

Uniqueness of Unification

of general relativity and the standard model with massive neutrinos:

The lack of alternatives yields estimates of particle masses.

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motionmountain.net/research

Preprint at researchgate.net/publication/389673692

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Constituents of nature

Black holes have entropy.

Thus, black holes are made of *fluctuating constituents*.

Black holes can be formed by amassing particles.

Black holes can be formed by curving space.

Thus, black holes, particles and space are made of *common* fluctuating constituents.

All of nature is made of common fluctuating constituents.

Properties of the constituents of nature

Black hole horizons and space are extended. Space is empty.

Black hole entropy depends on the black hole *surface* and on the *Planck area*.

Thus, black hole constituents cannot be of Planck size in all directions.

Thus, black hole constituents cannot be membranes.

Thus, black hole constituents cannot be of finite size but must reach the cosmological horizon.

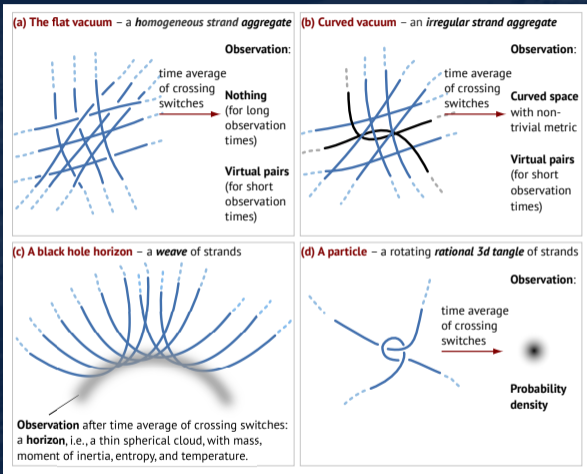
Thus, black hole constituents cannot have branches or crossings.

Thus, black hole constituents must be *unobservable* and thus obey *no equations*.

Thus, nature's constituents are *filiform with Planck area cross section*.

They fluctuate in 3d and are called *strands* (Fäden, fils, fili, draaden).

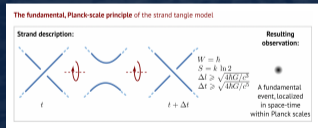
Claim: only strands yield all structures and all laws of nature



Fluctuating strands of Planck radius yield particle physics and general relativity.

Fluctuating strands agree with all observations.

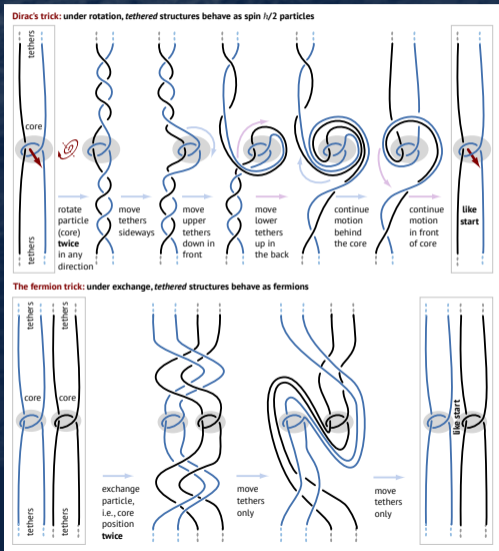
This follows from a single fundamental principle:



All observables are *composed* of crossing switches.

Phys. Part. Nucl. 50 (2019) 259 and a dozen more, listed at motionmountain.net/strands

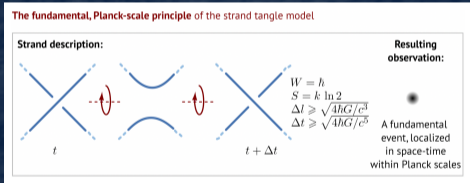
Only strands explain and derive \hbar and spin 1/2 fermions



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

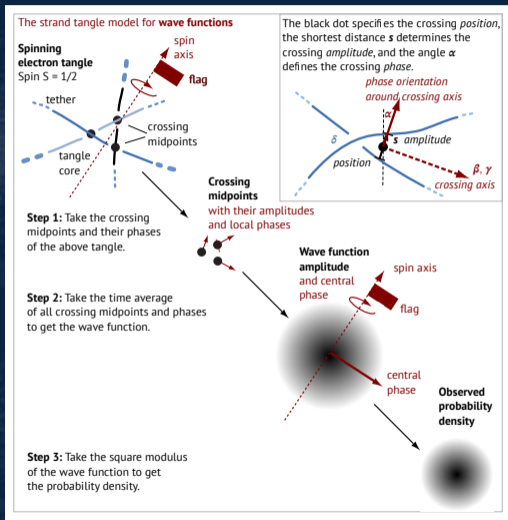
When moving, fermions spin like a moving windmill or a maple seed.

Each crossing switch produces a quantum of action \hbar :



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

Only strands explain and derive wave functions and quantum theory

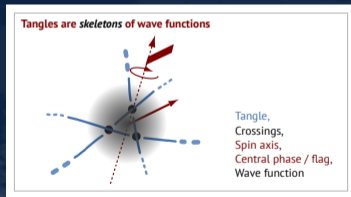


Wave functions are *oriented crossing densities* and form a Hilbert space.

Particles are *tangles*. This explains antiparticles and leads to the free *Dirac equation*. Reactions arise.

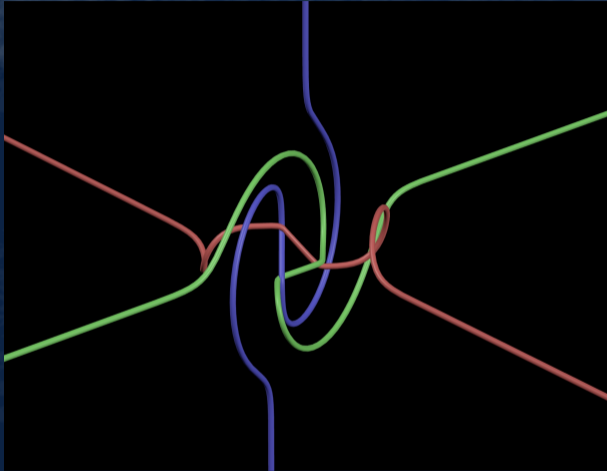
See researchgate.net/publication/361866270

Tangles are *skeletons* of wave functions:



Predictions: there are no measurable deviations from quantum theory; there is no other model for wave functions.

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

Only strands explain and derive the elementary fermion spectrum and quantum numbers

Quarks - 'tetrahedral' tangles made of two strands with four tethers (only simplest family members)

Parity $P = +1$, Baryon number $B = +1/3$, Spin $S = 1/2$

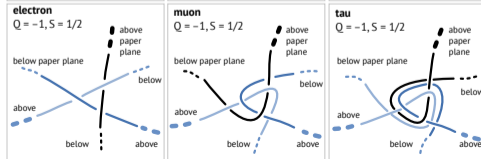
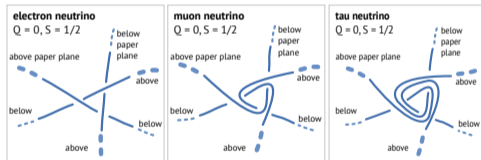
Charge $Q = -1/3$



Charge $Q = +2/3$



Leptons - 'cubic' tangles made of three strands along coordinate axes (only simplest family members)



Classifying tangles allows classifying elementary particles, yielding **three generations** of fermions and all their quantum numbers.

Topological chirality, $1/3$ of the signed crossing number, yields electric charge.

Geometric chirality yields parities and mass values for nonzero spin.

Predictions: there is no other elementary fermion and no elementary dark matter; neutrinos have mass; there is no other model for elementary particles.

Only strands explain and derive gauge interactions, Lie groups and coupling constants

Reidemeister move I or twist

Twists yield one deformation that leads to $U(1)$.

The electromagnetic interaction is twist transfer

virtual photon

fermion

vacuum

Reidemeister move II or poke

Pokes yield three generators that generate $SU(2)$.

The weak interaction is poke transfer

virtual weak boson

fermion

vacuum

Reidemeister move III or slide

Slides have $9 - 1 = 8$ generators that generate $SU(3)$.

The strong interaction is slide transfer

virtual gluon

fermion

vacuum

The table, or **Real Reidemeister move**, is related to a crossing switch in a 3-strand braid code that twist around a given axis that yields a $SU(2)$ Lie group. Rearrangement:

Pokes, or second Reidemeister moves, are pairs of closed segments from an $SU(2)$ Lie group, because the three rotations by π reproduce the $SU(2)$ algebra of the braid code.

Slides, or third Reidemeister moves, acting on strand pairs in three-strand structures, can be generalized to the generators of the Lie group $SU(3)$.

Elementary bosons are simple configurations of 1, 2 or 3 strands that propagate:

Real bosons:	Virtual bosons:
1 strand: photon wavelength	Spin $S = 1$
2 strands: W_1, W_2 (before $SU(2)$ symmetry breaking) wavelength	$S = 1$
2 strands: W_3 (before $SU(2)$ symmetry breaking) wavelength	$S = 1$
2 strands: graviton wavelength	$S = 2$
3 strands: eight gluons wavelength	$S = 1$
3 strands: Higgs boson	$S = 0$

Weak (real) vector bosons after $SU(2)$ symmetry breaking, thus massive (only the simplest family members)

W boson $S = 1$

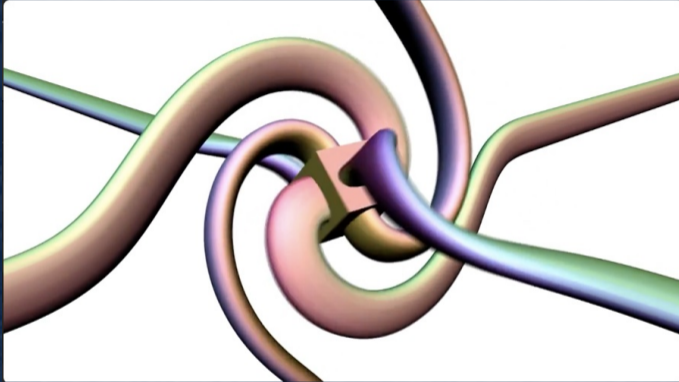
Z boson $S = 1$

Reidemeister's theorem from 1926 allows classifying gauge interactions, gauge bosons, and *deriving the three gauge groups*. Int. J. Geom. Meth. Mod. Phys. 21 (2024) 2450057

The average shape of chiral cores determines the **electromagnetic** and the **strong coupling constant**. J. Geom. Phys. 178 (2022) 104551, Int. J. Geom. Meth. Mod. Phys. 20 (2023) 2350095

Predictions: there are no additional gauge interactions; there is no other model for them.

Jason Hise's animation illustrates the motion of spinning leptons



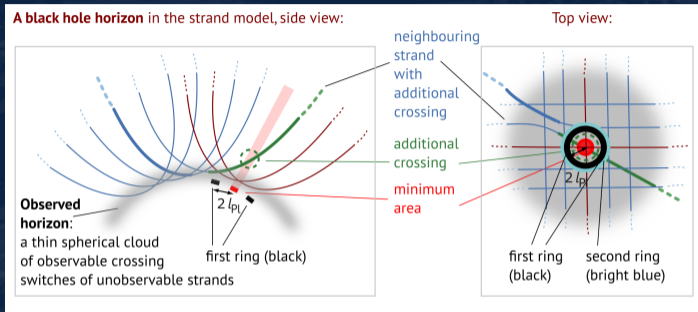
(Click.)

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*.

Only strands with Planck radius *also* explain general relativity



Black hole entropy follows from the statistics of crossing switches of strands.

Ind. J. Phys. 96 (2022) 3047

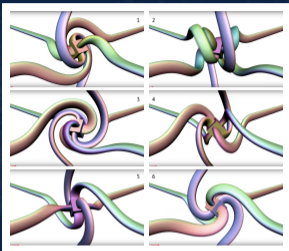
Also black hole temperature and energy follow from crossing switches of strands.

This implies the field equations of general relativity, as shown by Jacobson in 1995.

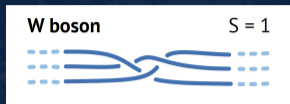
Predictions: no deviation from general relativity and no new quantum gravity effect will be observed; no other model of general relativity will explain elementary particles.

Only strands with Planck radius explain and derive particle masses

Leptons:



Bosons:



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Dirac's trick implies an *upper limit for lepton mass* given by $44 \text{ GeV}/c^2$.

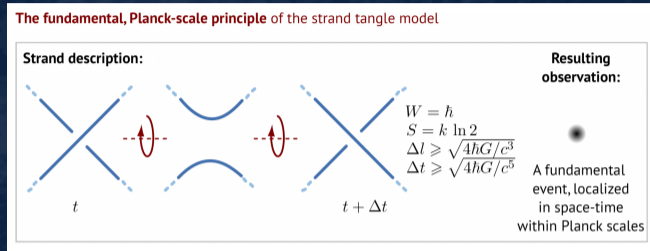
Boson motion implies a *mass for the W boson* between $32 \text{ GeV}/c^2$ and $8.4 \text{ TeV}/c^2$.

Tether motion imply a *mass for the Higgs* between $96 \text{ GeV}/c^2$ and $3.9 \text{ TeV}/c^2$.

Not precise, but ab initio – and strands solve the mass hierarchy problem.

Predictions: no deviation from the standard model with massive neutrinos will ever be observed; no other model derives elementary particle mass values ab initio.

Summary: *only* strands deduce physics from a single principle



- The fundamental principle deduces the Lagrangian of the standard model of particle physics with massive neutrinos.
- The fundamental principle deduces the Hilbert Lagrangian of general relativity.
- So far, all consequences of the fundamental principle agree with all observations.
- Predictions: no observation will ever contradict the two Lagrangians; no unified equations are possible; no other unified model is possible; more precise estimates of the masses, couplings and mixing angles are possible.