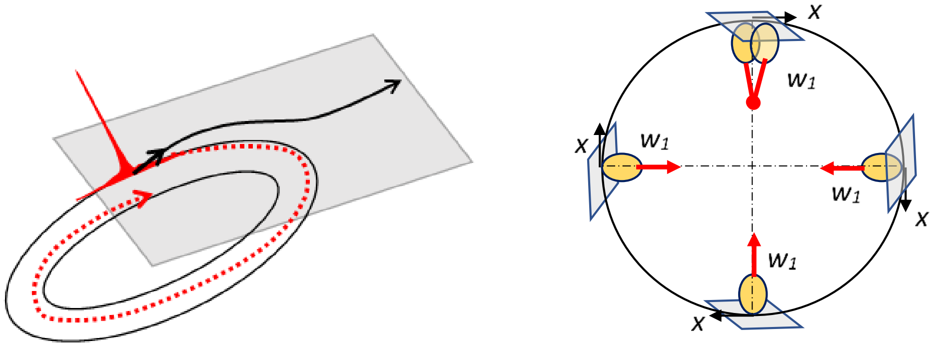
However the key question is: *why should we introduce them?* Because we have to do something with the gravitational strain close to a mass particle, and there are just two obvious choices. We can either make the gravity strain function smooth out into the quantum wave somehow; or we can extrapolate it, and turn it into a filament. The attraction of the latter is because it can now be used to explain and unify several well-known QM phenomena all at once.

- It allows us to specify an identity for the *localised particle,* as distinct from its *quantum wave function,* which extends across *space.* This helps resolve *wave-particle duality.*
- The filaments provide a mechanism for entanglement of separated particles. Entanglement will occur through connections between filaments.
- These connections provide a mechanism for non-local wave function collapse. This will occur through reconnections among a network of filaments.
- This provides a realistic mechanism for a Bohmian deterministic quantum theory, and is supported by that theory.

These refer of course to the most profoundly baffling features of quantum mechanics. Different opinions on these have inspired the variety of "quantum interpretations" – such as Bohr's Copenhagen interpretation; de Broglie-Bohm's deterministic underlying variables; Everetts's many-worlds; physical collapse models; discrete space-time models; and others. These differ fundamentally in their interpretation of the *QM wave function and its collapse process.*

- The *wave-particle duality* lies at the heart of quantum phenomenon. QM particles act like *waves* with interference patterns and superposition properties – but they act like discrete particles, with individual identities, in particle interactions, where energy and momenta are transferred in discrete *quanta* between particles.
- The most striking non-classical and *non-relativistic* effect in QM is entanglement, with non-local connections between particle states across space. There is no causal explanation for these non-local connections, they appear to contradict the rules of STR, but they are real and pervasive in QM.
- A fundamental problem is wave function collapse, which is supposed to happen discretely in time, punctuating the smooth wave function evolution. But it requires the wave-function to collapse non-locally, everywhere in space at once. There is no established micro-physical condition for *collapse* to occur.
- Bohm's deterministic theory shows that QM dynamics can be interpreted as the wave function acting as a wave-guide for an individual particle. This reproduces the *probability calculus* for QM, while taking particles as real point-like entities moving on real trajectories. But it requires wave functions to be non-locally connected across the universe.
- There is no agreement on what the *quantum wave function* represents as physical entity. It represents at least a probability amplitude, giving "probabilities of measurements" (Born, 1926). This the minimal interpretation. But it also seems like a physical disturbance, because of the interference and superposition behaviour. This is more baffling still in quantum field theories, with virtual particles.

For the general mechanism, our interpretation of filaments can be referred first to the de Broglie-Bohm *pilot wave* theory. The filament represents the point-particle, the wave function in space represents the wave guide. We take the QM wave function as a surface wave, and the filament as following it. This gives us a point-like particle to represent the electric mass-charge circulating the torus.



Micro-view of filament motion. **Macro-view of filament directions.**

Figure 37. LHS. In the microscopic view, filaments follow paths on the surface of the *WXYZ* space. They are guided by surface waves. They are identified as the *point-like mass-charges* rotating on the torus. RHS. In the cosmic view, the filaments point into the interior of the hyperspace. We propose filaments of particles are connected in a network.

The two key problems are: *how do the filaments move on the surface?* And: *what happens to the filaments inside the space?* We start with the first.

Pilot-wave mechanics.

In the pilot wave theory, the (Schrodinger) QM equation is reinterpreted as governing a particle moving under both classical and quantum potentials. This is essentially similar to our 5D-surface space (which has KG-type wave functions). One key problem with the de Broglie Bohm theory is that theorists have not been able to incorporate spin. But we now have the advantage that we now only need surface trajectories, because spin is produced from circular surface motions.

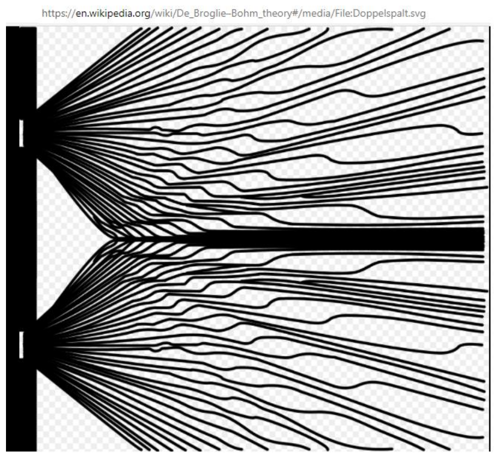


Figure 38. Pilot wave theory is often illustrated with this famous diagram of the *double-slit experiment.* In the standard interpretation, one particle (light or electron) goes through both slits, as a *quantum wave,* causing interference patterns. In the de Broglie-Bohm theory, there is a single particle, which goes through just one slit, but it moves on wiggly trajectories, due to the quantum potential. This duplicates the interference pattern.

The TAU version has the *filament* representing the particle, following the wiggly trajectories in the same way. The quantum potential must therefore be interpreted as acting on the filaments, which are the particle gravitational masses. We will not go into the mechanics here, but this is a profound and fascinating concept in quantum mechanics. Realism was scorned by the positivists, and it only became well-known in the 1980's.

> “De Broglie presented the pilot wave theory at the 1927 Solvay Conference. However, Wolfgang Pauli raised an objection to it at the conference, saying that it did not deal properly with the case of inelastic scattering. De Broglie was not able to find a response to this objection, and he abandoned the pilot-wave approach. Unlike David Bohm years later, de Broglie did not complete his theory to encompass the many-particle case. The many-particle case shows mathematically that the energy dissipation in inelastic scattering could be distributed to the surrounding field structure by a yet-unknown mechanism of the theory of hidden variables.
> In 1932, John von Neumann published a book, part of which claimed to prove that all hidden variable theories were impossible. This result was found to be flawed by Grete Hermann [1935] three years later, though this went unnoticed by the physics community for over fifty years.
> In 1952, David Bohm, dissatisfied with the prevailing orthodoxy, rediscovered de Broglie's pilot wave theory. Bohm developed pilot wave theory into what is now called the de Broglie–Bohm theory. The de Broglie–Bohm theory itself might have gone unnoticed by most physicists, if it had not been championed by John Bell, who also countered the objections to it. In 1987, John Bell rediscovered Grete Hermann's work, and thus showed the physics community that Pauli's and von Neumann's objections "only" showed that the pilot wave theory did not have locality.” Pilot Wave Theory. WIKIPEDIA.

The de Broglie-Bohm theory provides the starting point for our treatment, and we can adapt the pilot wave solutions with wiggly particle trajectories as the essential clue to our first problem. But there are several issues and differences. Deterministic QM has stalled on several fronts, including the problem of having strong *non-locality* without any mechanism*,* and also a failure to model spin systems. A key difference in our interpretation is to use the filaments to provide a realist mechanism for both the *non-local connections and a wave function collapse*. This adds a real wave-collapse, and a real causal transmission across space, to the usual deterministic theory, which has non-local connections, but no collapse. The collapse in our version may be simply conceived as chaotic, or it could be taken as intrinsically probabilistic. (Determinism punctuated by non-analytic points in trajectories). But the point is that *determinism* is not really the goal or the issue: *causality and non-locality* is the issue. Our theory is also intrinsically suited to *spin systems,* and we illustrate with the famous example of spin correlations.

The main point this leads into is the interpretation of the QM wave function and the *probability current.* Now so far we have just identified the wave function as playing the same kind of formal role as in conventional QM. However we really need to take it as a real wave perturbation in our theory. There are two essential proposals here: (A) the QM wavefunction ultimately represents a perturbation of space, (B) conservation of the probability current reflects conservation of 6D volume. This gives a natural interpretation of the probabilities. Exactly how a Bohmian mechanics will work is still an open question, but all the features are there.

But we now go on to the radical proposal of introducing filaments as particle identities, illustrated next with the example of spin correlations.

Spin and non-local connections.

The simplest illustration of quantum non-locality is through the connection between pairs of electron spin states.[20]

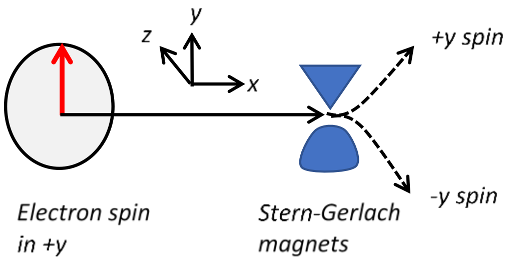


Figure 39. Simple Stern-Gerlach spin experiment. The electron may be prepared with spin in a definite direction in the *YZ* plane. The Stern-Gerlach magnets can be rotated in the *YZ-plane* to measure spin *up* or *down* at any angle in the *YZ* plane. Two component waves (channels) will deflect, up or down, through the magnets. The spin of the electron interacts with the magnetic fields.

Note that the deflection into two channels on the RHS by itself does not collapse the wave function to one or other channel – the two components can persist as a superposition, and be recombined. The measurement collapse is made by detecting *position* (up or down channels) after the components are split, with a detector that *localises* the electron. The whole electron is detected at just one place. The spin is collapsed as a single quanta of angular momentum *(ħ/2).*

The probabilities are determined by the *angle of the spin state* in the *YZ* plane, relative to the S-G magnets. For an electron prepared with *spin-up in y,* the probabilities are given by:

$prob(+y) = cos^2(\theta/2)$ QM probability of finding *spin-up in y*.

$prob(-y) = 1-cos^2(\theta/2) = sin^2(\theta/2)$ QM probability of finding *spin-down in y*.

where θ is the angle of the new spin measurement to *+y*. The probabilities are for the electron to be deflected *up* or *down.*

This is for a measurement of one electron. We then consider two electrons prepared in a coordinated initial state, called a *singlet pair*. This state is essentially like a pair of electrons in the lowest orbit of a hydrogen atom. There is only one *spatial wave-function* (spatial state) for this orbit, and two electrons (fermions) cannot occupy the same state. But two electrons can occupy the single orbit because they can have opposite spins. Conversely, two electrons in such a state must have opposite spins (or more precisely, superpositions of states with opposite spins).

[20] This experiment was originally done using silver atoms (Gerlach, 1923), but the principle is the same for any spin particles, with electrons the simplest in principle.

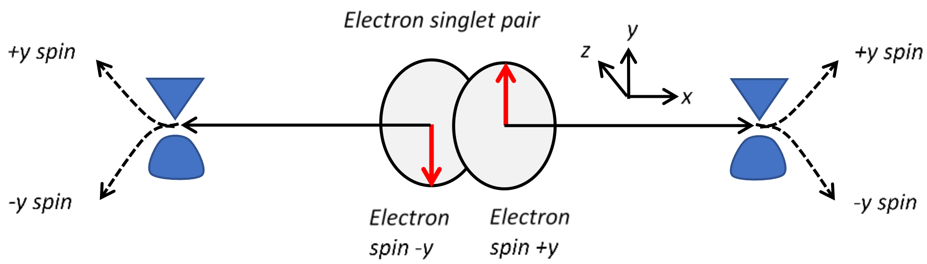


Figure 40. Electron pair spin experiment. Two electrons separated in a singlet state always have opposite spin (Pauli exclusion).

In the case of two electrons prepared in a singlet state, QM predicts that if the two magnets are set to measure spin at the same angle, the electrons are always measured with *opposite spins* – even though neither may have any definite spin at all before they are measured*.* This is required for momentum conservation: in the singlet state there is zero total spin, and the result must also add up to zero spin.

Now if the two magnets are set at a relative angle, θ*,* i.e. measuring spin on different axes, the probabilities of pairs of outcomes are determined by the probability law above. Each separately has a 0.5 probability of spin *up* or *down* at any angle, but the conditional probability of detecting *the second with spin down* at a relative angle θ *when the first is found with spin up* (on *+y*) is $cos^2(\theta/2)$*.*

The problem is to explain this correlation. The first idea that occurs is that the electrons have definite and opposite spin states when they separate, and we are just measuring pre-determined values. This would be classical determinism through *fixed underlying states*. Einstein *at al* (1935) started this debate by arguing that the purely statistical formalism of QM must be *incomplete,* and there must be underlying physical deterministic variables responsible for correlating the spins, otherwise it would imply instantaneous non-local connections of systems across space. Einstein rejected non-local connections as implying *action-at-a-distance,* contradicting STR and local causation.

However assigning a deterministic spin (in every direction) does *not* work. This was known in the 1930's, and Bohr rejected Einstein's argument that the description of the QM state is incomplete. (Einstein reasoned that it must be incomplete, on pain of contradicting *local causation in space-time,* which to Einstein was an unshakable principle). But physicists did not examine the problem in detail until John Bell (1964) showed something more profound. Bell's theorem shows basically that any way of assigning simple classical *determinate properties* to produce the correlations contradicts the QM probabilities, and that this can be tested experimentally by sampling different combinations of angles for measurements.[21] Aspect famously tested this in 1983, and the QM probabilities were confirmed – as everyone expected them to be – *even when done non-locally*.

von Neumann (1932) had given a proof against "hidden variables" in QM, but his proof assumes that hidden variables represent *fixed and determinate outcomes of measured properties.* QM means we cannot give an electron *determinate properties of spin in every direction at once.* But there is a more general way to model spin or other properties, using *dynamic underlying variables.*

---

[21] It just depends on the fact that the probabilities are $cos^2(\theta/2)$ *functions.* If they were linear: θ/π functions, a classical underlying variable explanation would work.

Now this *does* let “hidden variables” determine correlations. But the problem is that there must still be a non-local connection between the “hidden variable” properties of two spin-correlated particles.

The lasting conclusion is that *we cannot get rid of non-locality*. We will illustrate this with a model that gives a concrete visualisation of the situation.

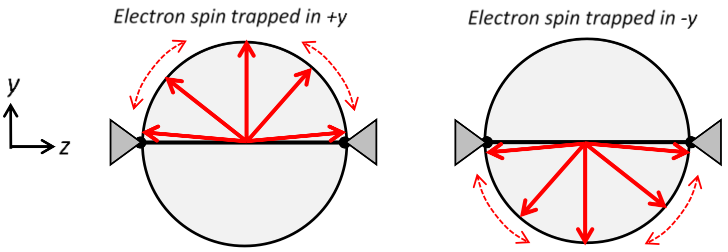


Figure 41. Instead of assigning a single fixed spin direction, we use a rotating “spin vector” in the *YZ plane.* A *spin measurement* is equivalent to inserting a *partition (triangles-and-bar)* orthogonal to the spin-up direction. This traps the *spin vector* in just one hemisphere. If it is trapped above it has *measured +y-spin.* If it is trapped below, it has *measured -y-spin.*

In this model, the “spin vector” is an underlying variable with a rapidly time-varying state, giving it a probability of being found within a given angle when measured. Thus *measured spin* is determined by a dynamic state – the spin-vector angle *at the moment the measurement is made*. Note if spin is found to be *+y* on an initial measurement of *y-spin*, it will be measured as *+y* on subsequent measurements of *y-spin.*

In the same way, *a determinate spin* in any direction is created by inserting a partition to trap the vector *up* or *down* relative to that direction. E.g. to determine spin in *z,* the partition is rotated 90 degrees.

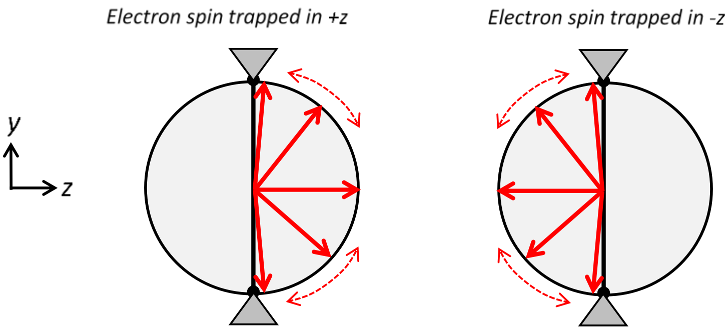


Figure 42. Spin determined as *±z* by being trapped on either side of the partition, now aligned orthogonal to *z*.

Spin can actually be measured in three directions, *x, y, z.* We can make the half-circles into hemispheres of a sphere, with the partition a circle dividing the sphere in two, and we get the full representation of 3-D spin, homomorphic to the Pauli matrices.

Note that this conforms to the QM principle that particles do not actually have macroscopic properties until they are measured.

In this picture, a particle in a definite (measured) spin state has a time-varying *spin-vector* state. Equally, two particles in two different prepared spin states (e.g. *+y* and *+z)* have partitions at different angles, but may at times have identical underlying *spin-vector* positions.

Now in this model, the process of making a *measurement* involves removing the existing partition and replacing it at a new angle. The spin-vector will be caught on one or other side. The probability of getting spin *up or down* on the new measurement is the probability of catching the vector on one or other side.

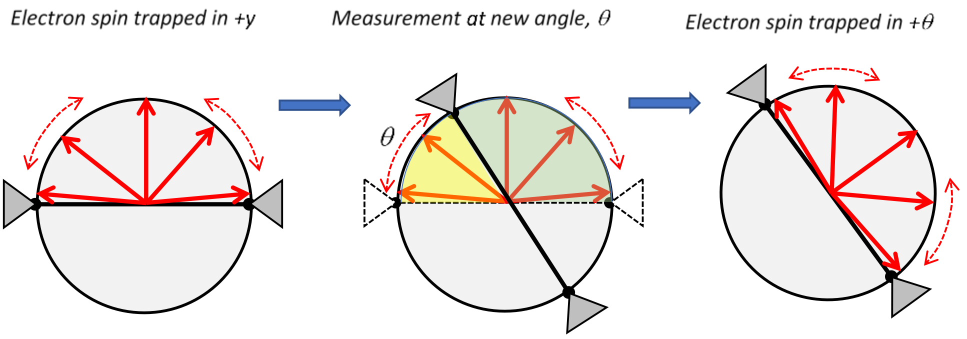


Figure 43. Measuring spin of a spin-up (*+y*) electron at a new angle, θ. It happens to be trapped in the $+\theta$ region, but could have been trapped in the $-\theta$ direction. The probability of being trapped in a given angular region is $sin^2(\theta/2)$ in terms of the angle illustrated.

We define the *spin vector* to spend the appropriate amount of time in the different angular regions, and we get the correct QM measurement probabilities back. But note that the probability is *not proportional to the angle,* i.e. it is not θ/π. That would allow a classical model. The probability is $sin^2(\theta/2)$ or $cos^2(\theta/2)$ (depending which axis we measure the angle from).

It is also possible for there to be *no spin determined,* i.e. no partition inserted, and for the vector to freely rotate. This is a real electron spin state (circular superposition, no spin determined).

This gives a precise model for electron spin from a deterministic underlying variable. We now consider what happens with the measurement of two electrons in a singlet state.

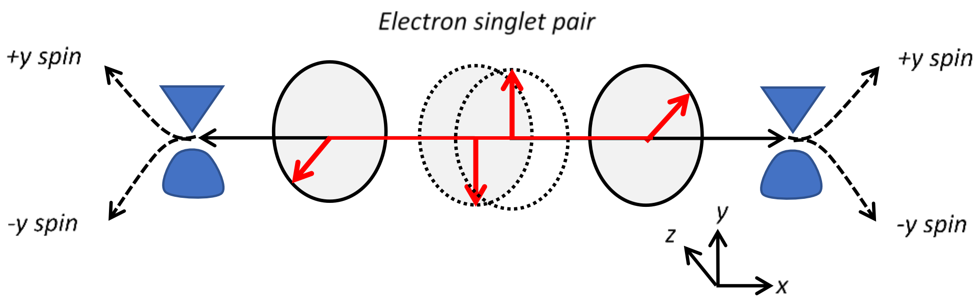


Figure 44. Two electrons in singlet state are separated and travel left and right. Either one could be measured first. For the QM probabilities the spin-vectors *must remain connected across space, and instantaneously pointing in opposite directions*, until one is measured. Then the connection breaks.

This is the critical point: the two spin vectors must remain instantly connected across space, as if they are joined by a rigid axle that keeps them pointing the in opposite directions. In the original singlet state there is no definite measured spin state, for either electron. (The electrons themselves are indistinguishable, and in superpositions of left and right positions at once.)

We then consider the two-stage process when a measurement is made.

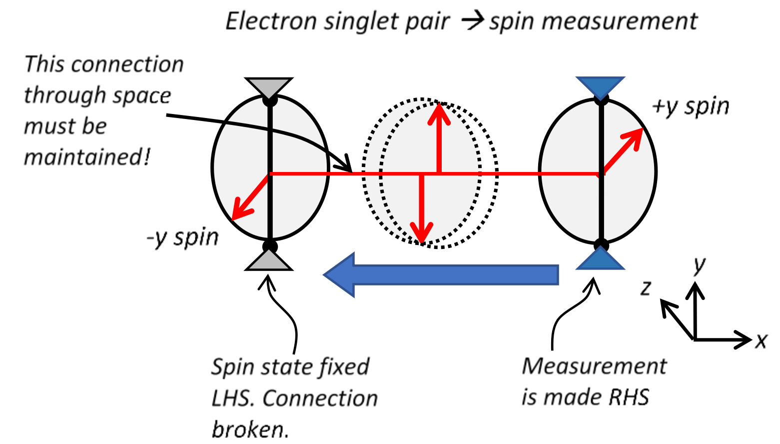


Figure 45. Stage 1. Before any measurement is made, the two electrons remain *dynamically connected,* as if the *spin vectors* were connected by an axle (red line).

Once the spin of one electron is measured, the spin vector of the other is instantaneously fixed in the opposite direction. Both electrons take on a definite spin state – they both have *partitions* inserted – and the connection (axle) is broken.

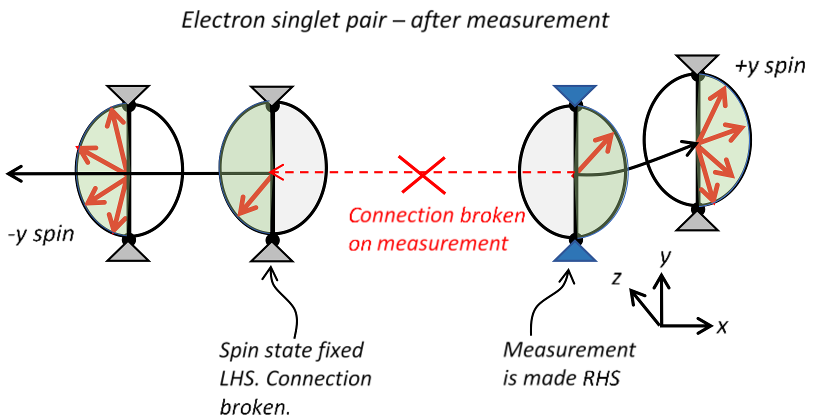


Figure 46. Stage 2. Once a measurement is made (e.g. on the RHS), the *spin vectors* on both sides are fixed, in opposite partitions. The *non-local connection is broken,* and the spins are henceforth independent of each other.

This is a kind of mechanical "hidden variable" model for spin states. It can be *deterministic,* since the motion of the spin vector can be deterministic. However we may assume it is unobservable and *chaotic*, and gives rise to irreducible probabilities. (But now it is *possible* that they might be controlled – something not conceivable in the purely statistical interpretation).

In ordinary QM, the non-local correlations between measurements are described probabilistically, without any attempt to give a model of the states. This hidden variable model illustrates exactly what is needed physically to connect states if we want a realist model. (This type of explicit model is not used in conventional physics, because it implies a definite temporal and causal order to the collapse events, which contradicts the standard interpretation of relativity theory, which denies any objective order of the space-like separated collapse events. But this is not a problem for us, as we have a realist conception of space and time.) We propose a real connection, using the filaments.

Bell's theorem.

Bell's theorem can be illustrated with our system. First we make *transition probability matrices* for the quantum system. We can consider measurements at three angles, *1 = 0, 2 = 30, 3 =90 degrees*. The first measurement can be made on the *spin-pair particle* because this determines to opposite spin for the particle we are going to measure. We can subsequently measure the spin at different angles on the particle.

Angle Δ		Angle 2	Measurements 2	
	1 and 2	**30**	up-2	down-2
Angle 1	**0**	**30**	0.5	0.5
Measure 1	up-1	0.5	0.4665	0.0335
	down-1	0.5	0.0335	0.4665

Figure 47. Transition probability matrix. We measure the *spin-pair particle* at 0 degrees, and this collapses our experimental particle to spin up or spin down at 0 degrees. Then we can measure it at 30 degrees. The matrix shows the probabilities of each outcome.

The probabilities for the *Measurements 2* match exactly what is expected *for a particle prepared with the Measurement-1 values.* That is to equivalent to saying: once the *other spin-pair particle has been measured on some spin axis,* our particle acts as if it has been *prepared in a pure spin state,* on that measurement axis.

The probabilities are calculated using: $cos^2(\theta/2)$ functions, where θ is the *angle difference*. E.g.

- *prob(up-2|up-1)* = $cos^2(\theta/2) = cos^2(15)$
- *prob(down-2|up-1) = 1 – prob(up-2|up-1)*
- *prob(up-1) = prob(down-1) = prob(up-2) = prob(down-2) = 0.5*

The absolute probability of spin-up or spin down on any given axis is 0.5.

The probability of a given sequence is the product e.g. in the example: *prob(up-1,up-2) = 0.5 x* $cos^2(15) = 0.4665$. It does not matter what order measurements 1 and 2 are performed because the transition probability is symmetric since: $cos^2(\theta/2) = cos^2(-\theta/2)$.

		Angle 3	Measurements 3	
	2 and 3	90	up-3	down-3
Angle 2	30	60	0.5	0.5
Measure 2	up-2	0.5	0.3750	0.1250
	down-2	0.5	0.1250	0.3750

		Angle 3	Measurements 3	
	1 and 3	90	up-3	down-3
Angle 1	0	90	0.5	0.5
Measure 1	up-1	0.5	0.2500	0.2500
	down-1	0.5	0.2500	0.2500

Figure 48. Transition probabilities for *30 – 90* and *0 – 90* degree measurements.

Note these are three different transition probability matrices, relating measurements on two angles.

Another possibility is a sequence with three measurements, through: *0 – 30 – 90*.

Angle Δ		Angle 2	Measurements 2			Measurement 3		
	1 and 2	30	up-2	down-2	0 to 30 to 90	up-3	down-3	Sums
Angle 1	0	30	0.5	0.5	60	0.5	0.5	1
Measure 1	up-1	0.5	0.4665	0.0335	up-1	0.3583	0.1417	0.5
	down-1	0.5	0.0335	0.4665	down-1	0.1417	0.3583	0.5

Figure 49. Transition probabilities for *0 – 30 – 90* degree measurements, right. We obtain the joint transition probability matrix by multiplying the two separate matrices for: *0 – 30* and then *30 - 90*. These represent the *spin correlations* between outcomes.

This represents transition probabilities for measuring *angle-3* (90 degrees) by first measuring *0* degrees, then measuring *30* degrees, then *90* degrees. Note the total probabilities for *up-3* and *down-3* are still *0.5,* but now the distribution of combinations is different to the previous one. E.g. the chance of obtaining *up-3* is much higher given *up-1 (0.358)* than *down-1* (0.1417). Without the *interpolated measurement* at 30 degrees, the probabilities are all 0.25, as above.

Now so far this is just standard QM, and we see the well-known feature that interpolating measurements in a sequence of spin measurements (or any measurements) changes probabilities of the outcomes. (This leads to the quantum Zeno paradox: if we could perform measurements continuously closely together, the state does not change.)

- With an isolated spin system, this is taken to mean that *measurement disturbs the spin state.*

- Measurements do not just measure an existing state and leave it fixed.

We know this because we can measure at *0-degrees, 90-degrees, then 0-degrees again,* and when we measure *0-degrees* again, it is not correlated to the first measurement. E.g. we can get: *up-0 → up-90 → down-0.* Now this is quite comprehensible: measurement (or state preparation) physically affects the system, and resets the spin variable. There is no other realistic choice in ordinary QM: the wave function collapses, and a new state is "prepared" after the measurement.

But the special problem raised by the spin correlations is that the measurement causing collapse is now being performed *clearly at a distance, on another particle.* That is to say: *measuring the spin on one electron that may be many miles away prepares the second electron in a specific spin state, without otherwise physically interacting with it.* The second electron behaves exactly like it has been collapsed into a prepared state, with a pure spin.

(In fact all quantum systems are spatially distributed, and wave collapse is always "instantaneous" over a spatial wave function. So wave collapse is intrinsically *non-local,* even with a single particle. But the spin-pair example brings home how definitely *non-local* the effect is.)

The big question in the field is to establish for sure that the correlations are caused by a non-local dynamic connection across space, rather than being somehow predetermined by a system of underlying local variables. The arguments are mainly due to Bell's theorems.

- Bell's Theorem shows that the correlations cannot be explained by having pre-determined underlying variables, and we are required to have a dynamic connection.

We can show Bell's reasoning in a simple way with our example.

For a hidden variable explanation, we imagine that we assign a determinate outcome for each particle on *its next future measurement,* with outcomes specified for *all possible future measurements.* (There are an infinite number: one for every angle. We now just consider assigning three simultaneously). We combine a collection of particles with determinate states in a statistical ensemble. We choose electrons in pairs, with opposite spin properties for every angle, so that takes care of the *correlations.* But the problem is whether we can make a statistical ensemble to duplicate the QM probabilities.

	up-90	down-90
up-0	0.25	0.25
down-0	0.25	0.25

	up-90	down-90
up-30	0.375	0.125
down-30	0.125	0.375

	up-30	down-30
up-0	0.467	0.034
down-0	0.034	0.467

0 degrees	30 degree	90 degree	Prob.
up	*up*	*up*	A
up	*up*	*down*	B
up	*down*	*up*	C
up	*down*	*down*	D
down	*up*	*up*	D
down	*up*	*down*	C
down	*down*	*up*	B
down	*down*	*down*	A

A+B+C+D = 0.5
A+B = 0.467
A+C = 0.25
A+D = 0.375
2A+0.5 = 0.467+0.25+0.375 = 1.0916
A = 0.2958

A	B	C	D	Sum
0.296	0.171	**-0.046**	0.079	0.500

Figure 50. We see individual transition probabilities in the three boxes. We make an *ensemble* of particles labelled *up* or *down* on all three spin angles, *0, 30* and *90* degrees. This shows the eight possible combinations of properties on the right. Then we solve for the statistical probabilities *A, B, C, D* required to get the QM probabilities. There is no solution – in this example, C is negative and cannot be a probability.

We construct an ensemble in the proportions of *A, B, C, D* to try to duplicate our QM probabilities. Because of symmetry, there are only 4 independent values, as e.g. *(up, up, up)* is equivalent to *(down, down, down),* etc. So: *A+B+C+D = 0.5.* We can then set conditions on them in pairs, to ensure the correct probabilities for each combination. This gives us four equations in 4 variables, and we can solve this. But there is no consistent solution: this example requires a negative value for *C*.

- *There is no solution for the QM probabilities. There is no ensemble that could work.*

The idea of the *ensemble* is that each individual particle is drawn from a collection of pairs, where each has pre-determined properties *for spin on each axis.* This determines the outcome of *the next measurement only*. (When a measurement is made, another state is drawn from the ensemble.) This is enough to ensure the correlations, because each pair is chosen with opposite spin properties, for every possible next measurement. If spin could be described by such an ensemble, this would remove the need for a *non-local connection* between the two spin states. But this example shows it cannot. Bell's theorems show more generally it cannot.

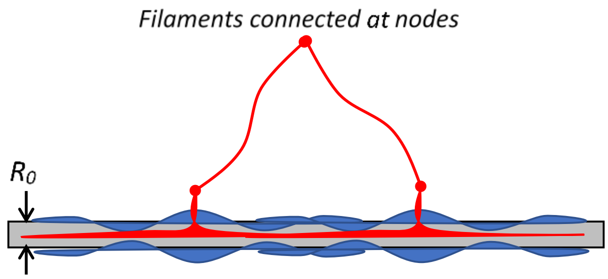
But note that there is a system with a transition probability that could be modelled like this: if we set the probability proportional to the *angle,* not cos^2 of the angle. Then we could have correlations without a dynamic connection. But it does not work for QM probabilities.

Bell's theorem essentially shows that we cannot remove the non-local connection across space. Not even with our *deterministic system*! So we accept it.

Entanglement and wave collapse.

This kind of model with dynamic underlying variables illustrates the feature that has proved impossible to remove: an "instantaneous connection" must be maintained between separated particles, which correlates states "*instantaneously"* at the two locations. This entanglement through spin is just one example: it is a generic feature that arises throughout QM. Whenever two or more particles interact, their states may become entangled. The striking thing is that they act like they are *physically connected,* but there is no plausible connection through ordinary 3D space.

Our "spin-vector" model also illustrates that the connection is as simple as a single "axle" connecting two rotating "spin vectors". The proposal is that the "axle" is provided by the filaments.



Two particles connected.

Figure 51. Two correlated (entangled) particles are physically connected through filaments. The spin states are coordinated by this physical connection.

The filaments connect particles separated in space. This provides exactly what we need for the spin model. We say the spin states are fixed relative to each other by the filament. The connection is equivalent to a single "axle" connecting two electrons. This is outside ordinary space. In ordinary physics there is nothing outside 3D space at all, and nothing inside 3D space that could connect them, and the effect is no less than magic. There is a lot of work in this area, checking if there are any possible ways to circumvent non-locality proofs. None can be found. We take the bull by the horns instead, and propose a real mechanism.

It would be *ad hoc* to propose such filaments as an explanation for entanglement, if this was their only role. But in the context of TAU they arise independently, and it is a problem what to do with them anyway. Assigning them this role in entanglement is a natural interpretation. The filaments provide the minimal non-local connections required. Without such a physical connection, QM is simply left with mysterious connections that have no explanation. Filaments will also let us make a distinction between smooth evolution and wave function collapse.

On the other hand, our fundamental theory TAU no longer tells us what these filaments are going to do, except in general terms. To make anything of them, we have to match them with properties found in quantum mechanics. The first is the transmission of information through them.

The filaments themselves are in vibrational states, corresponding to the particle wave functions. The speed of transmission in the filaments (which could be torsional or wave-like) will be greater than the speed of light, because the filaments are very thin, and a scale principle applies. As we saw in the cosmology, the speed of light increases for ordinary space with the ratio: $\sqrt{(R_U/R_W)}$. Assuming the filament radius is the Planck length, $R_A/\sqrt{D} \approx R_A/10^{20}$, we may expect a surface wave speed to be something like: $cD^{¼} \approx 10^{10}c$. This travels a distance of one light year in about 0.003 seconds. So it can connect quite distant events almost instantaneously.[22] (But note this speed is not known.) There may be torsion waves, or transverse vibrational waves (like guitar strings), and the speed may be as much as: $c\sqrt{D} \approx 10^{20}c$. The most extreme speed would be: cD, which would connect particles across the universe in the time of one particle cycle: $DR_A/cD = R_A/c$.[23] We cannot tell until we can develop a robust 6D continuum mechanical analysis. It may seem complex. But there are a lot of symmetries, and cannot be so many possibilities.[24]

In any case, we take the filaments to provide the critical connections between wave functions. E.g. in the case of the spin vectors, the filaments can carry *spin* through torsion. More generally they relate position-momentum properties. But now our physics has several modes of interaction, replacing the *wave-particle dualism* of the conventional model:

(a) Superposition of wave functions in space.
(b) Particles (filaments) following-and-creating wave functions in space.
(c) Filaments interacting, and making nodes or connections with each other.

The first mode is normal QM superposition. The second follows the Bohm pilot wave mechanism. The third is novel and involves breaking and reconnecting of filaments as the model for wave function collapse. Initially, we just propose that this happens, to give ourselves a theory – or to recognise what a theory must include.

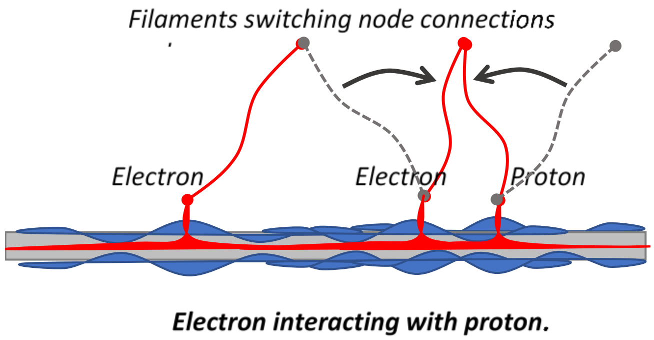


Figure 52. An electron in a singlet state with another electron is absorbed by a proton. This reconnects filament nodes.

[22] There is a problem from the fact the connection is not instantaneous. If two separated system can be measured very close to simultaneously in the filament frame of reference, they may get conflicting results, and this could contradict QM. For collapse events separated by 1,000 km, the time is about 3 x10^{-13} secs. This is about the minimal time for an electron measurement, so this is not very likely. But there are several ways this could be resolved to avoid a theoretical conundrum.
[23] This allows a *space-symmetric universe,* where every particle has a mirror image on the opposite side of the universe, connected directly by a filament.
[24] This also raises the question of the length of filaments. We could match wave motions in the filaments to periods of particles, but the estimates we get vary from 10^{-5} – 10^{8} m, depending on assumptions. So this is still an unknown point of the model. What we need now is a unified solution to TAU.

The measurement of one electron (through being localised with a proton) breaks the singlet electron-electron connection, and establishes a new electron-proton connection. This represents a position measurement of the electron. Note that it also breaks (at least some) external connections of the proton, since it is equally a measurement of the proton. (So note that there may be multiple node connections.)

In this mechanism, *wave collapse* only happens when two *filaments* come in close contact in the surface to interact. Two interacting filaments must separate from previous connections, and connect with each other. This now raises questions about the filament interactions, the nodal structures that could be formed, and the reestablishment of the quantum spatial wave function when connections are broken.

How does an electron filament separate from one node (the other electron), and move to join another (proton)? It moves through space? We normally see this as an "instantaneous" wave collapse, but now it takes a finite time.

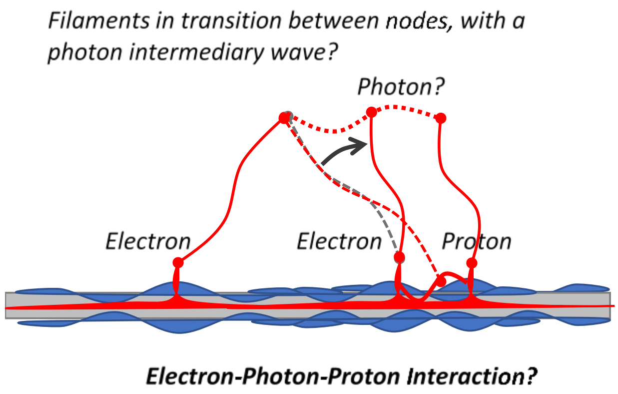


Figure 53. The filament of an electron, half-way between its original singlet state node and its next proton node. This is an EM energy exchange.

This also raises the question of photons. Photons exist as QM surface waves, but do they have filaments? By assumption, the mass particles have filaments, with the Planck length radius. But photons have no *rest-mass* component, and in TAU, they do not have a *gravitational strain.* They are like electrons turned sideways. We can image we turn the filament sideways, so that it points along a wavelength through space. Now photons can have entangled states. However, when we look carefully, we find that photons are not entangled with photons. Rather photon *modes* are entangled with each other. (e.g. van Enk, 2004).

One hypothesis is therefore that photons have filaments, but they only join back to themselves, in loops. E.g. when an electron absorbs a photon, it produces an electron with a higher energy, and another photon.

This then raises the question of the number of particles that can be entangled. We have shown only pairs of particles. But there may be more than two particles connected at a single filament node. And it also seems that the construction may be hierarchical. This corresponds to systems of filaments embedded in higher-level filament networks. Do they keep joining up to further nodes higher up?

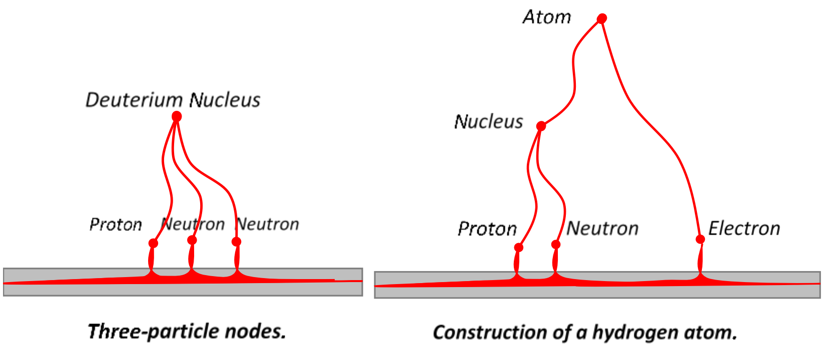


Figure 54. LHS. Three-particle node for a deuterium nucleus. RHS. Hierarchical construction for a hydrogen atom, with the electron joining above the nucleus.

As far as the *nucleus* is concerned, this multiple-joining allows the *nucleons* to maintain their individual particle identities, while forming the *nucleus* as a single entity. This should conform to standard QM for ordinary atomic systems. Then an atom is formed by as second node connecting an electron with the nucleus. So we have a second level hierarchy. We will have to make our filaments behave to match the way particles, atoms, etc, combine, in constructions of processes and states. But the particle behaviour itself is in the phenomenon: we are just making it explicit.

There are many phenomena that could be considered. E.g. superconductive states. But the fermion versus boson behaviour is the most fundamental. Two fermions cannot occupy the same state while multiple bosons can. This was proposed by Pauli in 1925 as the *exclusion principle* for electrons, and in a generalised form it is regarded as a fundamental principle. But it is one of those profound quantum mechanical *rules* with no underlying explanation. We can now try to explain it in terms of the impossibility of filaments occupying the same state.

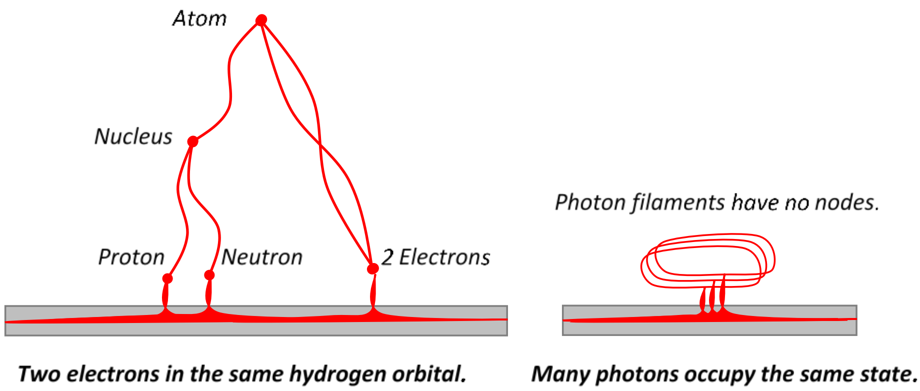
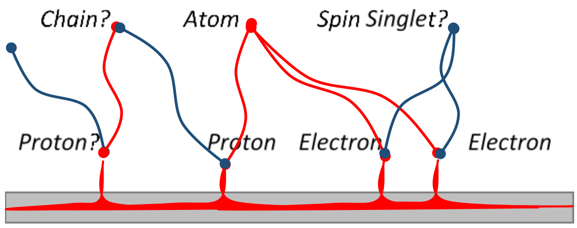


Figure 55. LHS. Two electrons (fermions) with opposite spin can occupy the same spatial wave function in an atom, because their filaments are separated by spin states. But no more filaments can be added to the node. RHS. Many photons can occupy the same state, because their filaments do not have join into a nodal structure.

Having filaments gives a new mechanism to explain the behaviour. It seems like the difference between fermion and boson behaviour in TAU will relate to filament behaviour. This is another reason to think photons have only self-joining filaments. The massive vector bosons *(W+, W-, Z)* persist for only a microscopic time, and may be unable to form stable filaments. The formation of stable filaments may also be expected to provide the distinction between *real particles* and the *virtual particles* in quantum field theory.

But another question is then *how many filaments?* If it works to record particle interactions using just one filament, fine; but what if it requires two or more filaments per particle?



Could there be two filaments per fermion?

Figure 56. Is there just one filament per electron and proton? Could there be two?

TAU does not tell us this, so we will have to work it out from observational physics.

- How many connections are possible or required to make entanglement work?

We can bring it back to known theory by relating it to the construction of the Hilbert space for complex particle systems. But now it raises questions over how *complete* that construction is. It lets us illustrate how distinct constructions could be possible.

It is also worth noting a major logical difference between having one or two filaments, if we construct larger *hierarchical filament networks*.

- With just one filament per particle/node, joining above, networks can only make simple *tree hierarchies,* from above. These are limited for representing information.
- With two filaments (or more) per node, networks can make all kinds of complex relational structures, including CAT2 type networks.[25] These networks allow general graphs or relations, and are ideal for representing information.

The speculative but interesting question this relates to is the possibility of complex *hierarchical nodal structures.* We see a second-level node for the *atom* above. But could there be multiple levels above atoms? Representing entanglement among larger entities. Do measurements or collapse events occur in a hierarchy, with "cascading" effects?

E.g. can we entangle *measurement systems and object systems*, and use collapse to switch "measurements" on or off? We can then potentially use collapse to transmit signals non-locally, by testing whether an entangled measurement produces interference. This is the question of *superluminal signalling.* Conventional proofs in QM tells us this cannot be done. (E.g. Ghirardi *et al* 1979, 1980). But these proofs make an assumption: that the result will be as if no intermediate collapse occurs. The question we are asking is whether there is a real collapse, and it appears to be still an open question. Systems in ordinary atomic physics or chemistry are not normally conceived with higher levels of hierarchical complexity. E.g. interference experiments are rarely designed with

[25] Holster 2021.

hierarchical collapse sequences of measuring devices – where "measuring devices" themselves go into superposition. However it is possible to test for such effects.

This is also related to one of the oldest questions in QM, about the cause and description of wave collapse. The filament construction in our theory is reflected by the *Hilbert space description* in ordinary QM. The Hilbert space for a single particle, say H_1, is a kind of state-space, representing the possible wave functions for the particle. Any possible QM state is a *vector* in the Hilbert space. For a system with two particles, we take the Hilbert product space: $H_1 \otimes H_2$. The system as a whole has a state vector in this space. For more particles, we may take multiple products: $(H_1 \otimes H_2) \otimes \ldots \otimes H_N$. Now in the standard picture, the *state vector* evolves smoothly in the Hilbert space (by the Schrodinger equation) until a measurement is made, then it "collapses" to a new vector – which is a subspace of it present range. E.g. for our two-particle spin system, it will continue in smooth evolution until one electron is measured, when the state vector will collapse in the space: $H_1 \otimes H_2$, from a *superposition of spin-location states* to a specific spin-location state. This collapse generally happens physically when a particle is *localised in physical space.*

But one of the famous conundrums of QM measurement theory (Schrodinger, Wigner and others) is that the measuring instrument (say the atoms in a detector that absorbs an electron in one channel) can be included in a larger Hilbert space, say: $H_1 \otimes H_2 \otimes H_3$, describing the system and the measurement instrument together. Then how do we get a *collapse event* in this larger space? Do we have to measure this system in turn from the outside? Is that an infinite regression? And why not just have a smooth evolution in this larger space, with multiple "measurement outcomes" coexisting in superposition?

The measurement *collapse* to a single state vector in: $H_1 \otimes H_2$ might be replaced by a superposition of separate measurement outcome states in $H_1 \otimes H_2 \otimes H_3$. But do measuring instruments really persist in superpositions of states? And can we keep extending this until we get to the whole universe? There are several radically different answers suggested in the literature, depending on the interpretation of QM adopted.

But the primary observation for us surely comes back to the specificity of our conscious experience. We think there is a collapse because *we consciously register only one outcome* for experiments, or observations. Only *one atom absorbs the electron.* Only *one lotto number* is actually picked.

If both outcomes persisted in superposition, in a larger Hilbert space, then supposedly, *both conscious states of an observer* persist. This is highlighted by Schrodinger's cat as an absurd outcome. Everett's "many worlds" interpretation of QM takes this conclusion seriously, allowing all outcomes to persist, and splitting observers into multiple "realities" all at once – perhaps the most radical metaphysical implication in scientific history! (*Seriously? Yeah, seriously! The world splits every instant and everything happens! Do you believe that? No not really.*) Other models propose physical conditions for collapse. Others try to show it doesn't matter or is not measurable.

TAU gives a mechanism for discrete collapse events. They are now recorded in the interactions of the filaments. This also means TAU may allow some different possibilities to the conventional theory. The Hilbert space vector describes *surface wave functions,* in superpositions, and this is just to say that the *surface waves* evolve smoothly between collapse events, as usual. But the Hilbert space itself is now determined by the particles/filaments/nodes.

Complex systems.

We cannot introduce another level of *quantisation*, representing *superposition of filaments.* Filament arrangements represent particle states. We have mixtures of states. Now collapse events (measurements) mean the *state vector changes,* but can also mean the *state space* changes. Changes of the state space are of fundamental importance in non-equilibrium or far-from-equilibrium thermodynamics – where structures and structured processes appear in nature. It is not simply the steady evolution of the system in a given state space that matters, but *changes of the state space,* which are changes in the *possible states of the system.*

This is illustrated by the early-universe entropy production, which is a *phase-change phenomenon*. In our theory, as in the conventional one, the universe began expanding in a very homogenised (maximal-entropy) state in the initial highly compact space (with few states available), but when it exploded, a vast number of new states became available, as stable particle states. Once it flipped into the larger exploding state space, the first homogenous state that crystalised out represented a very *low entropy* state indeed! For a universe expanding with many particles, the "equilibrium state" is not the homogeneous state, like a thin featureless gas, it is a gravitationally clumped state. The universe is in a far-from-equilibrium process, evolving through gravitationally clumped states, creating complex structures and entanglements: galaxies, stars, planets, chemistry, life, etc.

We have a natural explanation of *thermodynamic irreversibility,* given the universe has a cyclic collapse. It is *not expected to be time symmetric,* because the laws are intrinsically directional, through *retarded causation,* i.e. *retarded potentials.* While the universe is expanding and contracting, processes go about their normal thermodynamic cycles, and produce complex structures. At end of a cosmic cycle, everything gets compressed, the state space gets compressed, the entropy is suddenly forced down. When the universe expands again, the thermodynamic behaviour continues in a new cycle, in the same direction.

We do not have the major problem of explaining *time asymmetry* with *directionless space-time* that conventional accounts have, because time is intrinsically directional, and has a direction specified in the fundamental laws of physics. Time directionality is evident in several fundamental laws. First in *retarded potentials.* Second in the directional spin of the QM wave. Third in the asymmetry of the weak force. Fourth, in the general asymmetry of the probabilistic laws of QM. (Holster, 2003 (a)). Actually these are already present as *lawlike asymmetries of physics,* they are just not recognised as such, leading to the "mystery" of why the universe is asymmetric in time when the laws are symmetric in time. Time asymmetry is not mysterious in TAU.

But the question that genuinely puzzles scientists is how *so much complexity has arisen.* Planet Earth is bursting at the seams with complex systems – largely because Earth has developed life. Life involves vast molecular complexity, supported by informational complexity: cells, DNA, genes, organs, neural networks, nervous systems, language, consciousness and thought. How do we explain all this complexity? And is it simply due to classical interactions? Or is there a role for quantum features? Or further structures?

Note the *number of filaments and their connectivity* now gives a measure of complexity, and a different source of complexity to simple wave disturbances. It provides a *topological complexity.* The

TAU filaments introduce the question of higher levels of hierarchical complexity, forming complex entangled QM systems. This leads to the possibility of experiments testing for “cascading” systems of hierarchical entanglement – tests of whether logical structures of filaments play a role. These effects have not been considered much yet, and experiments may be difficult.

But we might also expect to see it play a role in complex natural systems (the fecundity of nature: everything gets used somewhere). And nowadays, the role of *quantum entanglement* is increasingly found to be important in complex natural and living systems.

If entanglement is really embodied through filament networks, it may provide structures that come into play in natural information systems. The brain or nervous system is the most spectacular candidate for a large-scale entangled system. And scientists have been considering this for some time. But the brain is immensely complex, difficult to observe in operation, and it is not evident how to test the hypothesis that it creates and sustains a *single large-scale quantum mechanical system,* relating many hierarchical parts (neurons). Or what the “hierarchical structure” could be like. But we do know what the system is made from in bulk.

The brain is about 90% liquid water, with 10% structural material (by molecule count). A quantum brain would require that water solutions are able to act as a host for coherent quantum waves, entangling many particles. If this is possible, we might expect that some related properties may be evident in simpler water systems. And indeed, water with solutes of various kinds, surface constraints (e.g. cells, membranes) of various kinds, under the influence of EM treatments of various kinds, is now well known to display many inexplicable behaviours. (E.g. Ball 1999, 2008; Pollack 2013; Ho 2012(a), Chaplin Website, for different views).

In fact there are many weird and wonderful water phenomenon There are experiments that show inexplicable “water memory” effects, others showing fine-grained *exclusion zones* and “water structures” at interfaces and surfaces, and others showing inexplicable effects of weak EM fields on water properties. Another phenomenon suggested as having a quantum mechanical explanation is the “floating water bridge”. Subtle effects are evident in the universal role of water in processes of transcription of DNA, protein reactions, cellular mechanisms, neural mechanisms, etc. Roles for coherent quantum mechanical states in some water phenomenon have been proposed since at least the 1980s.

Multiple explanations for various anomalous water phenomenon have been proposed, but there is still no scientific consensus, and there remains a lively debate. Water itself remains the most mysterious substance in chemistry, and it has delicately balanced micro-properties (tiny molecule, high dipole moment, high ionisation, high mixture of covalent and ionic bonding), that makes water states extremely difficult to observe, or to model quantum mechanically. In fact our best models of water still cannot even explain the boiling and freezing points (or another 60-odd known anomalies).

So it is suggested that simple water systems may provide a natural laboratory for testing information effects of entanglement and collapse phenomenon, and this is in parallel with the idea that our brains have a fundamentally quantum mechanical level of operation. Alternatively, experiments with complex entangled states are increasingly possible in condensed state quantum physics, especially with the rise of quantum computing technology. It is this area, of low-energy, delicately controlled, nano-physics that TAU filaments may have some application.

This concerns the role of quantum processes in information systems, and leads to some very metaphysical questions. So having raised the question, we will conclude this survey with a few brief comments.

Metaphysics.

TAU clearly disrupts conventional metaphysics of modern physics, which is based on taking *4D space-time* as the fundamental entity. According to most physicists today, all reality must be defined in the *space-time manifold* model. The possibility of *realism about space and time* is not considered a viable question by most.[26] This has strong implications in academic philosophy of physics. It is probably why physicists take *time reversal symmetry* as a fundamental principle, and refuse to consider evidence that time is asymmetric. Metaphysical theories tell physicists that time should be symmetric. But time actually has a preferred direction in physics, as in life and in consciousness.

Metaphysical beliefs in physics like "everything must exist eternally in a symmetric *space-time"* have the function of constraining the possible theories that can be considered, and constraining the imagination. Metaphysical beliefs or codes remain a powerful method for the *demarcation* of belief systems. E.g. *time flow, simultaneity* or the *aether* are generally regarded as out of bounds in physics today.

However, apart from this function of controlling belief systems, "space-time metaphysics" is very abstract, and has little practical impact in the real world. The philosophical meaning primarily taken from modern physics is more likely to be *materialist reductionism.* The message is that theories are already so good and the foundations are so well understood that there is no chance of any serious fundamental revision of "scientific reality" possible any more. It is allowed that a unified theory may change things a little of course – but only within the limits of known physics, by resolving some puzzles, making the known theories work a little better – but without changing the fundamental knowledge of reality that has been built up over the last fifty years.

TAU radically contradicts this conservative message. It means that the world is a very different place to the one imagined in conventional physics. Not just in the abstract philosophy, but in real things. The most radical difference is of course that it introduces higher dimensions, *with real structures and processes.* And these become essential bearers of *information.* What other metaphysical consequences does it lead to? Implications are most evident for a theory of consciousness.

We know that the content of consciousness is closely connected with the state of the brain. But the origin of consciousness itself remains mysterious. There are no really specific models that link it directly to *fundamental physics*. Certainly none that are generally accepted. But the filament structures we have introduced in TAU opens a new possibility.

[26] It is popularly held that the Michelson-Morley experiment along with the Einstein-Minkowski version of Special Relativity conclusively ruled out the possibility of realism about space or time over a century ago, by dismissing the classical *spatial aether.* But we should realise by now that is very naïve.

The possible dependence of conscious states as *quantum states* has been long considered as an important question by realists about mental states.[27] There is substantial evidence and considerable speculation that a coherent QM wave function, representing a complex hierarchical state, is produced by the brain, and this is responsible for conscious content. This is a *realist* concept, of a mental-physical correlate, and an alternative to classical reductionism.

Reductive materialism makes the brain a discrete Turing machine, just like a digital computer, with a classical mechanical state. Both classical and quantum systems can represent information. However a single complex quantum state is much richer, and represents a *relational state* wholistically – as illustrated by the radical differences between digital and quantum computers. As suggested above, it can potentially be *"self-observing",* which we can associate with having higher-level hierarchical states, that can induce or observe collapse of lower-level states.

Materialists traditionally argue that all that is required for consciousness is a "functional representation of information". This simple *mechanical reductionist* view was developed in the context of classical physics, and became the "functionalist view" of intelligence, with Turing and von Neumann. But it seems to explain nothing about consciousness. It is independent of any empirical facts about the operation of neural processes or fundamental physics that must ultimately underpin a reduction of conscious states.

To some cognitive scientists (studying brain processes) and some philosophical realists, it seems very likely that "conscious states" correspond to *single wholistic quantum mechanical states,* not to classical "digital information" states. There is no evidence that magnetic disks or transistor arrays that represent information are conscious – any more than a book is conscious. There is equally no evidence that software programs are conscious, even though they can act "intelligently" in a behaviourist sense.

Traditional materialism (functionalism; reductive behaviourism) is anti-realist about consciousness, and often denies it exists. Materialists instead propose "behavioural criteria" to define the "meaning" of the term consciousness, or the meanings of language for "conscious states". For these philosophers it comes down to a semantic problem of how to define the term "consciousness". Realists by contrast think consciousness is real, and must be associated with some kind of specific states, processes or entities, that produce and support the peculiar quality of "conscious experience".

Now consciousness has now also been long and famously associated with the mysterious phenomenon of wave function collapse in quantum mechanics – sometimes through an appeal to an "observer" that has to be added from outside physics proper – or sometimes as pointing to a non-physical aspect of reality – or as a level of physics not yet comprehended.

Now with TAU, the filaments introduce a network hierarchy of *physical connections and information-carrying structures* that can potentially play the role of a realist correlate of conscious states. It appears suited to this because of the wholistic nature and interconnected nature of such a network.

[27] Although it has been rejected as a meaningful question by some positivists, logical behaviourists, pragmatists, etc. Some philosophers claim to explain "consciousness" with *semantic-behaviourist theories,* not as a natural phenomenon. They think that if we can *explain our language for talking about consciousness* there is nothing further to explain. But a scientific explanation of the phenomenon is required.

But this raises another fundamental question for us: what ultimately happens to the particle filaments “above”? Do filaments always join to other filaments? Does the nodal structure just stop at some level? Or do nodes keep joining inside the large “internal space” of the universe, to even higher-level structures? Are there nodes representing our personal conscious identity? If so are they temporary states, dependant on the body, or do they persist independently?

We do not try to answer these questions here. But once we introduce a filament structure, the universe is suddenly filled with *potential information and interactions* that are outside the domain of causation of purely local forces in 3D space. There are many empirical questions to be answered about TAU before we have to confront this. But it still leads us to ask: what would it mean in terms of the reality we live in? The fact that it has strong implications is exactly why it is interesting as an alternative to standard scientific metaphysics.

I think we will remain confronted with a choice between two new world views, mirroring the two main views currently held, but in a more complex physical universe.

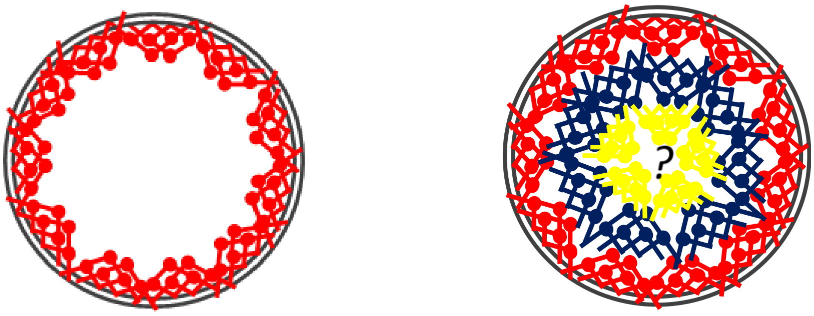


Figure 57. Two possibilities for the interior of the TAU universe. LHS. Empty. Filaments connect QM particles, but they are shallow and transitory, and dependant on material surface particles. RHS. Universe full of filamentous structures. It supports entities and information processes inside.

In the “full universe”, the first level (red) may be transitory, and dependant on material particles, but a second level (blue) may contain permanent entities, and in this , case, there might be a series of levels (yellow). These levels are not dependant on material objects for their existence. Is there a central entity holding them all together?

The first picture is still consistent with materialist reductionism. Materialists could identify consciousness as a special kind of filament state without stretching too hard. This state has the “wholistic” quality of a multi-particle quantum wave function, and the idea is that it enables an hierarchical quantum logic, with a certain autonomy from the purely mechanical particle behaviour alone. This may have some advantages in specifically explaining the generation of conscious states, by the central nervous system. But this picture can still deny any *permanent entities* in the filament network. I.e. it can deny “minds”, “souls”, “spirits”, etc, as long-lasting entities that host conscious states. It can deny anything carrying a lasting personal identity beyond the transitory *states of consciousness*. This is the conclusion that materialists primarily want. The denial of *conscious states* is not really so important: the denial of *minds as containers of consciousness,* the denial of *non-*

physical entities carrying personal identity, is the main point. So this view can remain consistent with atheism, moral nihilism, spiritual nihilism, and other conclusions that materialists want.

In the second picture, we have a complex hierarchy of entities, which may include lasting or permanent entities, at higher levels in the filament network. This could include "minds" as autonomous entities – i.e. lasting entities representing personal identity – the souls, spirits, ghosts, angels, demons, gods, etc of traditional folk belief; or the spiritual entities of various theologies. In this picture, *states* of consciousness are transitory and connected to physical events (just as we experience them), but they are states *of* higher-level entities. This allows realism about all kinds of non-physical entities. This does not reflect the specific views of any theology. But it allows spiritual belief systems to be consistent with material causality.

Now the reason for bringing this up is not argue for either choice here. It is an open question. The point is just to illustrate that if TAU is confirmed as a scientific theory, it opens up these possibilities. It resurrects these traditional metaphysical questions as real debates within science. The present state of science claims to leave no scope for such questions – fundamental physics claims to have all the essential answers about the contents of the natural world. But TAU means the natural world is much larger and more complex than our present scientific metaphysics recognises. Most certainly it introduces something dramatic: a world filled with *hidden information.* How such *information* is communicated among physical systems then becomes a new mystery.

TAU is a proposed as a unified theory, and if it is successful it might be thought – or feared – that it spells an end to fundamental scientific questions. But the opposite is the case. TAU opens up far more questions, scientific and philosophical and metaphysical, than presently conceived as possibilities in the current era of scientific certainty.

I will conclude this survey of the theory here. It is an attempt to give the big picture. Obviously there are a lot of detailed questions, derivations and conceptual explanations required. These are addressed in subsequent Chapters

To conclude we now briefly propose answers to the questions that we began with.

Answers.

Questions	Answers
What is dark matter?	Free energy in space; clumping of background energy; created by interchange with gravitational energy in the expansion process.
What is dark energy?	Not a real substance. Partly an observational effect from changing constants, but a real acceleration in part of the expansion cycle.
Why are different measures of the Hubble constant incompatible?	Observational inconsistencies from failing to take into account the changing constants.
Why did stars and galaxies form so fast in the early universe?	Gravity was stronger.
What is the quantum wave function?	An abstract mathematical description of a real perturbation of space.
What causes wave function collapse?	Reconnections of particle filaments, reflecting localisation of particles in space.
What provides the space-like connection for quantum entanglement?	Particle filaments.
Is there a deterministic level of physics underlying quantum mechanics?	There is a *determinate level* of underlying properties, but trajectories are intrinsically chaotic, and not *deterministic*.
What is the speed and frame of reference for wave function collapse?	The speed of waves on the filaments ~ $10^{10}c$ - $10^{20}c$; in the frame of the filaments.
Is quantum mechanics the fundamental description?	It is fundamental for the wave perturbation, but not for the particles or for measurement.
Why are there so many independent parameters in the Standard Model?	Because it is a phenomenological description of a simpler fundamental geometry.
Does the Standard Model represent the complete set of particles?	No.
Is there a reduction of the Standard Model to something simpler?	Yes.
Why can't physics predict any particle masses or force constants?	It does not have the fundamental model that determines the relationships.
Why do the electric charges of the electron and proton exactly match?	They are (time-reversed) wave components of exactly the same type.
What is the neutrino mass?	About: $m_e\sqrt{(1-(m_e/m_p)^2)} \approx 0.075eV$ for the electron neutrino.
Why does the weak force fail time and space reversal symmetry?	Spin is asymmetric in the torus, associated with a global spin state of space itself.
What is the quantum description of gravity?	Bohmian mechanics for the particle filaments. There is no quantisation of gravity as a force.
Is the black hole event-horizon singularity physically real?	The event-horizon disappears for black holes, (but another appears as filaments for particles).
Is the black hole central singularity real?	No. And no space-time worm-holes.

Is General Relativity fundamental or an approximation?	Approximation.
What is the source of irreversibility of processes (thermodynamics)?	Retarded causality, through centralised coordination of waves. This creates an entropy cycle in the global expansion.
Why are the fundamental laws asymmetric in time?	Causality is based on wave motions, and intrinsically directed to the future. Also there is an asymmetric direction of spin.
Why are the fundamental laws asymmetric in space?	Filaments point in a common direction, to the inside of the 3-space, and have an asymmetric direction of rotation.
What is the flow of time in physics?	What Newton said.
What generated the low-entropy state of the universe?	A cyclic expansion and contraction of the state-space.
What will the future expansion of the universe be?	The universe will recontract and collapse.
What happened in the very early universe before the Big Bang?	It "bounced" at maximal compaction, when the radius was still about 10,000 km.
Why is the universe made of matter instead of anti-matter?	The universe may have very large regions of matter and anti-matter, separated by voids.
Do dimensionless ratios of constants reflect physical relationships?	Yes. $q^2/4\pi\varepsilon_o hc \approx (m_e/m_p)^{2/3}$ and: $R_{universe} \approx \hbar^2/m_e m_p^2 G$.
Do the fundamental constants of physics change with time?	Yes, but they are determined by the expansion of space, not by time as such.
How many dimensions does space have?	At least six. (Possibly nine …).
Is String Theory the only way to generalise to a multi-dimensional space?	No.

Appendix. TAU Project Summary.

TAU Quantum Particles.

TAU starts by postulating a six dimensional geometric model that naturally reproduces basic principles of *relativistic quantum mechanics.* To obtain particles, this is implemented as the *torus model.* This geometry largely determines the theories of quantum particles, gravity and cosmology that develop. It models the key long-lived *relativistic QM particles,* as the natural wave function solution for the geometry. This gives an exact model for the electron, the electromagnetic force, and the photon to start with. It matches with classical and quantum electrodynamics. It also provides a proton, a neutron and a neutrino,. These are all the key long-lived stable particles. They have their main properties predicted more or less exactly.

The geometry predicts further unstable higher-energy particles, which may be identified e.g. with vector bosons. It indicates two orthogonal components of protons and neutrons, which may be identified with up and down quarks to match the Standard Model. In addition to the long-range EM force, it allows two short-range forces, on a scale corresponding to the weak and strong forces. Solutions for short-lived particles and forces have not been solved yet. The next step to fully reproduce the Standard Model.

TAU provides the appropriate quantum properties, and appropriate length scales, for the general mass scales of the Standard Model particles and forces. There is every prospect of reproducing the full Standard Model because the is a viable model for the first-generation of particles. What is primarily missing is a strong theory for the three *generations* of particles (e.g. the *muon* and *tau* in addition to the *electron.*) A mechanism is proposed, but has not been solved or confirmed. Finding a solution for the muon in particular would strongly confirm the model.

- The basic particle model generates *relativistic quantum particles* with properties and equations matching known physics, reducing electrodynamics and STR to a simpler basis.
- The general hypothesis is that *all the fundamental particles can be constructed from space,* with the whole range of particles determined by a natural geometry. The full reduction of the whole Standard Model is the open question.
- This possibility appears convincing from general considerations. There is only limited flexibility to adapt the theory, and solutions are strongly determined.

TAU Gravity.

Gravity is determined in TAU by curvature of space and its effect on the speed of light. This curvature is directly produced by particle energies, which are stored in the local strain of the micro-dimension. This gives a physical model for *mass energy and gravitational potential energy.* There is a natural *strain function* for the micro-torus in the vicinity of a mass. This curves space and changes the local speed of light. Gravity is not quantised, or quantizable: as in GTR, it is not a *force*. The local solution matches the standard GTR Schwarzschild central mass solution closely for weak gravity (but with measurable differences). It has stronger differences in strong gravity, as we approach a central mass. It changes the nature of black holes. These differences can be tested with practical experiments. The *strain function* can also be extended to very short distances, down to the quantum level of individual particles. At the particle centre, this results in a "filament-like" extension (and extrusion) of space. These "filaments" are not introduced *ad hoc:* they are the natural extension of the solution for gravity, where it merges with the quantum wave. They *individuate particles* in the model – representing wave-particle duality. The filament radius (at the 3D surface) is tiny (Planck scale). But the filaments may extend for large distances. Filaments of interacting and *entangled particles* are connected, through nodes, and this gives *quantum jumps and entanglement* properties. *Wave function collapse* events are reconnections of filaments. This means entangled particles are physically connected, outside ordinary space, through the filaments. The connections are "almost instantaneous" because the speed of transmission through filaments is much faster than the local speed *c* in the surface. Smooth evolution of the surface waves follows quantum mechanics. The surface waves provide *wave guides* for the almost-point-like filaments. The dynamics for the motion of the filaments corresponds to a version of Bohmian deterministic mechanics. Thus gravity is merges with particle dynamics at the quantum level.

- Whether the predictions for weak gravity in the solar system can be confirmed by experiment is the immediate decisive question.
- There are significant differences for black holes, and galaxy and star formation. These can provide further tests.
- Bohmian mechanics provides a general principle that can be extended in TAU to complex particle systems and spin.

TAU Cosmology.

The TAU cosmological model is largely determined by the gravity model. It conforms empirically to the main sequence of conventional cosmology after the Big Bang, but it explains effects like dark matter and dark energy quite differently, and predicts some very different effects. Most of these effects relate to known anomalies in cosmology. A striking prediction is a set of direct relationships among *fundamental constants* ($c, h, G, \varepsilon_0, m_e, m_p, q$) and the expansion parameter ($R_{Universe}$). In TAU, the constants characterise properties of space, and change with expansion. These relationships strongly unify the gravity, particle and cosmology theories. This requires a set of transformations, changing from our customary *instrumentally-defined* variables (for space, time, mass, and charge) to the *true model variables*. The laws of nature are only time translation invariant in the *true variables.* This means observations referring across significant cosmological periods must be recalculated. An early theory of such transformations was proposed by Dirac, to explain the "large number coincidences". TAU gives a precise version, with an underlying mechanism. The simplest solution to TAU model so far indicates that we are somewhere around halfway through the expansion phase of a finite closed bounded cyclic universe. Novel generic effects are predicted, including precise relationships between fundamental constants, stronger gravity in the early universe, Hubble tension, the "dark energy" effects, and real dark matter. The closed cyclic universe means a directional thermodynamic cycle. A simple solution to the cosmological sequence is provided here, but this may change substantially when fitted more precisely.

- Whether the cosmology is consistent when closely compared against detailed cosmological observations is the main question.
- Primary relationships predicted between fundamental constants and expansion are consistent, and the predicted rate of change of *G* is close to experimental limits.
- The prediction of the dark energy effect, Hubble tension, dark matter and other effects are broadly confirmed, and open to be tested more precisely.

References

The following is a wider set of references than referred to in this paper, with background on some fundamental topics. The general theories discussed are well known, and WIKIPEDIA provides good summaries of many mathematic topics in physics. Some general introductions, and some older papers where concepts first appeared are given, along with recent experimental papers of relevance. A short selection of papers on water is given separately after the main references.

Some Wikipedia Articles – follow the links.

Wikipedia. 2021. Age of the universe - Wikipedia
Wikipedia. 2021. Bell's theorem - Wikipedia
Wikipedia. 2021. Committee on Data for Science and Technology - Wikipedia
Wikipedia. 2021. Compton wavelength - Wikipedia
Wikipedia. 2021. De Broglie–Bohm theory - Wikipedia
Wikipedia. 2021. Dirac equation - Wikipedia
Wikipedia. 2021. Electron - Wikipedia
Wikipedia. 2021. Expansion of the universe - Wikipedia
Wikipedia. 2021. General relativity - Wikipedia
Wikipedia. 2021. Grand Unified Theory - Wikipedia
Wikipedia. 2021. Gravity - Wikipedia
Wikipedia. 2021. Hubble's law - Wikipedia
Wikipedia. 2021. Klein–Gordon equation - Wikipedia
Wikipedia. 2021. Pilot wave theory - Wikipedia
Wikipedia. 2021. Proton - Wikipedia
Wikipedia. 2021. Quantum nonlocality - Wikipedia
Wikipedia. 2021. Standard Model - Wikipedia
Wikipedia. 2021. Special relativity - Wikipedia
Wikipedia. 2021. String theory - Wikipedia

General References Physics.

Aharonov, Y. and Bergmann, P. and Lebowitz, J. 1964, "Time Asymmetry in Quantum Process of Measurement". Phys.Rev. 134, 6B, pp. B1410-B1418.

Albert, David Z. 2000. Time and Chance. Harvard University Press.

Anderson, J. D.; Schubert, G.; Trimble, V.; Feldman, M. R. (April 2015), "Measurements of Newton's gravitational constant and the length of day", EPL, 110 (1): 10002, arXiv:1504.06604, Bibcode:2015EL....11010002A, doi:10.1209/0295-5075/110/10002, S2CID 119293843

Antognini, Aldo; et al. (25 January 2013). "Proton Structure from the Measurement of 2S-2P Transition Frequencies of Muonic Hydrogen" (PDF). Science. 339 (6118): 417–420. Bibcode:2013Sci...339..417A. doi:10.1126/science.1230016. hdl:10316/79993. PMID 23349284. S2CID 346658.

Aspect, Alain and Grangier, Philippe and Roger, Gerard, 1982, "Experimental Realization of Einstein-Podolski-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequality.". Phys.Rev.Let. 49, 2, pp. 91-94.

Barnothy, Jeno M. and Barnothy, Madeline F. 1991. “What is Time?” Comments on Astrophysics, 15 (5), pp. 279-281.

Barrow, John D. 1988. The World within the World. Clarendon.

Bell J.S. 1964. "On the Einstein-Podolsky-Rosen Paradox. Physics", 1:195-200, reprinted in Bell 1987.

Bell, J.S., 1966, "On the Problem of Hidden Variables in Quantum Mechanics.". Rev.Mod.Phys. 38, pp. 447-452

Bell’s Theorem (Stanford Encyclopedia of Philosophy)

Bellifante, F.J., 1978, Measurement and Time Reversal in Quantum Theory.. Pergamon Press Ltd.

Belot,Gordon. 2004. “Dust, Time and Symmetry”. http://philsci-archive.pitt.edu/archive/00001581/01/DustTimeSymmetry.html [Forthocmming in BJPS).

Beltrametti, Enrico and Cassinelli, Gianni, 1981, The Logic of Quantum Mechanics. Addison-Wesley.

Beltrametti, Enrico and van Fraassen, Bas, 1979, Current Issues in Quantum Logic. Plenum Press.

Bertolami Orfeu and J. Páramos, 2003. “The Pioneer anomaly in a bimetric theory of gravity on the brane”. http://arxiv.org preprint gr-qc/0310101

Bertolami, Orfeu, 2003. “Three Key Tests to Gravity.” http://arxiv.org preprint gr-qc/0306093.

Bezginov, N.; Valdez, T.; Horbatsch, M.; Marsman, A.; Vutha, A. C.; Hessels, E. A. (2019-09-06). "A measurement of the atomic hydrogen Lamb shift and the proton charge radius". Science. 365 (6457): 1007–1012. Bibcode:2019Sci...365.1007B. doi:10.1126/science.aau7807. ISSN 0036-8075. PMID 31488684. S2CID 201845158.

Bills, Bruce G. Ray, Richard D. 1999. GEOPHYSICAL RESEARCH LETTERS, VOL. 26, NO. 19, 3045-3048, OCTOBER 1, 1999. "Lunar Orbital Evolution: A Synthesis of Recent Results."

Bohm, David and B.J.Hiley, 1975, "On the Intuitive Understanding of Nonlocality as Implied by Quantum Theory". Found.Phys. 5 (1) pp. 93-107.

Bohm, David and Bub, J, 1966, "A Proposed Solution to the Measurement Problem in Quantum Mechanics by a Hidden Variable Theory." Rev.Mod.Phys. 38 (3) pp. 453-469.

Bohm, David and Hiley, B.J., 1975, "On the Intuitive Understanding of Nonlocality as Implied by Quantum Theory". Found.Phys. 5, 1, pp. 93-107.

Bohm, David, 1980, Wholeness and the Implicate Order. Routledge and Kegan.

Bohm, David, 1987, "The Implicate Order and Prigogine's Notions of Irreversibility". Found.Phys. 17, 7, pp. 667-677.

Bohm, David. 1951. Quantum Theory. Prentice-Hall Inc.

Bohr, Niels, 1935, "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?". Phys.Rev. 48, pp. 696-702.

Bohr, Niels, 1949, "Discussions with Einstein on Epistemological Problems in Atomic Physics". In Schilpp, 1949, Schilpp, (ed.) 1949.

Boltzmann, Ludwig. 1964 [1896-1898]. Trans. Stephen G. Brush. Lectures on Gas Theory. University of California Press. pp. 51-62, 441-452.

Bondi, Hermann, 1964, Relativity and Common Sense. Heinman Educational Books Ltd.

Bordley, Robert, 1986, "Higher Derivatives of Velocity and Quantum Theory". Phys.Let.A 118, 3, pp. 107-111.

Born, Max, 1949, Natural Philosophy of Cause and Chance. Oxford.

Boyce, William E. and DiPrima, Richard C., 1986, Elementary Differential Equations and Boundary Value Problems. John Wiley and Sons.

Bridges, Jane. 1977. Model Theory. Clarendon Press.

Brown, James Ward and Churchill, Ruel V. 1993. Fourier Series and Boundary Value Problems. McGraw-Hill.

Bub, J., 1969, "What is a Hidden Variable Theory of Quantum Phenomena?". Int.J.Theo.Phy. 2, pp. 101-123.

Bub, J., 1973, "On the Possibility of a Phase-Space Reconstruction of Quantum Statistics.". Found.Phys. pp. 29-44.

Bussey, P.J., 1984, "Does The Wave function Collapse?" Phys.Let.A 106 (9), pp. 407.

Bussey, P.J., 1987, "The Fate of Schrodinger's Cat". Phys.Let.A 120 (2), pp. 51-53.

Callender, C. 2000. “Is Time Handed in a Quantum World?”. Proc.Arist.Soc, 121, pp. 247-269.

Capek, M, 0, "The Fiction of Instants".

Capek, M, 1966, "Time in Relativity Theory: Arguments for a Philosophy of Becoming.". In Frazer, 1966, The Voices of Time. George Braziller.

Capek, Milic, 1976, The Concepts of Space and Time. Their structure and development.. Reidel.

Chang, C.C. and H.J. Keisler. 1973. Model Theory. North-Holland.

Church, Alonzo. 1956. An Introduction to Mathematical Logic I. Princeton.

Clarke, C.J.S., 1977, "Time in General Relativity". Foundations of Space-time Theories.

Clauser, J.F. and Shimony, A., 1978, "Bell's Theorem: experimental tests and implications.". Reports on Progress in Physics 41, pp. 1881-1927.

Cocke, W.J., 1967, "Statistical Time Symmetry and two-time Boundary Conditions in Physics and Cosmology". Phys.Rev. 160, 5, pp. 1165-1170.

Cohen, David W., 1989, An Introduction to Hilbert Space and Quantum Logic. Springer-Verlag.

Cohen, L., 1966, "Can Quantum Mechanics be Formulated as a Classical Probability Theory?". Phil.Sci. 33, pp. 317-322.

Cohen-Tannoudji, Claude and Diu, Bernard and Laloe, Franck, 1988, Quantum Mechanics Volume One.

Cooper, Leon N., 1973, "Wave function and Observer in the Quantum Theory". In Mehra, 1973, The Physicist's Conception of Nature.

Cramer, John, 1986, "The Transactional Interpretation of Quantum Mechanics". Rev.Mod.Phys. 58, 3, pp. 647-687.

D'Amato, Susan, 1986, "Multiple-Time Measurements on Quantum Mechanical Systems". In Roth, et alia, 1986, Fundamental Questions in Quantum Mechanics. Gordon and Breach.

Davies, P.C.W. 1974. The Physics of Time Asymmetry. Surry University Press.

Davies, P.C.W., 1986, "Time Asymmetry and Quantum Mechanics". In Flood, et alia, 1986, The Nature of Time. Basil Blackwood.

Davies, Paul, 2002, "That mysterious flow.". Sci.Amer. Sep., pp. 24-29.

de Beauregard, Olivia Costa 1972. "No Paradox in the Theory of Time Asymmetry". In Frazer, et alia, 1972, The Study of Time.

de Beauregard, Olivia Costa 1977, "Two Lectures on the Direction of Time". Synthese 35, pp. 129-154.

de Beauregard, Olivia Costa, 1972, "Time in Relativity Theory: Arguments for a Philosophy of Being". In Frazer, et alia, 1972, The Study of Time. Springer-Verlag.

de Beauregard, Olivia Costa, 1976, "Mecanique Quantique Relativiste". C.R. Acad. SC. Paris 282, pp. 1251-4.

de Beauregard, Olivia Costa, 1980, "CPT Invariance and Interpretation of Quantum Mechanics". Found.Phys. 10, 7/8, pp. 513-531.

de Beauregard, Olivia Costa, 1983, "Running Backwards the Mermin Device: Causality in EPR Correlations". Am.J.Phys. 51, 6, pp. 513-16.

de Beauregard, Olivia Costa, 1987, "On the Zigzagging Causality EPR Model: Answer to Vigier and Coworkers and Sutherland". Found.Phys. 17, 8, pp. 775-85.

de Beauregard, Olivia Costa. 1980. "CPT Invariance and Interpretation of Quantum Mechanics". Found.Phys. 10, 7/8, pp. 513-531.

de Beauregard, Olivia Costa. 1987. Time, the Physical Magnitude. Reidel.

Denbigh, K.G., 1980, "In Defense of the Direction of Time". .

Denbigh, K.G., 1981, Three Concepts of Time. Springer-Verlag.

d'Espagnat, B., 1976, Conceptual Foundations of Quantum Mechanics. Benjamin, Massachusetts.

d'Espagnat, Bernard, 1979, "The Quantum Theory and Reality". Sci.Amer. Nov., pp. 128-141.

DeWitt, Bryce S., 1970, "Quantum Mechanics and Reality". Physics Today 23, pp. 30-35.

Dicke, R.H. 1961. “Dirac’s Cosmology and Mach’s Principle” (with reply by Dirac). Nature 192 (Nov.4), pp.440-441.

Diósi , L., 1987, “A universal master equation for the gravitational violation of quantum mechanics,” Physics Letters A, 120: 377–381

Dirac, P.A.M., 1958 [1930] The Principles of Quantum Mechanics. Oxford.

Dirac, P.A.M., 1969, "Fundamental Constants and Their Development in Time". Symposium talk (lost reference).

Dyson, Freeman 1977. “The fundamental constants and their time variation”, in Salam and Wigner, 1972.

Earman, John. 1967. "Irreversibility and Temporal Asymmetry".   J.Phil. LXIV, 18, pp. 543-549.

Earman, John. 1969. "The Anisotropy of Time". Aust.J.Phil. 47, 3, pp. 273-295.

Eddington, A.S., 1923, The Mathematical Theory of Relativity. Cambridge.

Eddington, A.S., 1928, The Nature of the Physical World. Collins.

Eden, R.J. and Polkinghorne, J.C., 1972, "Dirac in Cambridge.". Aspects of Quantum Theory..

Ehlers, J., Rosenblum, A., Goldberg, J. N. and Havas, P. 1976. “Comments on gravitational radiation damping and energy loss in binary systems”, Astrophys. J. Lett., 208, L77–L81

Einstein, Albert and Podolsky, B. and Rosen, N., 1935, "Can Quantum Mechanical Description of Reality Be Considered Complete?".   Phys.Rev. 47, pp. 777-779.

Einstein, Albert, 1922, The Meaning of Relativity. Methuen.

Einstein, Albert. 1919. "What Is The Theory Of Relativity?" German History in Documents and Images. http://germanhistorydocs.ghi-dc.org/pdf/eng/EDU_Einstein_ENGLISH.pdf

Elliott, J.P. and Dawber, P.C., 1979, Symmetry in Physcis (Vol 1 and 2). Oxford.

Epstein, Lewis Carroll. 1983. Relativity Visualised. Insight Press, San Francisco.

Everett, Hugh, 1957, ""Relative State" Formulation of Quantum Mechanics".   Rev.Mod.Phys. 29, 3, pp. 454465.

Evrard, Daniel and Thieffine, Fransois, 1988, "Microphysical Nonseperability and Relativistic Signals". Found.Phys. 18, 5, pp. 575-83.

Feynman, R.P. and Hibbs, A.R., 1965, Quantum Mechanics and Path Integrals. McGraw-Hill Book Company.

Fine, Arthur and P. Teller. 1977. "Algebraic Constraints on Hidden Variables." Found.Phys. 8 pp. 629-37.

Fine, Arthur. 1974, "On the Completeness of the Quantum Theory". Synthese 29 pp. 257-89.

Fine, Arthur. 1982. "Hidden Variables, Joint Probability, and the Bell Inequalities." Phys.Rev.Let. 48 pp. 291-5.

Fine, Arthur. 1982. "Joint Distributions, Quantum Correlations, and Commuting Observables." J.Math.Phy. 23 pp. 1306-10.

Fine, Arthur. 1986. The Shaky Game: Einstein, Realism, and the Quantum Theory. University of Chicago Press.

Flood, R and Lockwood, M, 1986, The Nature of Time. Basil Blackwell.

Ford, Kenneth W., 1963, The World of Elementary Particles. Xerox College Publishing.

Frazer, (ed.) 1966. The Voices of Time. Springer-Verlag.

Frazer, (ed.) 1972. The Study of Time. Springer-Verlag.

Friedman, M., 1973, "Relativity principles, absolute objects and symmetry groups.". In Suppes (ed.), 1973, Suppes.

Friedman, M., 1977, "Simultaneity in Newtonian mechanics and special relativity". Foundations of Space-Time Theories..

Gabbay, D and Guenthner, F, 1986, Handbook of Philosophical Logic. D.Reidel.

Gasiororowicz, S. 1966. Elementary Particle Physics. John Wiley and Sons. New York.

Ghirardi, G.C. and Weber, T, 1979, "On Some Recent Suggestions of Superluminal Communication Through the Collapse of the Wave Function". Lettere Al Nuovo Cimento 26, 18, pp. 599-663.

Ghirardi, G.C. T. Weber, C. Omero and A. Rimini. 1979. "Small-Time Behavior of Quantum Nondecay Probability and Zeno's Paradox in Quantum Mechanics". Il Nuovo Cimento 52A (4) pp. 421-441

Ghirardi, G.C., A. Rimini and T. Weber. 1980. "A General Argument against Superluminal Transmission through the Quantum Mechanical Measurement Process". Lettere Al Nuovo Cimento 27 (10) pp. 293-298.

Gleason, A.M. 1957. "Measures on the Closed Subspaces of a Hilbert Space." J.Math.Mech. 6 pp. 885-893.

Goenner, H.F. 1980. “Local isometric embedding of Reimannian manifolds and Einstein’s theory of gravitation.” In Held (1980), vol.1, pp. 441-68.

Gold, T. 1962. “The Arrow of Time”. Am.J.Phys. 30, pp. 403-410.

Gribbin, John, 1984. In Search of Schrodinger's Cat. Black Swan.

Gribbin, John. 1993. In The Beginning: the birth of the living universe. Penguin.

Griffiths, Robert, 1986, "Quantum Interpretation Using Consistent Histories". In Roth, et alia, 1986, Fundamental Questions in Quantum Mechanics. Gordon and Breach.

Grunbaum, Adolf. 1973 [1963]. Philosophical Problems of Time and Space. Second enlarged edition. Dordrecht: Reidel.

Harris, Edward G., 1972, A Pedestrian Approach to Quantum Field Theory. John Wiley and Sons.

Havas, P., 1968, "Causality requirements and the theory of relativity". Synthese 15, pp. 75-102.

Hawking, S. W., and Israel, S.W. (eds.), 1979, General Relativity: An Einstein Centennial Survey. Cambridge.

Hawking, S.W. and Ellis, G.F.R., 1973. “The Large Scale Structure of Space-Time.” Cambridge.

Hawking, Stephen, 1968, "The Existence of Cosmic Time Functions". Proc.Roy.Soc.A. 308, pp. 433-435.

Hawking, Stephen, and Roger Penrose, 1995. The Nature of Space and Time. Cambridge.

Hawking, Stephen. 1985. “Arrow of Time in Cosmology”. Phys.Rev. D. 33, pp.2489-95.

Hazewinkel, Michiel, ed. (2001), "Klein-Gordon equation", Encyclopedia of Mathematics, Springer, ISBN 978-1-55608-010-4).

Healy, Richard. 1981. “Statistical Theories, Quantum Mechanics and the Directedness of Time”. In Reduction, Time and Reality, ed. R. Healey. Cambridge, pp.99-127.

Held, A. (ed). 1980. General Relativity and Gravitation. One Hundred Years after the Birth of Albert Einstein. 2 vols. Plenum, New York.

Hofmann, F. and Müller, J. 2018. “Relativistic tests with lunar laser ranging”. Class. Quantum Grav, 35, 3. “A relative temporal variation of the gravitational constant is estimated as (7.1±7.6)10-14 yr-1.”

Holland, P.R. and J.P. Vigier. 1988. "The Quantum Potential and Signaling in the Einstein-Podolsky-Rosen Experiment". Found.Phys. 18 (7) pp. 741-50.

Hollinger, H.B. and Zenzen, M.J. 1985. The Nature of Irreversibility. Reidel.

Holster, A.T. 2003 (a), “The criterion for time symmetry of probabilistic theories and the reversibility of quantum mechanics", New Journal of Physics. Oct. 2003.

Holster, A.T. 2003 (b). “The quantum mechanical time reversal operator.” PhilSci Archive pre-print. http://philsci-archive.pitt.edu/1449/

Holster, A.T. 2003(c). “The incompleteness of extensional object languages of physics and time reversal. Part 1.” [http://philsci-archive.pitt.edu].

Holster, A.T. 2003(d). “The incompleteness of extensional object languages of physics and time reversal. Part 2.” [http://philsci-archive.pitt.edu].

Holster, A.T. 2003. “Proper Time, Coordinate Systems and Lorentz Transformations". The Internet Encyclopedia of Philosophy. USA. http://www.iep.utm.edu/proper-t/

Holster, A.T. 2017. “An Alternative to the Schwarzschild solution of GTR.” http://vixra.org/abs/1712.0491

Holster, A.T. 2021 (a). “Introduction to CAT4. Part 1. Axioms.” Introduction to CAT4: Part 1. Axioms, viXra.org e-Print archive, viXra:2101.0089

Holster, A.T. 2021 (b). “Introduction to CAT4. Part 2. CAT2.” Introduction to Cat4: Part 2. Cat2, viXra.org e-Print archive, viXra:2101.0088

Horwich, P. 1987. Asymmetries in Time. M.I.T. Press.

Hutchison, Keith. 1993. “Is Classical Mechanics Really Time-Reversible and Deterministic?”. Brit.J.Phil.Sci. 44¸ pp.107-323.

Jauch, J.M., and Rohrlich, F. The Theory of Positrons and Electrons. New York: Addison-Wesley. 1955. pp 88-96.

Jauch, Josef. 1968. Foundations of Quantum Mechanics. Addison-Wesley.

Jordan Thomas, 2004. “Modified Newtonian dynamics from acceleration fluctuations.” http://arxiv.org preprint astro-ph/0402384.

Kay, David C. 1976. Theory and Problems of Tensor Calculus. McGraw-Hill.

Kay, David C., 1988, Tensor Calculus. McGraw-Hill Book Company.

Kiehn, R.M., 1976, "Retrodictive Determinism". Int.J.Engng Sci. 14, pp. 749-754.

Kobayashi, S. and K. Nomizu. 1963. Foundations of Differential Geometry. Wiley.

Kochen, S. and E. Specker. 1967. "The problem of hidden variables in quantum mechanics." J.Math.Mech. 17, pp. 59-87.

Kraus, B and Cirac, J.I., 2001, "Optimal creation of entanglement using a two-qubit gate". Phys.Rev. 63, .

Kripps, H, 1989, "The Objectivity of Quantum Probabilities". Aust.J.Phil. 67, 4, pp. 423-431.

Kripps, H., 1987, The Metaphysics of Quantum Theory. Oxford.

Kuz'menko, V.A. 2007. “On the nature of entanglement”. arXiv preprint arXiv:0706.2488.

Lachieze-Rey, Marc, 1995, Cosmology. A First Course.. Cambridge.

Landau, and Lifshitz, , 1971, Relativistic Quantum Theory. Pergamon Press Ltd.

Landau, L.D. and Lifshitz, E.M. and (Trans.M. Hamermesh). 1960, Quantum Mechanics. Pergamon Press Ltd.

Landau, Lev D. and Lifshitz, Evgeny M. 1975. Course on Theoretical Physics Vol. 2: The Classical Theory of Fields. Butterworth-Heinemann.

Landsberg, 1982. The Enigma of Time. Adam Hilger.

Lee, T.D., 1963, Symmetries, Asymmetries, and the World of Particles. University of Washington Press.

Lehmkuhl, Dennis. 2010. “Mass-Energy-Momentum in General Relativity. Only there because of Spacetime?” http://philsci-archive.pitt.edu/5137/1/Lehmkuhl_MassEnergyMomentum_and_spacetime_structure.pdf

Lewis, G.N. 1932. "The Symmetry of Time and Physics". In Landsberg, 1982.

Lord, Eric. 1976. Tensors, Relativity and Cosmology. Tata McGaw-Hill Publishing Co.

Lorentz, H.A. 1904. “Electromagnetic phenomena in a system moving with any velocity smaller than that of light.” KNAWPr. 6, pp. 809-31.

Lorrain, Paul, Dale P. Corson and Fancois Lorrain. 1988. Electromagnetic Fields and Waves. W.H.Freeman and Co.

Lui, Chuang, 1993, "The Arrow of Time in Quantum Gravity". Phil.Sci. 60, pp. 619-637.

Malament, David. 2003. “On the time reversal invariance of classical electromagnetic theory.” [http://philsci-archive.pitt.edu].

Marshall, T.W. and Santos, E. and Selleri, F., 1983, "Local Realism has not been Refuted by Atomic Cascade Experiments". Phys.Let. 98A, pp. 5-9.

Mathews, G, 1979, "Time's Arrow and the Structure of Spacetime". Phil.Sci. 46, pp. 82-97.

Matthews, Philip S.C. 1986. Quantum Chemistry of Atoms and Molecules. Cambridge University Press.

Maudlin, Tim, 1994, Quantum Non-Locality and Relativity. Blackwell.

Maxwell, Nicholas. 1972, "A New Look at the Quantum Mechanical Problem of Measurement". Aust.J.Phil. 40, pp. 1431-1435.

Maxwell, Nicholas. 1985, "Are Probabilism and Special Relativity Incompatible?". Phil.Sci. 52, pp. 23-43.

Maxwell, Nicholas. 1988, "Quantum Proposition Theory: A Testable Resolution of the Wave/Particle Dilemma". Brit.J.Phil.Sc 39, pp. 1-50.

Mbelek, J.P. and M. Michalski, 2003. "Can conventional forces really explain the anomalous acceleration of Pioneer 10/11?". http://arxiv.org preprint gr-qc/0310088.

McCall, Storrs. 1966. "Temporal flux". Am.Phil.Quart. 3, pp. 270-281.

McCall, Storrs. 1976. "Objective time flow". Phil.Sci. 43, pp. 337-362.

McCauley, Joseph, 1997, Classical Mechanics. Cambridge.

McTaggart, J.E., 1908, "The Unreality of Time". Mind new series, 17, pp. 457-474.

Mermin, David N. 1981, "Bringing Home the Atomic World: Quantum Mysteries for Anybody". Am.J.Phys. 49, 10, pp. 940-43.

Mermin, David N. 1981, "Quantum Mysteries for Anyone". Rev.Mod.Phys. LI, 863, pp. 397-408.

Merzbacher, Eugene. 1970. Quantum Mechanics. John Wiley and Sons. New York.

Messiah, A. 1966. Quantum Mechanics. New York: John Wiley and Sons. 1966.

Milgrom, Mordehai, 2002, "Does dark matter really exist?". Scientific American Aug., pp. 30-37.

Minkowski 1907–1908, pp. 53–111 "The Fundamental Equations for Electromagnetic Processes in Moving Bodies".

Misner, C.W., K.S. Thorne and J.A. Wheeler. 1973. Gravitation. Freeman.

Mould, J.; Uddin, S. A. (10 April 2014), "Constraining a Possible Variation of G with Type Ia Supernovae", Publications of the Astronomical Society of Australia, 31: e015, arXiv:1402.1534, Bibcode:2014PASA...31...15M, doi:10.1017/pasa.2014.9, S2CID 119292899

Müller, J. and Biskupek, L., 2007. "Variations of the gravitational constant from lunar laser ranging data", Class. Quantum Grav., 24, 4533–4538.

Musser, George. 1998, "Pioneering Gas Leak?", Scientific American, December 1998, pp.12-13.

NASA Website Pioneer homepage: http://spaceprojects.arc.nasa.gov/Space_projects/pioneer/Pnhome.html

Nerlich, G., 1979, "Is curvature intrinsic to physical space?". Phil.Sci. 46, pp. 439-458.

Nerlich, G., 1979, "What can geometry explain?". Brit.J.Phil.Sc 30, pp. 69-83.

Newton, Isaac, 1912, Mathematical Principles of Natural Philosophy.

Nieto, Michael Martin and Slava G. Turyshev, 2003. “Finding the Origin of the Pioneer Anomaly.” http://arxiv.org preprint gr-qc/0308017.

Noerdlinger, Peter D. 2004. “Solar mass loss, the Astronomical Unit, and the scale of the Solar System.” http://home.comcast.net/~pdnoerd/SmassLoss.html

Oas, Gary. 2014 “Full derivation of the Schwarzchild solution”. https://web.stanford.edu/~oas/SI/SRGR/notes/SchwarzschildSolution.pdf

Palle Davor, 2004. “On the anomalous acceleration in the solar system.” http://arxiv.org preprint astro-ph/0402304.

Pavlov, Dmitry A.; James G. Williams; Vladimir V. Suvorkin. 2016. ArXiv.org. “Determining parameters of Moon’s orbital and rotational motion from LLR observations using GRAIL and IERS-recommended models”. The final publication is available at Springer via http://dx.doi.org/10.1007/s10569-016-9712-1.

Pegg, David T., Stephen M. Barnett and John Jeffers. 2002. “Quantum retrodiction in open systems.” Phys.Rev.A. 66 (022106).

Penrose, R, 1979, "Singularities and Time-Asymmetry". In Hawking, et alia, 1979, General Relativity: An Einstein Centennial Surevy. Cambridge.

Penrose, R, 1986, "Big Bangs, Black Holes and 'Time's Arrow'." In Flood, et alia, 1986.

Penrose, R. 1989. The Emperor's New Mind. Oxford.

Penrose, R. 1996, “On gravity’s role in quantum state reduction,” General Relativity and Gravitation, 28: 581–600.

Penrose, R., 1989, The Emperor’s New Mind, Oxford: Oxford University Press.

Petley, Brian William. 1985. The Fundamental Physical Constants and the Frontier of Measurement. Adam Hilger.

Pioneer NASA http://spaceprojects.arc.nasa.gov/Space_projects/pioneer/Pnhome.html

Pitjeva, E.V. 2015. “Determination of the Value of the Heliocentric Gravitational Constant from Modern Observations of Planets and Spacecraft.” Journal of Physical and Chemical Reference Data 44, 031210 (2015)

Planck, Max, 1998, Eight Lectures on Theoretical Physics. Dover.

Popper, K.R., 1956, "The Arrow of Time". Nature 177, 4507, pp. 538.

Prigogine, Ilya and Prigogine, George and Rosenfeld, Leon, 1972, "The Macroscopic Level of Quantum Mechanics". Nature 240, pp. 25-27.

Prigogine, Ilya, 1969, "Time, Irreversibility and Structure". Symposium.

Prigogine, Ilya, and Issabelle Stengers, 1985. Order out of Chaos. Fontana Paperbacks.

Ranada Antonio F. 2004. “Pioneer acceleration and variation of light speed: experimental situation”. http://arxiv.org preprint gr-qc/0402120.

Ranada Antonio F. 2004. “On the Pioneer acceleration as light acceleration.” http://arxiv.org preprint gr-qc/0403013.

Rastall, Peter, 1985, "Locality, Bell's Theorem, and Quantum Mechanics". Found.Phys. 15, 9, pp. 963-980.

Redhead, M.L.G., 1986, "Relativity and Quantum Mechanics - Conflict or Peaceful Coexistence.". Annals of New York Academy of Sciences. 480, pp. 14-20.

Redhead, Michael. 1990. Incompleteness, Nonlocality, and Realism. Oxford.

Reichenbach, Hans. 1957. The Direction of Time. Berkeley.

Rietdijk, C.W. and Selleri, F., 1985, "Proof of a Quantum Mechanical Nonlocal Influence". Found.Phys. 15 (3), pp. 303-317.

Rietdijk, C.W., 1987, "Retroactive Effects form Measurement". Found.Phys. 17, 3, pp. 297-311.

Rindler, Wolfgang. 1977. Essential Relativity. Special, General, Cosmological. Springer-Verlag.

Sachs, Robert. 1987. The Physics of Time Reversal. University of Chicago Press.

Salam, Abdus and E.P. Wigner, (eds.) 1972. Aspects of Quantum Theory. Cambridge.

Schewe, Phillip F. and Ben Stein, 2000. “Best measurement of the gravitational constant.” http://www.aip.org/enews/physnews/2000/split/pnu482-1.html

Schiller, Ralph, 1962, "Deterministic Interpretations of the Quantum Theory". In Wartofski, 1962, Boston Studies in Philosophy of Science. Synthese Library Vol 1..

Schrodinger, Erwin. 1950. “Irreversibility”. Proc.R.Ir.Ac. 53 pp. 189-95.

Schwarzschild, K. (1916). "Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie". Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften. 7: 189–196. English translation: Antoci, S., Loinger, A. 1999. "On the gravitational field of a mass point according to Einstein's theory". arXiv:physics/9905030.

Shearer, Paul. "Proton size puzzle reinforced!" 2013. Paul Shearer Institute. 25 January 2013.

Shimony, A., 1984, "Controllable and Uncontrollable Non-Locality". In Kamefuchi (ed), et alia, 1984, Kamefuch et alia (eds).

Shimony, Abner, 1963, "Role of the Observer in Quantum Theory". Am.J.Phys. 31, pp. 755-773.

Sidharth Burra Gautam, 2004. “Discrete Space Time and Dark Energy”. http://arxiv.org preprint physics/0402007

Sklarr, Lawrence. 1974. Space, Time, and Spacetime. University of California Press.

Spiegel, Maurray R., 1986, Laplace Transformations. McGraw-Hill Book Company.

Spiegel, Murray, R. 1974. Theory and Problems of Advanced Calculus. McGraw-Hill.

Spiegel, Murray, R. 1974. Theory and Problems of Complex Variables. McGraw-Hill.

Spivak, Michael. 1979. A Comprehensive Introduction to Differential Geometry. Publish or Perish.

Srinivas, M.D., 1978, "Conditional Probabilities and Statistical Independence in Quantum Theory". J.Math.Phys. 19, 8, pp. 1705-10.

Stapp, Henry, 1985, "Consciousness and Values in the Quantum Universe". Found.Phys. 15, 1, pp. 35-47.

Stapp, Henry, 1988, "Quantum Nonlocality". Found.Phys. 18, 4, pp. 427-448.

Sudbery, A. 1984. "The Observation of Decay". Annals of Physics 157, pp. 512-36.

Suppes (ed.), P., 1973, Space, Time and Geometry.. Reidel.

Suppes (ed.), Patrick, 1976, Logic and Probability in Quantum Mechanics. Kluwer Academic Publishers.

Susskind, Leonard, 2003/1997. “Black Holes and the Information Paradox”. Sci.Am. 13 (1) Special Edition: The Edge of Physics.

Svetlichny,, G. and Redhead, M.L.G. and Brown, H.R. and Butterfield, J., 1988, "Do the Bell Inequalities Require the Existence of Joint Probabilities?". Phil.Sci. 55, pp. 387-401.

Tan, E.-K., John Jeffers, and Stephen M Barnett. 2003/2004. “Field state measurement in a micromaser using retrodictive quantum theory.” To appear in: Phys.Rev.A.

Torretti, Roberto. 1983. Relativity and Geometry. Dover.

Trencevski Kostadin. ed, 2004. “Hubble red shift and the anomalous acceleration of Pioneer 10 and 11”. http://arxiv.org preprint gr-qc/0402024.

Turyshev, S. G.; Toth, V. T.; Kinsella, G.; Lee, S.-C.; Lok, S. M.; Ellis, J. 2012. "Support for the Thermal Origin of the Pioneer Anomaly". Physical Review Letters. 108 (24): 241101. arXiv:1204.2507.

Turyshev, S.G. and Williams, J.G., 2007. “Space-Based Tests of Gravity with Laser Ranging”, Int. J. Mod. Phys. D, 16, 2165–2179, (2007).

van Enk, S.J. 2004/2018. “Entangled states of light.” arXiv:quant-ph/0403119v1.

Vanderburgh, William L. 2003. “The Dark Matter Double Bind: Astrophysical Aspects of the Evidential Warrant for General Relativity.” Phil.Sci. 70 (4) pp.812-832.

Vojinovic, Marko, 2010. “Schwarzschild Solution in General Relativity.” http://gfm.cii.fc.ul.pt/events/lecture_series/general_relativity/gfm-general_relativity-lecture4.pdf

von Neumann, John. 1932. Mathematical Foundations of Quantum Mechanics (Trans. Robert T. Beyer, 1955). Princeton University Press.

Wald, Robert M. 1984, General Relativity. University of Chicago Press.

Wangsness, Roald K. 1979. Electromagnetic Fields. Wiley and Sons.

Watanabe, Satosi 1955. "Symmetry of Physical Laws. Part 2. Q-Number Theory of Space-Time Inversions and Charge Conjugation". Rev.Mod.Phys. 27, 1, pp. 40-76.

Watanabe, Satosi. 1955. "Symmetry of Physical Laws. Part 3. Prediction and Retrodiction." Rev.Mod.Phys. 27.

Watanabe, Satosi. 1965. "Conditional Probability in Physics". Suppl.Prog.Theor.Phys. (Kyoto) Extra Number, pp. 135-167.

Watanabe, Satosi. 1966. "Time and the Probabilistic View of the World". In Frazer (ed), 1966, The Voices of Time, Springer.

Watanabe, Satosi. 1972. "Creative Time." In Frazer (ed), 1972, The Study of Time, Springer.

Weyl, H, 1949, Philosophy of Mathematics and Natural Science. Priceton.

Weyl, H. and (Trans. H.L. Brose)., , 1950, Space-Time-Matter. Dover.

Whitney, H. 1936. "Differentiable Manifolds". Ann.Math. 37, pp. 645-80.

Whitney, H. 1936. "The self-intersections of a smooth n-manifold in 2n space." Ann.Math. 45, pp. 220-46.

Whitney, Hassler (1992), Eells, James; Toledo, Domingo (eds.), Collected Papers, Boston: Birkhäuser, ISBN 0-8176-3560-2

Whitrow, G.J., 1961, The Natural Philosophy of Time. Clarendon.

Whitrow, G.J., 1972, "Reflections on the History of the Concept of Time". In Frazer, et alia, 1972, The Study of Time. Springer-Verlag.

Whitrow, G.J., 1976, "'Becoming' and the Nature of Time". In Capek, 1976, The Concepts of Space and Time. D.Reidel.

Wigner, E., 1961, “Remarks on the mind-body question,” in Good, I.J., (ed.) The Scientist Speculates, London: Heinemann: 284–302.

Will, Clifford M. 2014. “The Confrontation between General Relativity and Experiment.” (Living Review series). arXiv:1403.7377v1 [gr-qc] 28 Mar 2014

Williams, J.G., Boggs, D.H. Secular tidal changes in lunar orbit and Earth rotation. Celest Mech Dyn Astr 126, 89–129 (2016). https://doi.org/10.1007/s10569-016-9702-3

Xiong, W.; Gasparian, A.; Gao, H.; Dutta, D.; Khandaker, M.; Liyanage, N.; Pasyuk, E.; Peng, C.; Bai, X.; Ye, L.; Gnanvo, K. (November 2019). "A small proton charge radius from an electron–proton scattering experiment". Nature. 575 (7781): 147–150. Bibcode:2019Natur.575..147X. doi:10.1038/s41586-019-1721-2. ISSN 1476-4687. OSTI 1575200. PMID 31695211. S2CID 207831686.

Zbinden, H., J. Brendel, N. Gisin, and W. Tittel. 2003. “Experimental test of non-local quantum correlation in relativistic configurations”. Phys.Rev.A, 63 (022111).

Zeh, H.Dieter. 1989. The Physical Basis of the Direction of Time. Springer-Verlag.

Water References – a sample of controversial topics.

Ball, P. 1999. H2O. A biography of water. Phoenix.

Ball, P. 2008. Water — An Enduring Mystery. Nature 2008, 452, 291-292.

Benveniste, J. 1994. Memory of water revisited. Nature, 370, 6488.

Bunkin, Nikolay F. 2014, Gorelik, Vladimir S., Kozlov, Valeriy A., Shkirin, Alexey V. and Suyazov, Nikolay V. 2014. Colloidal Crystal Formation at the "Nafion−Water" Interface. dx.doi.org/10.1021/jp4100729| J. Phys. Chem. B 2014, 118, 3372−3377

Chai et alia 2008. J. Phys. Chem. A 2008, 112, 2242-2247. "Spectroscopic Studies of Solutes in Aqueous Solution". Bing-hua Chai, Jian-ming Zheng, Qing Zhao, and Gerald H. Pollack.

Chaplin, M.F., 2007. The Memory of Water: an overview. Homeopathy, 96, 143-150.

Chaplin, Martin. (Website). http://www1.lsbu.ac.uk/water/water_vibrational_spectrum.html

De Ninno, A., De Francesco, M., 2018. Water molecules ordering in strong electrolyte solutions. Chemical Physics Letters, 705, 7-11.

Del Giudice, E., Tedeschi, A., Vitiello, G., Voeikov, V., 2013. Coherent structures in liquid water close to hydrophilic surfaces, J. of Physics: Conference Series 442, 012028, 1-5. 74

Deryagin BV, Golovanov MV (1986) Electromagnetic nature of forces of repulsion forming aureoles around cells. Colloid J USSR 48(2):209–211.

Elia V, Ausanio G, De Ninno A, Germano R, Napoli E and Niccoli M. 2014. Experimental Evidences of Stable Water Nanostructures at Standard Pressure and Temperature Obtained by Iterative Filtration. WATER 5, 2014.

Florea, D.; Musa, S.; Huyghe, J.; Wyss, H. Long-Range Repulsion of Colloids driven by Ion Exchange and Diffusiophoresis. Proceedings of the National Academy of Sciences 2014, 111, 6554-6559.

Fröhlich, H. 1970. "Long range coherence and the action of enzymes." Nature 228(5276):1093.

Fuchs E. C., L. F. Agostino, A. Wexler, R. M. Wagterveld, J. Tuinstra, J. Woisetschläger. 2010. The behavior of a floating water bridge under reduced gravity conditions. Journal of Physics D-applied Physics, pp. 25501.

Fuchs, E. C. J. Woisetschläger, K. Gatterer, E. Maier, R. Pecnik, G. Holler, H. Eisenkölbl. 2007. The floating water bridge. Journal of Physics D-applied Physics, pp. 6112-6114.

Gallo, P.; Amann-Winkel, K.; Angell, C.; Anisimov, M.; Caupin, F.; Chakravarty, C.; Lascaris, E.; Loerting, T.; Panagiotopoulos, A.; Russo, J.,…, L.G.M. Pettersson. Water: A Tale of Two Liquids. Chemical Reviews 2016, 116, 7463-7500.

Ho, MW (2012a). Living Rainbow H2O, World Scientific and Imperial College Press, Singapore and London.

Ho, MW. (2011). Quantum coherent water & life. Science in Society 51: 26-28.

Holster, A.T. 2017. "Effects of Radio Frequency Water Treatment on Revival of Wilted Flowers." http://www.waterjournal.org/volume-8/holster

Jahn, Robert G. and Dunne, Brenda J., 1986, "On the Quantum Mechanics of Consciousness, with Application to Anomalous Phenomena". Found.Phys. 16, 8, pp. 721-772.

Lippincott, E. R., Stromberg, R.R., Grant, W.H., Cessac, G.L., 1969. Polywater. Vibrational spectra indicate unique stable polymeric structure. Science, 164, 3887, 1482-1487.

Montagnier, L., Aisa, J., Ferris, S., Montagnier, J.-L., Lavallee, C., 2009. Electromagnetic signals are produced by aqueous nanostructures derived from bacterial DNA sequences. Interdiscip Sci. Comput Life Sci., 1, 81-90.

Nilsson, A.; Pettersson. L. G. M. The Structural Origin of Anomalous Properties of Liquid Water. Nature Comm., 2015, 6, 8998 (1-11).

Pollack, G. H. The fourth phase of water. Beyond Solid, Liquid, and Vapor; Ebner & Sons. Publishers: Seattle WA, USA, 2013.

Renati, P., Kovacs, Z., De Ninno, A., Tsenkova, R., 2019. Temperature dependence analysis of the NIR spectra of liquid water confirms the existence of two phases, one of which is in a coherent state. J. Mol.Liquids, 292, 11149, 1-10.

Sbitnev, Valeriy I. and Konstantinov, B.P. 2016. “Quantum consciousness in warm, wet, and noisy brain”. arXiv:1606.00258v3 [q-bio.NC] 14 Jul 2016

Schurr JM. 2013. Phenomena associated with gel-water interfaces. Analyses and alternatives to the long-range ordered water hypothesis. J Phys Chem B 117(25):7653–7674.

Segarra-Martí, J., Roca-Sanjuan, D., Merchan, M.. 2014. Can the Hexagonal Ice-like Model Render the Spectroscopic Fingerprints of Structured Water? Feedback from Quantum-Chemical Computations, Entropy 2014, 16, 4101-4120

Segarra-Martí, J.; Roca-Sanjuán, D.; Merchán, M. 2014. On the hexagonal ice-like model of structured water: Theoretical analysis of the low-lying excited states. Comput. Theor. Chem. 2014, doi:10.1016/j.comptc.2014.02.012.

Skinner L. B., C. J. Benmore, B. Shyam, J. K. R. Weber, J. B. Parise. 2012. Structure of the floating water bridge and water in an electric field. Proceedings of the National Academy of Sciences of the United States of America, pp. 16463-16468.

Tao, Y., Zou, W294., Jia, J., Li, W., Cremer, D., 2017. Different ways of hydrogen bonding in water – why does warm water freeze faster than cold water? J. Chem. Theory Comput, 13, 1, 55–76.

Wexler Adam D., Mónica López Sáenz, Oliver Schreer, Jakob Woisetschläger, Elmar C. Fuchs. 2014. The Preparation of Electrohydrodynamic Bridges from Polar Dielectric Liquids. Journal of visualized experiments.

Yinnon TA, Elia V, Napoli E, Germano R, Liu ZQ. 2016. Water Ordering Induced by Interfaces: An Experimental and Theoretical Study. WATER 7, 96-128, 2016.

Yoo et alia. 2011. J Phys Chem Lett. 2011 February 18; 2(6): 532–536. doi:10.1021/jz200057g. “Impact of Hydrophilic Surfaces on Interfacial Water Dynamics Probed with NMR Spectroscopy”. Hyok Yoo, Rajan Paranji, and Gerald H. Pollack.

Zheng, J.M. and Pollack, G. H. 2003. “Long range forces extending from polymer surfaces.” Phys Rev E.: 68: 031408, 2003

Acknowledgements.

Special thanks go to Patricia Holster for feedback and support In this study. Thanks go to Jeremey Praat, Paramattma, and Bruce Small, for conversations and encouragement in the formative stages of this theory. Thanks go to Johan Kronholm for encouragement to continue this study. All errors and opinions are the author's.