PLANCK-SCALE MATERIALS FROM MODIFIED DETERMINISTIC QUBIT MECHANICS

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Using mechanics from Valentine, we propose exotic states of matter and behaviors at Planck scale that, while impractical experimentally, may offer insights into intermediate processes or theorized high-energy scenarios. We infer a geodesic default for propagation, a view on entropy, reasons for physical ontology, and phases of matter and phenomena near Planck length on a spectrum towards infinitely-propagating noncollapsing fermions. Wavefunctions at Planck scale, far from their expectation values, are interleaved combs at Planck intervals with interaction radius starting as small as 6.0e28 eV, or a quarter-Planck-length, with collapse variance like quantum foam. When calculated with vacuum flux and other matter, the wavefunctions exhibit classical distributions at larger scale, expressing as fundamental fields when treated statistically. If our interpretation of gravitation holds, then grand unification energy is the same as that for a unified field theory, and we can demonstrate expressions of all of them within an instance of the mechanism. The strong force is not yet calibrated.

Keywords: deterministic, physicality, vacuum, fermion, propagation, quantization, entanglement, spontaneous symmetry breaking, electroweak, Higgs boson, particles, quantum foam, grand unification, unified field theory.

1. Introduction

In earlier work [2, 3], we proposed foundations for deterministic mechanics for physics at all energies, using two free parameters, to infer emergent behaviors in physical systems. Here, using the same mechanics, we infer phases of matter and their probability densities at grand unification energies, near the Planck length.

We can also find context-based behaviors, limited to zones in multidimensional statistical parameters, from which we can infer states of matter.

We also described [4] a context for different fundamental forces having the same unified basis, their observable classical behaviors defined by attribution to larger bodies and to the macro effect of the interaction in the locality of interest. Gravitation, electric charge, strong, and electroweak forces all propagate as a unified carrier [4: 3], but their fields are not fundamental, only statistically derived, so we don't make any claim of a unified field, only a unified mechanism. From our mechanism, we also derived named forces and effects, particularly at high energies, and found them to be non-special expressions of the same collapse mechanism.

Here, we explore these boundaries that determine our physical ontologies, and how the context of quantum collapse affects our attribution of forces.

2. Recap

2.1 *Deterministic rules* [2]

1) Waves are bound in pairs as oscillators or qubits.
2) Waves propagate radially, as light speed bosons, having equivalence of phase, distance, and time:

$$d\varphi = ds = dt \quad (1)$$

3) Nonunique waves, having the same phase and source, are excluded from interactions.
4) An oscillator's mass is a function of its wave phases,

$$\rho = e^{-i(\varphi_B - \varphi_A)} \quad (2)$$

5) ρ modulates phase φ of other overlapping waves.
6) Two waves, from different fermions, with $\varphi = 0$ at a unique point, collapse their bosons into a **fermion**.

2.2 *The fermion event*

The fermion event exists only at an instant, after which the fermion is no longer a point, but is radiating. We don't specify the background, but as an example, we use a flat (3,1) metric as being most relatable. Propagation is fundamentally a phase offset, and Rule 2 applies for its equivalence with space and time.

Everything about this fermion is encoded in the waves on its shell. We regard the fermion event a state of matter, because it's a condition with special uniqueness properties [4: 2.2]. It doesn't have a size-equivalent energy because it's a point, but its mass-energy, a different measure, is encoded in the wave phases, and contributes to its expectation value for size or energy required to make it decoherent. It naturally decays instantly, but its parts can reform later.

> Fermion event, $0\,\ell_P$.

2.3 *Quantum information and propagation*

The wave pairs (rule 1) resemble **oscillators** or **qubits**, with an elliptical skew (rule 4) to encode **mass**.

There is no continuous classical movement of the fermion. It's a quantum teleportation to a new point. For example, for a conserved fermion cycle **A → D** (fig.1), two oscillators from fermion **A** each collapse in events **B** and **C** respectively, then they in turn collapse to a new fermion solution **D** on the shells from **B** and **C**.

A **shell** is the time, distance, or phase offset from a fermion event as it propagates; they're all equivalent (rule 2), like a sphere expanding from a point in space and time. On the shell are **entangled** waves, encoded in pairs as **bosons**. They share the same spatial identity, and are indistinguishable from each other unless they are unique in phase. Waves sharing a common phase on the shell are **excluded** from interactions (rule 3).

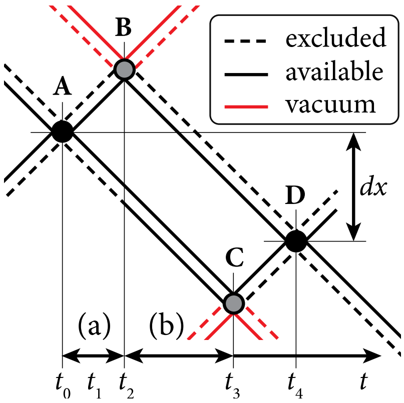

Figure 1. Propagation of a conserved fermion from **A** to **D**. Each line is a wave; each pair of lines is a boson.

2.3.1 *Entropy and the propagation geodesic*

In terms of propagation, light-speed radiation is the default condition, until the shell is collapsed by another shell. Implications:

- Propagation is a geodesic in spacetime, without needing a force to cause action, similar to gravitation being a factor in the natural geodesic for curved spacetime in general relativity.
- Propagation is inherently thermodynamic, because the default behaviour of a fermion is to radiate away in bosonic state. We could re-base thermodynamics with these quantum foundations.
- At regular Planck-length intervals, each wave has opportunity (fig.2) to interact with an external shell. We can derive entropy functions from outcomes of these opportunities.
- The expectation value for particle radius is related not directly to mass, but to the intrinsic mass-energy encoded in its bosons, and vacuum flux density, which determine macro structural behaviour like momentum, inertia, gravitation, and charge.

2.4 *Vacuum*

Immediately after a fermion event, the fermion exists not as a point that might have momentum, but as a radiating shell of oscillators (rule 2). We structure the vacuum as many oscillators that radiated from previous fermions. These instances of discrete 'vacuum energy' have the same structure and mechanics as the objective fermions of interest that we call "matter". It's convenient to consider vacuum as degenerate flux when we're studying the coherence of matter.

As a thought experiment, we can remove this vacuum, so we're left with, say a single fermion in void. This fermion would radiate forever if there are no other shells to collapse it. That in itself could be a phase of matter because of its unique behavior.

Infinitely propagating shell, $\infty\,(0\,\text{eV})$

All other phases occupy a spectrum of interaction somewhere between the fermion event and the infinitely propagating shell.

All the fermions in the universe are in this propagation state at any given instant, unless you happen upon an exact match for a fermion event.

If we exit our thought experiment and re-add the vacuum, or add another propagating shell, then the shell may collapse at some future event where its world-line crosses with the other shell.

3. The smallest scale

Each active wave on the shell has a comb of impulses, and they're all interleaved, repeating every Planck length, offset from the origin [4: 2.2].

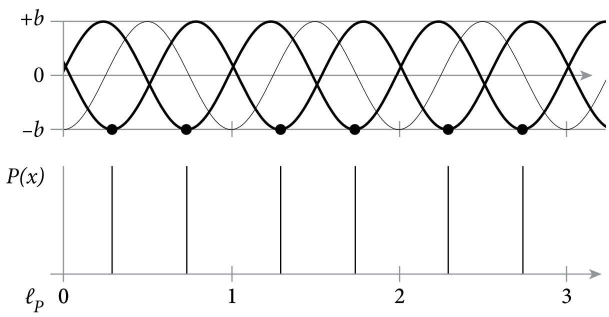

Figure 2. With two active waves, opportunities interleave, and repeat every cycle.

3.1 *The smallest conserved particle*

We derive a particle's expectation value as the flux density of vacuum sufficient to compete with a particle's own conserved reconstitution pattern and make it lose coherence [4: 3.8].

The densest possible particle is a conserved pattern that repeats (fig.1) in the smallest timeframe or has the smallest interaction radius. In other words, the particle with the highest possible energy.

Given the reconstitution pattern, the smallest particle is a fermion that radiates as a shell, then its two on-shell boson components each collapse, and then return to each other to reform the fermion:

1. The first opportunity from the shell aligns with another shell to form event **B** (fig.1).
2. The second opportunity aligns with another shell to form event **C**.
3. Event **D** aligns close to Planck length 1.

This creates a conserved particle with an external radius for event **C** of around $0.75\,\ell_P$ or $\sim 1.6\times10^{28}\,\text{eV}$, and for event **B**, $0.25\,\ell_P$ or $\sim 6.0\times10^{28}\,\text{eV}$, for bosons with near-zero intrinsic mass-energy (rule 2).

Other configurations of wave phase are possible: both **B** and **C** may both be around $0.25\,\ell_P$ if their masses differ, and the particle can be net stationary if successive collapse points alternate about the center. This gives a particle size of $\sim 6.0\times10^{28}\,\text{eV}$. Setting up events experimentally for such particles would require unreasonable precision.

3.2 *Structures of a sub–Planck-scale particle*

Such a small particle relies on external input to create virtual anti-fermions **B** and **C** (fig.1) for the outbound collapse events. For this to operate at such a high energy needs a coherent vacuum flux sufficient to nearly guarantee an interaction at the first opportunity, or a matter array of the highest density. There are two ways to do this at small scale:

- A confined particle supported by an incoherent vacuum flux with very high density. This would be highly unstable and quickly evaporate.
- An array, supported by a regular tessellation of the **A** to **D** pattern in both space and time, is the most coherent input. The centre of the structure would be stable while supported by neighbours, but the edges would evaporate and erode the array at light speed.

Planck-scale array, $\sim 1.6\times10^{28}\,\text{eV}$.

So either of these are theoretically possible, and could be temporary states of other interactions, but Planck-scale matter is impractical to create or sustain due to its instability.

The array can take two forms, or somewhere in between, depending on the skew of the **A** to **D** pattern (difference in timing of **B** and **C**):

- Locally confined with the exact same parts reconstituting and likely classically stationary, like fig.1 where vacuum contributes to **B** and **C**.
- Conducting a coherent flux.

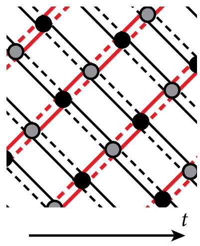

Figure 3. Planck-scale array, conducting coherent vacuum flux currents.

This array will evaporate at the edges unless supported by flux that is the density of the array itself. If somehow compressed, this array will quickly return to exactly the ideal spacing.

Again, we emphasize this is of limited experimental value; the scale implies a supporting vacuum flux temperature of around $7.0\times10^{32}\,\text{K}$, using Boltzmann.

3.3 *Quantized scale*

Our first examples (3.1) were the most compact, but if a fermion shell has already radiated past the first opportunity, the second is open for an incoming shell, and then the third, and so on.

The radius at which a shell collapses is quantized, as a series of opportunities, repeating every Planck length. This gives us two phenomena:

Quantum foam, $2.0\times10^{28}\,\text{eV}$.

Spacetime remains smooth; the quantum foam is present as quantization 'noise' at all scales, more significantly near Planck scale, compared to the propagation radius.

Quantized-density compact array, $1.2\times10^{28}\,\text{eV}/n$.

These quantized densities correspond to radius of each tooth on the comb of probability density (fig.2).
Such arrays have a distinct behaviour:

- Compression or expansion shocks with each micro-phase-change, as the environmental vacuum changes where parts of the array change interaction radius and induce similar in neighboring parts. This imposes **quantum states** or **energy levels**.

- One possible configuration is that the whole array steps in the same direction at every collapse.

3.4 *The smallest conserved and confined particle*

If we impose a constraint, that the a particle has no external support, then it is necessarily a confined collection of fermions, repeating a sequence using only shells from itself, and will be larger than the smallest possible particle.

A single fermion needs support to remain conserved, otherwise it propagates spherically until it meets another shell, so we don't regard that as a confined particle.

Most simple structures need vacuum flux at their outer interactions, but we can avoid this by aligning those vacuum-interacting events onto other such events.

The smallest such structure we can think of is a two-fermion composite ring, that alternates between matter and antimatter states, with a total interaction surface radius of 1.5 ℓ_P. There's a phase offset between the matter fermions, to avoid non-uniqueness of antimatter solutions, and so on. It resembles fig.3, but with a spatial 'modulo wrap' every two fermions.

A four-fermion ring also works, with the same period but larger size.

This structure is unstable in vacuum flux, because any substitutions that change phase or mass-energy would break the sequence, causing its decay or annihilation.

Particle: Two-fermion ring, $\sim 8.0 \times 10^{27}$ eV.

3.5 *Classical forces at the smallest scale*

Regardless of scale, observing these behaviors as classical forces on the radius of the fermion, from elastic collisions using a targeted coherent flux or vacuum flux:

- A fuzzy spherical object with an internal pressure, up to event **B** (fig.1), and another pressure up to event **C** at its outer edge.
- A potential well, or what looks like a repulsive force that is strongest inside the radii of events **B** and **C**.
- In the presence of sufficient vacuum flux, the most likely outcome is collapse at events **B** and **C**. This looks like a boundary for elastic collisions.
- If any of the particle's bosons are confined in a composite, then **B** or **C** might be screened because internal interactions win over vacuum flux, and make the composite's shape seem more complicated as a codependent structure. To probe the screened interaction needs a flux that approaches its weak-interaction radius.
- The size of the particle (4) depends on the environmental flux density. A high flux density provides more possible interactions, so the particle bosons tend to collapse at a smaller radius.

3.6 *Exclusion, density, and degeneracy pressure*

Rules 3 and 6 create an exclusion principle, which we can interpret for fermions as they propagate to determine which their intrinsic waves are active (7).

Shell coupling interactions require active and distinguishable waves of different origin or phase.

Exclusion does not directly create a pressure or fuzzy boundary that determines particle size; that we attribute to quantized opportunities for coupling. That, combined with the inevitable propagation of shells, create a **degeneracy pressure**.

This means we can have fermion events that are much closer together than Planck length, but that situation is temporary; they radiate away with little opportunity to collapse at that size, because of the limited quanitization opportunities and their small area of interaction. It's a temporary process, much like an annihilation.

Sub-Planck dissipation, $> 1.6 \times 10^{28}$ eV.

Bosons can overlap to infinite density, provided they do not fulfil the condition for collapse as they intersect.

4. The size of a particle

4.1 *Mass-energy widens the collapse window*

Mass generation (rule 4) and the modulating effect of mass (rule 5), are intrinsic to the structure of every oscillator, and the mass propagates with every oscillator collapse.

Our structure for a fermion has the required elements for the doublets of the Higgs mechanism, except we provide an elliptical skew to encode mass-generation, which phase-modulates other shells on the overlap, to induce wave collapse. We avoid extrinsic bosons and couplings to generate mass.

From another perspective, the phase modulation of an external shell widens the phase window for collapse of a fermion shell (Rule 5).

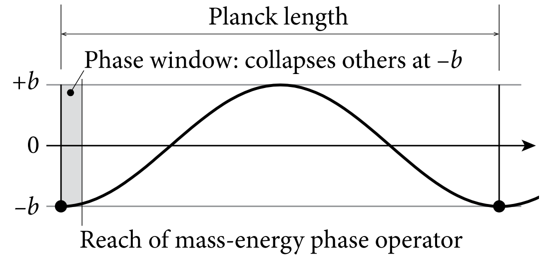

Figure 4. This boson has a mass-energy that imposes a phase modulation on any overlapping boson, possibly triggering its collapse.

This means that if both shells have no mass, then at the single point where overlap begins, both shells must have $\varphi = 0$ to collapse. However, if either shell has mass, then it imposes a modulation on the other, and widens the phase window, increasing the probability of collapse.

4.2 *Matter-vacuum polarization by mass*

In a vacuum flux, this gives the emergent macro effect of keeping large-mass fermions in the locality and polarizing lesser-mass fermions into vacuum because they are likely to propagate to large radius before collapse. It looks like a quantum version of Brownian motion.

This polarization informs our view about what is particle, and what is a field or wave. For us, there is no distinction because the same mechanism is at work for both, but we acknowledge how the emergent expression is observed.

4.3 *A general PDF for a wave on a shell*

It looks like we cannot use combs to derive a classical inverse-square law for gravitation or charge. It's in the realm of quantum solutions, rather than classical, with the additional bonuses of having no aymptote and not needing renormalization.

Without vacuum (2.4), an oscillator would propagate radially at light speed, and the probability of interaction with anything else does not diminish with radius.

However, we can find a probability distribution function if we make compromises, losing the deterministic interpretation and the phase dependence of comb solutions by converting the phase window into a probability of interaction within one Planck length. From the geometry of an expanding sphere intersecting with vacuum flux,

$$P_H(r) = p^r \left(1 - (1-p)^{\frac{dV(r)}{dr}}\right) \tag{3}$$

we obtain an expectation value for the shell's interaction radius [3, 4],

$$r = (\ln 2)/\rho \tag{4}$$

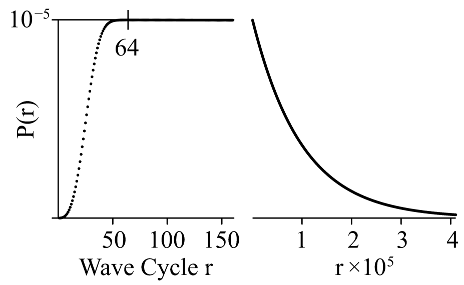

Figure 5. Plot of eq.3, $P_H(r)$ for $p = 10^{-5}$.

In doing so, we have also compromised by spreading the possible external interaction events over the life of the shell. Applying this to any situation rapidly becomes complicated, even for a single shell in a homogenous quantum vacuum flux, and more so for multiple branching possibilities over time. However, this curve:

- Suffices for classical scales where phase is not important, but it's not always clear when that is.
- Removes the ghost bosons required to explain deviations from singularities and asymptotes when theorists expect inverse-power curves.
- Has no asymptote, increasing with available surface area and, like Shannon entropy, diminishing with successive null-outcomes.
- Integrates to an area of 1.0 total probability for infinite time.

4.4 *Vacuum affects particle size*

In earlier work [2], we derived a fermion's apparent size by the mass-energy of its active shells and the energy of the vacuum as a flux of discrete shells or quanta, as an expectation value of the resulting probability distribution function. This leads to two lines of exploration:

- We think that this Planck quantization, along with two free parameters [4: 6.1] of mass-energy, calibrates the interaction scales for larger structures and their interactions, and could likewise generate values for Standard Model free parameters and generators.
- This vacuum flux density depends on local matter, and varies across cosmological distances, giving rise to another cause of redshift [3], and a source of dark matter in extra-galactic filaments [1].

The expectation value is one such measure of a boundary that approximates a surface of interaction for a conserved entity, and therefore a classical material object. There are other such boundaries, defined by probability distribution functions at various scales and contexts.

5. Matter and antimatter

An oscillator has two waves, separated by $0.25+\rho$ cycles.

- For **matter**, partner waves *lag* by ≈ 0.25 cycles.
- For **antimatter**, partner waves *lead* by ≈ 0.25 cycles.

Treating this as an oscillator, the collapse-triggering wave is the reference wave, with the partner wave as the order term. This determines the sign of both its phase modulation and angular momentum.

Because the waves having $\varphi = 0$ are excluded after the fermion event, its first oscillator may collapse with opposite-signed mass and modulation direction. This typically leads to a repeating sequence of alternating matter and antimatter (fig.1), noting that antimatter-matter-... sequences are an equally valid perspective.

$$\mathbf{A} \rightarrow \mathbf{BC} \rightarrow (\mathbf{D{=}A}) \tag{5}$$

Mass ρ (eq.2) modulates the phases of other overlapping waves (rule 5), allowing a oscillator with mass to collapse other oscillators having non-excluded waves with a phase between $-\rho$ and 0 at the point oscillators overlap. We call this a **phase window**.

Positive and negative mass therefore have access to different phase windows of vacuum energy or confined flux. After a weak interaction (7.1) on a shell, both waves of the remaining oscillator are non-excluded, so it carries both signs of phase modulation, for a phase window twice as wide as a single non-excluded wave. This availability enables vacuum flux to flow through fermion networks without the need for intermediate fermions of opposite sign.

5.1 *Matter-antimatter asymmetry*

- **Matter** interacts near 0 cycles, and relatively,
- **Antimatter** interacts near 0.25 cycles.

Their partner waves are near 0.25 cycles for matter, and near 0.75 cycles for antimatter (fig.2). This results in a different collapse radius for each wave of an oscillator, which affects all interactions.

This violates matter–antimatter symmetry [3], making vacuum polarization more probable at high energies, such as those theorized in big bang fermiogenesis.

This is most significant at the smallest distances ($\ell_P/4$) and highest energies, and the imbalance lessens at large distances as the probabilities even out with distance and interaction area.

6. Coherence and plasma

For oscillators of high mass, in a vacuum of low mass oscillators, we picture a conserved fermion having Brownian-like motion while it retains its full identity with confined component oscillators.

An electromagnetic interaction has decoherence with the interchange of oscillators, but we can 'watch' the oscillator with high mass and think of it as conserved because we observe its propagation, and not the conduction of the vacuum flux.

If we then consider a confined composite, say of quarks, their interaction radius will be small, compared that of oscillators from the environmental vacuum.

To make the particle decoherent or annihilate, we disrupt the repeating pattern of the particle with a shell that creates its own event before the pattern's own event.

Increasing the number of environmental oscillators, or the input of high-mass oscillators, increases the probability of decoherence of the composite structure. This applies to many structures, including the smallest of particles through to the largest of black holes [3].

Matter state: **Plasma**.

Plasma is the state where matter fails to re-constitute consistently, and fermions have no continued identity.

Where there is no recurring composite structure, and we can identify two masses of components, we regard the oscillators as a plasma. With the lighter components as a flux for the heavier components, the plasma has electromagnetic charged interactions.

7. Weak interaction

The weak interaction is the first collapse of a boson from the shell of a radiating fermion, making other waves available rather than excluded. Although this can happen at any radius for a fermion, from around $0.25\,\ell_P$ or larger, we're most familiar with it around $10^{18}\,\ell_P$, we think because that scale balances with the 'pressure' of vacuum flux.

It's important in high-energy physics because we see Higgs, W and Z bosons encoded in doublets in the interaction [4: 3.2], which maps well to standard treatments of the Standard Model. It's powerful in this mechanism because it's inherent to the journey of every fermion. For that reason, we'll reproduce earlier work [4] here in this section.

Fig.1 shows event **B** removing a boson from the shell from **A**, making all waves available on the boson that spans events **A** to **C**.

Shells are always **bosonic**, having an even number of non-excluded waves available for interaction at any given time [3: 3.6.1]:

- **Weak-broken** shells have two waves as one oscillator. Neither waves are excluded unless they share the same phase with another wave on the shell.
- Unbroken shells have one non-excluded wave from each of two oscillators on the shell. Oscillators may collapse independently, and when one does, any co-excluded waves in other oscillators are weak-broken and become available for interaction.

7.1 *Z, W, and Higgs/Goldstone bosons [4]*

Rather than considering the weak interaction as a distinct field, we identify it as the possible changes in the potential of the expanding shell. Component waves of Z and W bosons are spread over all oscillators in the shell, and the waves may collapse independently to change the potential (7.2).

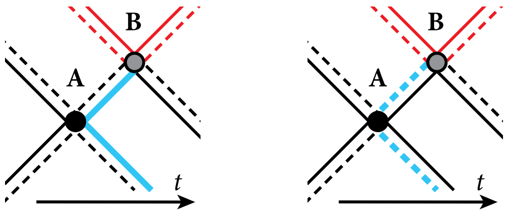

Figure 6. Left: W± boson, solid lines from **A**.
Right: Z boson, dashed lines from **A**.

- The **W± bosons** are the two *available* waves from fermion **A**, with non-identical phases, and mass that induces interactions with other oscillators.
- The **Z boson** is the *excluded* output of fermion **A**. By rule 3, "waves having the same phase and source are excluded from interactions", which screens the Z boson until fermion **B** at t_2, which is a vacuum interaction with a non-excluded wave from fermion **A**. After **B**, the remaining oscillator from **A** is available as a superposition of two entangled waves expressing conjugate masses, like a Majorana particle.
- A **Goldstone boson** is all waves output from a fermion. For example, for 1st generation fermions, two of the four waves are non-excluded at any given time, until both its oscillators are collapsed, resembling the doublet of the scalar Higgs field.

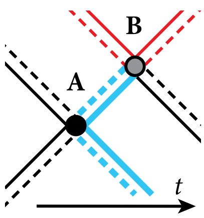

Figure 7. Goldstone boson: all lines from **A**.

7.2 *Composite collapse functions, SSB*

Modulation acts independently for each wave, so mass values are non-associative, and do not accumulate nor cancel. Positive and negative values do not cancel.

For homogenous weak-broken *vacuum* oscillators, we can assume positive and negative mass magnitudes are identical. The pre–weak-broken function is $[-\rho_1, -\rho_2][\rho_{vac}, -\rho_{vac}]$ and the post–weak-broken function is either $[\rho_2, -\rho_2][\rho_{vac}, -\rho_{vac}]$ or $[\rho_1, -\rho_1][\rho_{vac}, -\rho_{vac}]$.

Doublet techniques for degeneracy and spontaneous symmetry breaking are useful here.

Boson	Wave	Emitted	Weak-broken options	
			1	2
1	1	excluded	off-shell	ρ_1
	2	$-\rho_1$	off-shell	$-\rho_1$
2	1	excluded	ρ_2	off-shell
	2	$-\rho_2$	$-\rho_2$	off-shell

Table 1: On-shell mass ρ, to modulate other bosons.

8. Other Standard Model features and gravitation

In [4], we explained how other features are also encoded in our structure of the fermion and its mechanics: gravitation, electromagentism and charge, generations, and flavors. The strong force is an outlier, being a tiered residual effect from composite structures, and calibrated by the Planck-scale quantization, macro structure, and vacuum flux.

We'll not repeat that content here, except to note we represent gravitation as an attribution of flux origin, rather than a fundamental force. A large classical body collapses and re-radiates vacuum oscillators, which contributes to the local vacuum flux, which may then collapse fermions, some distance from the body, towards the source.

9. Conclusions

Our representation encodes phenomena of the standard model (and gravitation, not detailed here) in a single uniform mechanism. It is not a unified field, because a unified field summarizes the discrete interactions as statistics, losing vital information at high energies, abandoning deterministic computation, and admitting complications with the uncertainty principle.

Its quantization, due to limited opportunities for interaction, infers combed probability distributions at Planck scales, or grand unification energies, which defines a minimum sustainable size for conserved matter particles, demonstrates jittery noise behaviours like quantum foam, and helps us describe exotic phases of matter and related phenomena.

If our interpretation of gravitation [4] holds, then grand unification energy is the same as that of a unified field theory, admitting gravitation, and we can demonstrate expression of all of them within the **A** to **D** diagram of fig.1 when imposed onto different contexts.

9.1 *Phenomena at scale*

Phenomenon	Scale
Fermion event (2.2)	$0\,\ell_P$
Phase modulation (4.1), $\rho_A \approx 10^{-24}$ [2]	$\rho\,\ell_P$
Sub-Planck dissipation (3.6)	$<0.75\,\ell_P$
Near-Planck particle/array (3.3)	$0.25\,\ell_P$, $0.75\,\ell_P$
Matter-antimatter asymmetry* (5.1)	$[0.25, 0.75]+n\,\ell_P$
Quantized-density compact array (3.3)	$[0.25, 0.75]+n\,\ell_P$
Weak interaction (7)	$\geqslant\sim 0.25\,\ell_P$
Gravitation (8)	$\geqslant\sim 0.25\,\ell_P$
Infinitely propagating shell (2.4)	$\infty(0\,\mathrm{eV})$

Table 2: The minimum scale for phenomena, varying with mass-energy. *Most noticeable scale.

9.2 *Origins of forces and emergent effects*

Fermion event
Collapse of two waves from two shells, having uniqueness conditions (2.1).

Vacuum
Shells of fermions, not associated with matter (2.4).

Degeneracy pressure
Quantized opportunities for coupling, on the inevitable propagation of shells (3.6).

Gravitation
Vacuum flux attributed to classical objects (8).

Higgs mechanism
The four waves from a fermion, encoded as doublets (7).

Weak interaction
Change in shell potential at its first boson collapse (7).

Electromagnetism
Condution of flux through a particle [4].

Oscillator
A pair of waves offset by a quarter-cycle, with a mass-energy skew (2.1).

Shell
A set of oscillators sharing the geometry of an offset from a fermion event (2.3).

Boson
Fundamentally, an oscillator on a shell (2.1).

Vacuum fluctuations
A fermion event from vacuum shells [4].

Quantum foam
Planck-interval collapse opportunitites as a comb function, rather than a smooth function (3).

Mass-energy
Elliptical skew of an oscillator (2.1).

Strong force
Confined currents between a coherent system of fermion events at around $10^{19}\,\ell_P$, calibrated by parameter A [4].

10. References

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