Towards the unification of physics

How come the quantum?

Using Kauffman's topological origin of Planck's quantum of action $\hbar$

to understand the origin of elementary particle masses

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motionmountain.net/research

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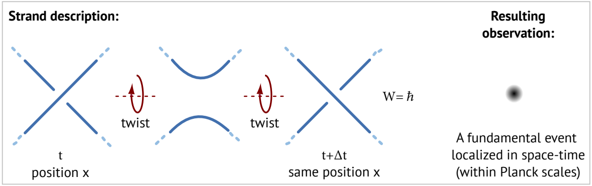
Kauffman's suggestion: $\hbar$ is due to twist-induced crossing switches of strands

The fundamental principle of the strand tangle model



A *crossing* is the region of the smallest distance between two strands.

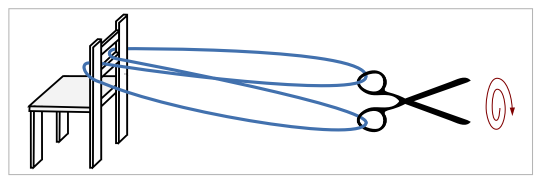
Kauffman (1987) proposed that *crossing switches* explain, model and visualize $\hbar$ and thus *every aspect of quantum theory – and of nature.*

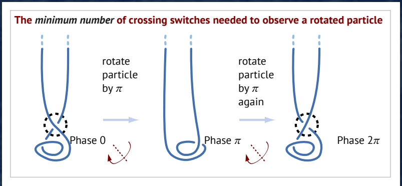
Testing this claim implies checking spin 1/2 behaviour, fermion behaviour, the principle of least action, quantization of action and angular momentum, de Broglie's relations about wave-particle duality, wave functions, the Schrödinger equation, spinors, and the Dirac equation, Hilbert spaces and interfering electrons and photons, Heisenberg's indeterminacy relations and canonical commutation relations, entanglement, the measurement process, particle masses, particle physics and quantum gravity.

Prediction: Because all measurement apparatuses, measurement units and measurement processes make use of $\hbar$, any model for $\hbar$ must reproduce all observations in nature.

Dirac's explanation about how strands explain and imply $\hbar$

Objects tethered with strands behave like spin $\hbar/2$ particles: they return to the original situation after a rotation by 4π, not after a rotation by 2π.





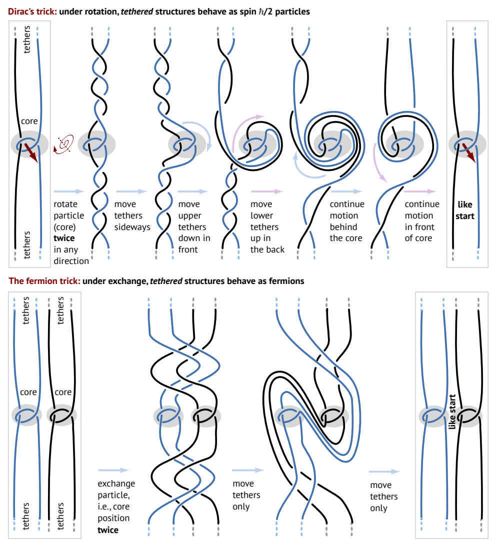
This only works if *strands are unobservable*. Their radius is unobservably small. They are uncuttable, extremely flexible and permanently fluctuating.

Crossing switches are observable because a rotation by 2π is observable.

Crossing switches yield $\hbar$ because a rotation by 2π is the smallest observable change, and thus the smallest measurable action.

Predictions: $\hbar$ is constant and invariant; no other model for $\hbar$ exists. All confirmed.

Tangles of strands explain and model spin 1/2 fermions



Spinning fermions are *rotating rational tangle cores* continuously performing Dirac's trick.

When moving, fermions spin like a moving windmill or a maple seed.

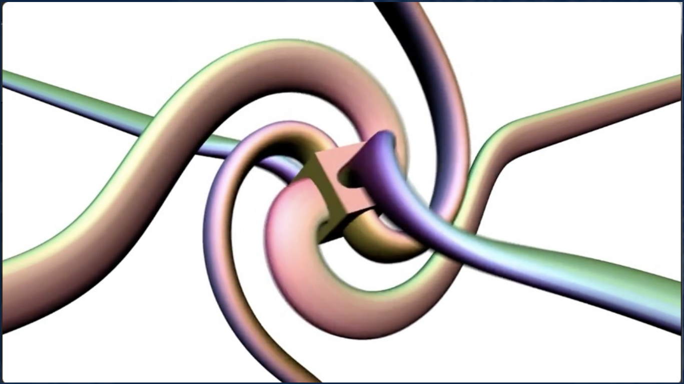
The spin-statistics theorem and Pauli's exclusion principle are valid for fermions.

Tethered fermions *can orbit* each other continuously.

researchgate.net/publication/361866270.

Predictions: there is no elementary spin 3/2 particle; there is no particle with spin between 0 and 1/2; there are no anyons; no action below $\hbar$ is observable; there is no other model for $\hbar$ and spin 1/2. All confirmed.

Jason Hise's animation illustrates the motion of spinning leptons



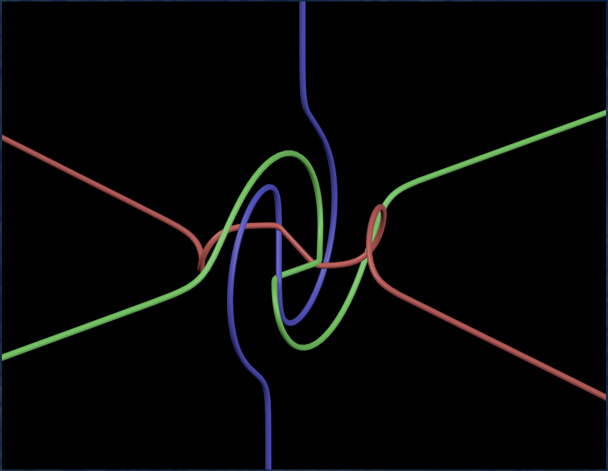
(Click.)

motionmountain.net/videos.html#strands

The rotating cube represents the chiral tangle core of the spinning lepton.

Classifying the possible core topologies leads to the *observed lepton spectrum*.

A Desmos animation of a spinning electron, programmed by Ronwnor



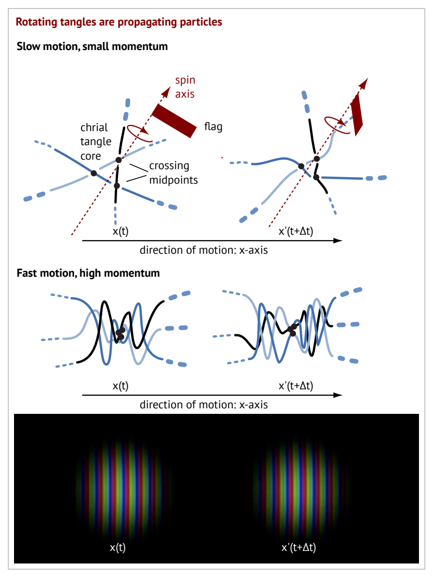
(Click.)

Animation at desmos.com/3d/46kkmamfwy

The *central triangle* is the spinning *chiral electron* core; each chiral crossing yields an electric charge e/3.

researchgate.net/publication/389673692

Strands explain and derive the expressions about wave-particle duality



Spinning particles advance with the rotation of their chiral core.

Each rotation implies a crossing switch.

Each crossing switch corresponds to $\hbar$.

This implies *de Broglie's relation*

$$\lambda = 2\pi\hbar/p$$

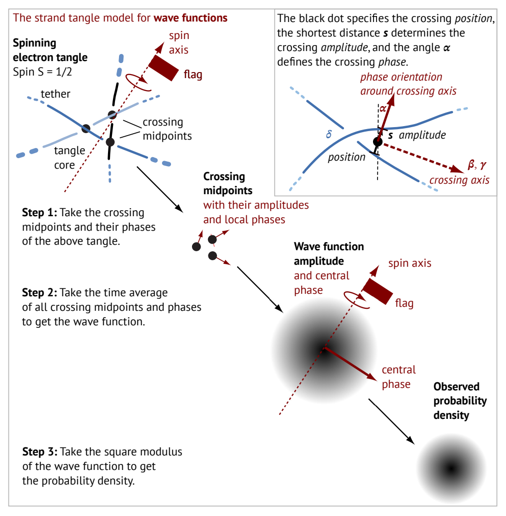
between wavelength λ and momentum p, and to the relation

$$f = E/2\pi\hbar$$

between energy E and frequency f.

Predictions: no deviation from wave-particle duality is measurable; no other model derives the relations. All confirmed.

Strands explain and derive wave functions and quantum mechanics



motionmountain.net/strandsquantum.html

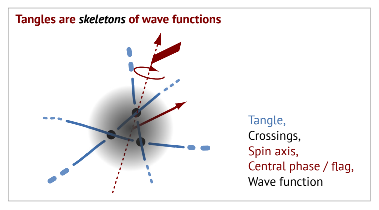
Particles are spinning tangles.

Wave functions are *oriented crossing densities* and form a Hilbert space.

This leads to the *free Schrödinger equation.*

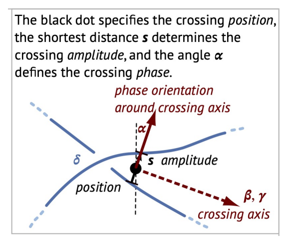
researchgate.net/publication/361866270.

Tangles are *skeletons* of wave functions:



Predictions: no measurable deviations from quantum theory; no other model for wave functions. All confirmed.

Tangled strands explain antiparticles, spinors, and the Dirac equation



Dirac spinors arise from oriented crossing densities when all angles are taken into account (3 additional angles).

Relativity is incorporated into the details of Dirac's trick (3 additional parameters).

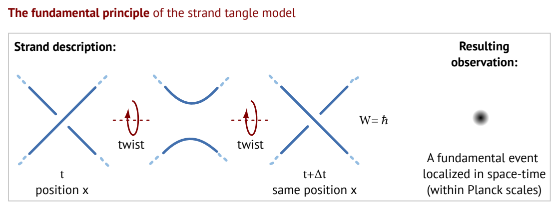
Antiparticles are *mirror tangles* rotating in the opposite direction.

Battey-Pratt and Racey *derived the Dirac equation* from tethered particles in 1980.
Int J Theor Phys 19, 437475 (1980) 437

Particles and antiparticles can annihilate and continuously transform into each other because of their topology: particles are *rational 3d tangles*, i.e., 3d braids. Only rational 3d tangles reproduce particle reactions, interactions and decays.
researchgate.net/publication/361866270.

Predictions: no measurable deviation from the free Dirac equation; no other model for deriving the equation ab initio; no other model explains particle reactions. All confirmed.

Strands explain Heisenberg's indeterminacy relation and canonical commutation relation



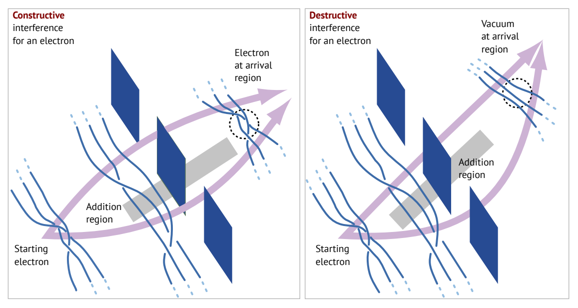
The crossing switch explains the indeterminacy relation (uncertainty relation).
The figure implies

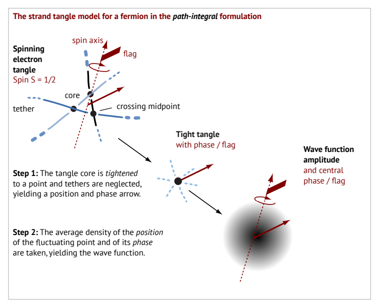
$$\Delta W \geqslant \hbar/2 \quad \text{and thus} \quad \Delta x \Delta p \geqslant \hbar/2$$

The behaviour of strands also explains the canonical commutation relation.

Predictions: no measurable deviation from the relations at any energy; no other model for the relations is possible. All confirmed.

Strands explain interference and path integrals





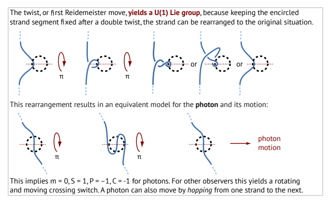
Interference is due to the behaviour of *partial* tangles.

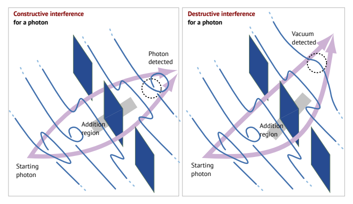
Interference requires tangle *hopping*.

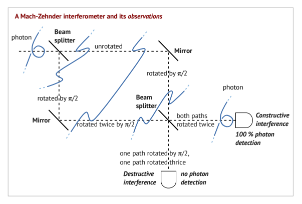
Path integrals follow from moving rotating tangle cores assumed to be *point-like*.

Predictions: no deviation from usual interference is measurable; no other model for interference and for path integrals is possible. All confirmed.

Strands explain photons and their interference







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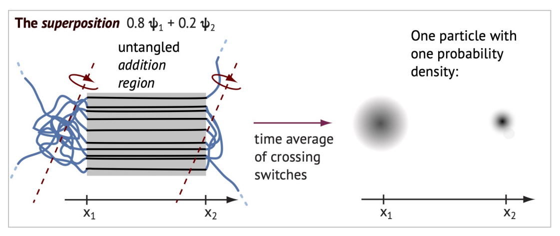
Photons are rotating loops in a single strand.

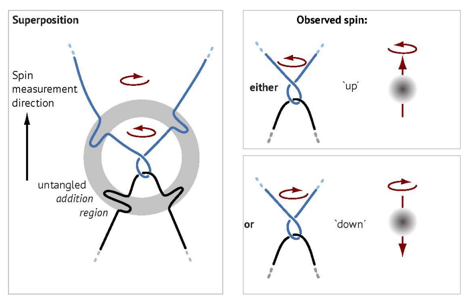
Rotating loops explain spin 1, wavelength, boson behaviour, vanishing mass, negative parities, “infinite” lifetime, and the U(1) gauge group.

J. Geom. Phys. 178 (2022) 104551

Predictions: no measurable deviation from photon properties; no other model for photons. All confirmed.

Strands explain decoherence and quantum measurements, avoiding hidden variables





youtu.be/-KGW3QvwFuE

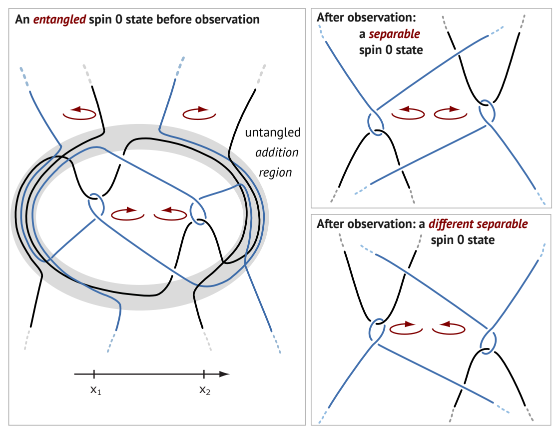
In measurements, the coupling to a bath *takes out* the addition region.

The strands in the bath, together with the fluctuating strands of the quantum system, yield *collapse* and *random* measurement outcomes. Decoherence is reproduced.

Because strands are unobservable, they are not variables, and they are not local.

Predictions: no measurable deviation from decoherence; no hidden variables; no other model for decoherence. All confirmed.

Strands explain entanglement



Quantum entanglement is due to *topological entanglement*.

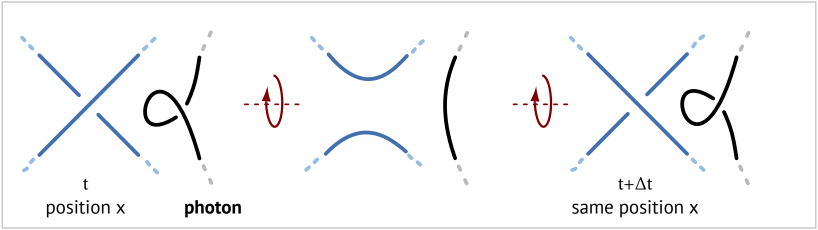
Measurements take out the addition region.

Three-particle entanglement is reproduced.

Predictions: no measurable deviation from quantum entanglement; no other model for entanglement is possible. All confirmed.

Strands explain the principle of least action: fewest crossing switches

Crossing switches couple to photons



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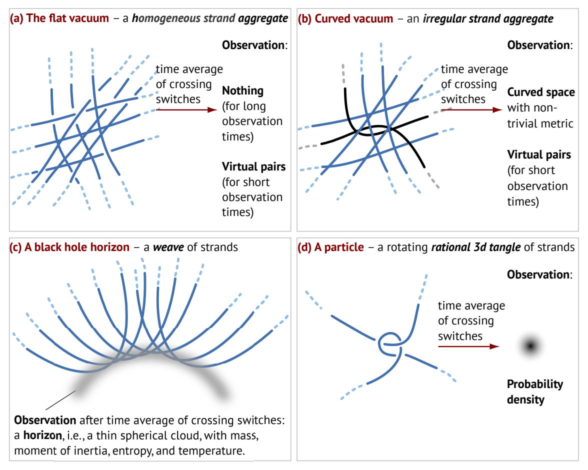
Action is the number of crossing switches.

Each crossing switch couples to *electromagnetic fields.*

The coupling is the reason that nature *minimizes* the number of crossing switches.

Predictions: no measurable deviation from the principle of least action; no other model and explanation for least action; all measurements are electromagnetic. All confirmed.

Strands yield all structures and all laws of nature



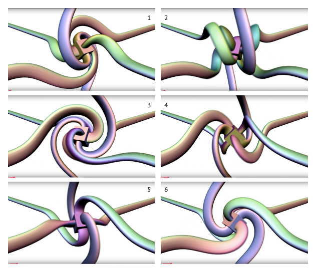
motionmountain.net/strands

Crossing switches of fluctuating strands of Planck radius yield the *standard model with massive neutrinos* and *general relativity* as limits of strand-based quantum gravity.

Phys. Part. Nucl. 50 (2019) 259 and a dozen other publications

Predictions: only 3 dimensions; no measurable deviations from the two Lagrangians; no other model will yield unification; no unified Lagrangian; no unified equations. All confirmed.

Strands *extend* quantum theory: strands explain particle mass



Particle mass can be determined once the *Planck radius of strands* is taken into account.

Such strands are still unobservable.

Mass is determined by the *probability of Dirac's trick* for a topologically chiral core.

Animation by Jason Hise at motionmountain.net/videos.html#strands

Dirac's trick (2 turns with 3 steps each) implies an *upper limit for lepton masses* given by

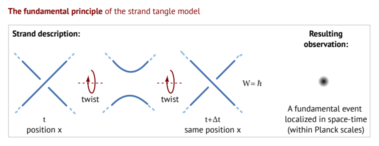
$$m_{\text{lepton}} < \left(\frac{1}{6!}\right)^{2\cdot 3} \approx 7.2 \times 10^{-18} \approx 44\,\mathrm{GeV}/c^2$$

Preprint at researchgate.net/publication/389673692.

Thus, strands solve the mass hierarchy problem. (The tau mass is $1.78\,\mathrm{GeV}/c^2$.)

Predictions: no heavier lepton will be discovered; neutrinos have mass; no other ab initio model for elementary particle mass values is possible; more and better estimates are possible. All confirmed.

Summary

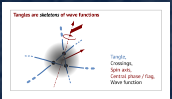


- Kauffman's visualization of $\hbar$ as an observable crossing switch of unobservable strands of Planck radius indeed *reproduces all observations* of quantum physics – and of nature.

- Modeling $\hbar$ as an observable crossing switch of unobservable strands is *unique.*

- The strand tangle model predicts the *lack of new physics.*

- The strand tangle model enables *more precise calculations* of the particle masses, coupling constants and mixing angles. researchgate.net/publication/389673692



- The strand tangle model is *useful for teaching* quantum theory.

* *

With a warm thank you to Lou Kauffman.

Appendix: Wheeler's challenge

The necessity of the quantum in the construction of existence: out of what deeper requirement does it arise? Behind it all is surely an idea so simple, so beautiful, so compelling that when – in a decade, a century, or a millennium – we grasp it, we will all say to each other, how could it have been otherwise? How could we have been so stupid for so long?
[...]
It will surely not be by asking always small questions that the community will some day find the answer to the great question, "How come the quantum?" To ask the right question, however, one must have, as is well known, some glimmer of the answer. It is also old experience that in order to break out of blank puzzlement and into the right question-and-answer circuit, one must try and try again. One must, if necessary, make a fool of oneself many times over [...]

From J. A. Wheeler, How Come the Quantum?, Annals of the New York Academy of Sciences 480 (1986) 304.

Dirac's scissor trick is from 1929. Kauffman's answer with crossing switches is from 1987.