MINIMAL DETERMINISTIC PHYSICALITY APPLIED TO COSMOLOGY

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This report summarizes ongoing research and development since our 2012 foundation paper, including the emergent effects of a deterministic mechanism for fermion interactions: (1) the coherence of black holes and particles using a quantum chaotic model; (2) wide-scale (anti)matter prevalence from exclusion and weak interaction during the fermion reconstitution process; and (3) red-shift due to variations of vacuum energy density. We provide a context for Standard Model fields, and show how gravitation can be accountably unified in the same mechanism, but not as a unified field.

Keywords: unified mechanism, physicality, deterministic, mass-energy, weak interaction, wave-particle duality, collapse, entanglement, spontaneous symmetry breaking, decay, gravitation, field, neutrino, fermion, boson, black hole, redshift, anti-matter asymmetry.

1. Introduction

Our deterministic mechanism has simple foundational rules for emergent physicality [7]:

1) Waves are bound in pairs as oscillators (**bosons**);
2) Waves propagate radially, and only at light speed, having equivalence of phase, distance, and time:

$$d\varphi = ds = dt$$

3) Waves having the same phase and source are excluded from interactions;
4) A boson's mass-energy is a function of its phases,

$$\rho = -b\, e^{-i(\varphi_{\mathbf{B}}-\varphi_{\mathbf{A}})}$$

5) Other sources' waves are phase-modulated by ρ;
6) Bosons collapse into a **fermion** where waves from two different bosons have value $-b$ at a unique point (fig.1, 3.2).

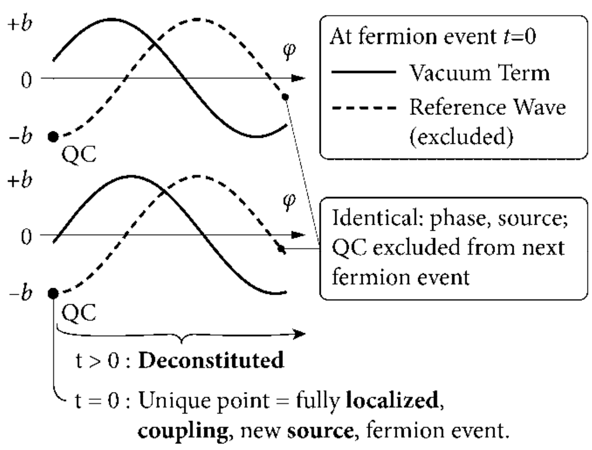

Figure 1. Phase evolution of a fermion's constituents.

We exploit $\pm b$ as a matter–vacuum duality, localizing waves in an interference process at unique spatial solutions of phase (2); and as a matter–anti-matter duality where structural evolution leads to a prevalence of one sign of matter over large regions, polarizing the other sign into vacuum energy (5).

2. Physicality

At a fermion, the four Dirac phases are present, though two are phase-shifted from being strict ± duals. Radiation resumes immediately from the new point source. Two of the waves emitted from the source have identical phase, so are **excluded** from interacting with other bosons because they are non-unique in all possible external variables (3.2, fig.4).

2.1. *Boson structure: mass, leading to wave collapse*

A boson's **mass-energy** is its elliptic deviation from a circular phase picture of $(\cos\varphi_{\mathbf{A}}, \cos\varphi_{\mathbf{B}})$; a scalar function of the phase difference between its two waves:

$$-b\rho = -b\cos(\varphi_{\mathbf{B}} - \varphi_{\mathbf{A}}) = -b\, e^{-i(\varphi_{\mathbf{B}}-\varphi_{\mathbf{A}})} \quad (1)$$

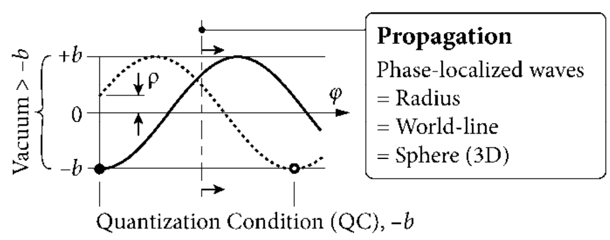

Figure 2. Boson structure.

While propagating, mass-energy is a **phase operator** on the waves of other overlapping bosons:

$$\varphi_{\text{modulated}} = \varphi_{\text{carrier}} + \textstyle\sum_n \rho_n \quad (2)$$

Or, in right-to-left operator notation:

$$\mathbf{W} = \rho\,\mathbf{Z} \tag{3}$$

In other words, where a boson overlaps another, its mass-energy widens the phase window for both its own collapse, and that of overlapping bosons, even those of zero mass, creating gravitational force as expected (3.7).

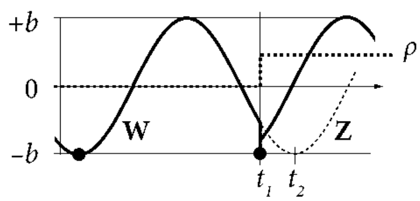

Figure 3. ρ phase-modulates $\mathbf{Z}$ to solutions of $\mathbf{W} = -b$, *advancing* or *retarding* the prospective quantization of fermions by a fraction of Planck length.

This can be integrated to a probability function for decay, propagation, collapse or decoherence (3.12).

3. Emergent Effects

3.1. *Particles*

1) Fundamental **bosons**: scalar radiation (2.1).
2) Fundamental **fermions**: points of locality (2, 3.2).

Particles are fermions or a confined system of fermions and bosons that consistently maintain their constitution (fig.4). Such particles (e.g. quarks, electrons, hadrons), have convenient ontological names while they maintain their constitution.

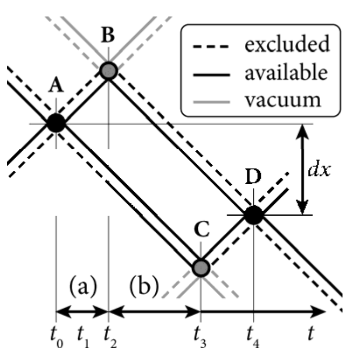

Figure 4. Fermion reconstitution with vacuum: Identical waves from fermion event **A** are excluded from triggering the next quantization condition until t_2. (a) weak-excluded until **B**; (b) weak-broken until **C**.

We should be careful to avoid correcting our imperfect abstract fields using fictitious force carrier 'particles'; such entities will be prone to nonconservation (3.7).

3.2. *Emergent localization of mass* [7]

Mass can be loosely localized by this mechanism (2.1). $P_H(r)$ (eq.4) gives us the history-dependent probability of collapse for a single wave for radius r, per wave cycle, incorporating the failure of previous events, and the remaining null-interaction term to infinity:

$$P_H(r) = p^r \left(1 - (1-p)^{\frac{dV(r)}{dr}}\right) \tag{4}$$

where p is the proportion of the phase cycle available for interaction due to mass-energy ρ (eq.1), and

$$P_H(\infty) \to 0\,; \quad \int_0^\infty P_H(r)\,dr = 1 \tag{5}$$

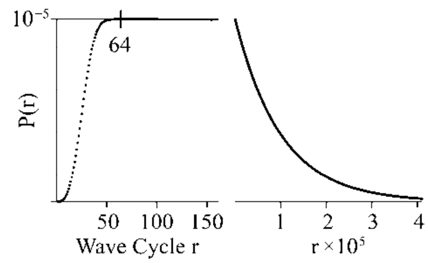

Figure 5. Probability distribution for single iteration of collapse, with radius r: plot of $P_H(r)$ for $p = 10^{-5}$, eq.4.

p may be varied over iterations or limits, to incorporate the introduction of waves throughout the life of the wave of interest. Large masses tend to collapse at smaller radius than smaller masses (eqs.1–4, Table 3), localizing the mass-energy of matter near its emission source, with lighter bosons more likely to be radiated away, becoming environmental **vacuum** energy.

Why are fermions collapsed, localized states?

To understand wave collapse and localization, we look at which terms are unique as a system evolves.

In Table 1, we have bosons **A** and **B** from different sources, each having waves **1** and **2**, with 'wave **1**' being the **reference** wave at collapse. For the 'fermion' column, the interacting waves [**A1**, **B1**] at $-b$ are identified only by their unique *spatial* solution. This can be considered dual to the boson state; bosons are distinguished by unique *source and phase* (but not space), are not coupled with other bosons, and have no unique spatial solution. At a fermion point, two waves of identical phase meet (2), but this does not violate the exclusion principle because they originated from different sources. Thus, *similar* fermions may exist as matter, only when their spatial identity is unique.

Table 1: Uniqueness of wave phase φ and space x, for components of a fermion event.

	pre-	fermion	post-
$(\varphi_{A1} = \varphi_{B1})$?	n/a	Unique	Unique
$(\varphi_{A2} = \varphi_{B2})$?	n/a	Non-unique	Non-unique
$(x_{A1} = x_{B1})$?	No	as point	n-sphere*
$(x_{A2} = x_{B2})$?	No	as point	n-sphere*

3.3. *Weak interaction*

The symmetry of the excluded waves (2) is broken with the collapse of one of the two bosons radiating from a fermion event: **disentangling** the collapsed boson, and enabling the other excluded wave sharing the shell (fig.4: **AC**). We map this to **spontaneous symmetry breaking** and the **weak interaction**; 'spontaneous' being attributed to vacuum energy as bosons. While this is no different from every other fundamental interaction, its *context* provides an emergent and measurable effect. How the particle behaves in its environment, depends on the first interaction being collapsed in a confined manner (internally), or a radiated manner (externally). A weak field is then a statistic of the difference between these wavefunctions (3.1, 3.12). This is difficult to distinguish as a conventional observation, because the interaction is inherent to *all* fermions (being the first event, of three total, required to reconstitute a fermion) but it is not always available to be measured externally.

3.4. *Sign of angular momentum*

Given any reference wave (fig.1), a boson's other wave is the **vacuum** wave (order term). As an oscillator (fig.2), they define its intrinsic angular momentum, with sign dependent on whether the reference wave *leads* or *trails* the vacuum wave.

3.5. *Decoherence*

The environmental vacuum flux provides the only reflection points (fig.4: **B,C**), external to the confined particle, that prevent bosons escaping to infinite distance. If that process fails, the particle changes its constitution, gaining matter, or becoming decoherent. Decoherence may be caused by: a lack of supporting environmental bosons, the introduction of disruptive bosons, or a composite's bosons slipping out of critical phase. In high-energy environments, this flux can be disruptive rather than supportive of constitution. Our approach is powerful in examining such speculative high-energy or early-universe conditions. Indeed, it is possible to treat black holes and particles similarly, and to examine decoherence in context of environmental variables (4).

3.6. *Particle genesis and unification energies*

If the flux density of vacuum energy increases from our background levels, to that of the particle itself, then the particle is likely to become decoherent as it approaches thermal equilibrium with its environment: it will decay into the flux of the vacuum to become part of its plasma [9]. Given that the external bosons are intercepting the particles' own interactions, we predict that such environments reduce the interaction size of the particles, with pressure-like effect [9], with consequences for emission and absorption of radiation (red-shift) [10].

If we apply this to QED and QCD scales, and increase the environmental vacuum energy (or provide enough incoming matter), then given time, the probability equalizes, between the particle continuing to preserve its constitution, or instead interacting with other bosons. This gives us a context for unifying particles on the common basis that we have described (2). If we know a particle's make-up, we can approximately identify the energy spectrum for its decay into 'soup', or condensation of plasma into conserved particles. Each system (with vacuum) has its own phase diagram, including weak interaction radii.

Traceable constituents

Our **constitution-invariant** approach offers some explanations where accepted hypotheses allow particles to be changed randomly by fields: we maintain instances of *bosons*, which themselves determine the type of particles that are maintained or the radiation that is emitted. We remove the 'dice-rolling'.

In doing so, we have not abandoned quantum field theory, which is a necessary compromise to enable relevant statistical computation of complicated systems. What we have here is a tool that may deliver quantum mechanics, and describe what its fields and interactions are, rather than assuming them to be purely abstract algebraic constructs and concepts.

3.7. *Wave collapse by gravitational sources*

Vacuum energy will interact with a large body (fig.6: **C**), and radiate from it as bosons, again as vacuum energy. The more mass-energy body **C** has, the more vacuum energy it will collapse and re-emit.

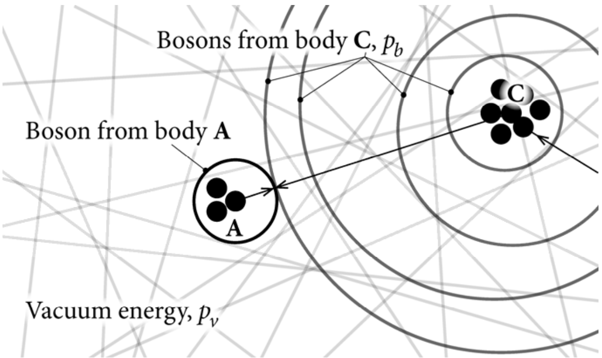

Figure 6. Gravitation: a boson from body **A** is collapsed by radiation from large body **C**, rather than by vacuum energy (shown here as planar waves, approximate to distant spheres).

As body **C**'s bosons radiate, some of them will collapse. With increasing radius, their area for interaction increases, giving a higher probability of collapse from vacuum energy, as per eq.4. Some of the bosons available to test particle **A** will be environmental vacuum energy, and some will have been emitted by body **C**. Where bosons from particle **C** are preferred, this results in a gravitational deflection (or 'force'). The resulting approximation of gravitational deflection [7] is comparable to classical formulations:

$$\nabla(r,b,v) \;= \nabla_b \frac{4\pi \; p_v p_b}{r^2} \qquad (6)$$

The mean deflection ∇, independent of the mass of the test particle, is the probability that the test particle (fig.6: **A**) will interact with the body's flux p_b, rather than with the environmental vacuum flux p_v, scaled by the mean expected vector ∇_b between particle events where the particle interacts with the body's bosons. Stable particles may become decoherent (3.5) in extreme gravitational flux, e.g. near a black hole (4).

The first opportunity for gravitational interaction is a point approximately between the bodies (see arrows meeting, fig.**6**), in contrast to the uniformly-distributed directionality of vacuum interactions, unless there are some large nearby structures that generate flux. The direction resulting from its own bosons collapsing will depend on its structure, including any structural changes that aggregate to its classical momentum.

Unification of the gravitational field?

We have reservations about whether a unified field theory can include gravity, instead suggesting that, although we get gravitation 'gratis' with our mechanism, it might not be helpful to search for a unified field in the conventional manner. Such a gravitational field would be a fictitious, prone to accountability problems.

The answer might instead lie in our approach, of finding a fundamental mechanism, with uniformly-defined entities, the simplest one-basis algebraic abstraction, and very simple rules (1). The standard interactions and fields are then statistical derivations of the fundamental interaction, with the added benefit of knowing what information is discarded when building such approximations. In fig.7, all bosons overlapping the test particle have the same structure. Fermions 1 and 2 are assumed to be an example sequence of fermion events within the test particle: respectively a virtual vacuum interaction, and (e.g.) a quark. For **charged** particles, the vacuum provides a flux current that passes through the particle, where bosons in the structure are substituted for like vacuum bosons, before being radiated later by the particle structure.

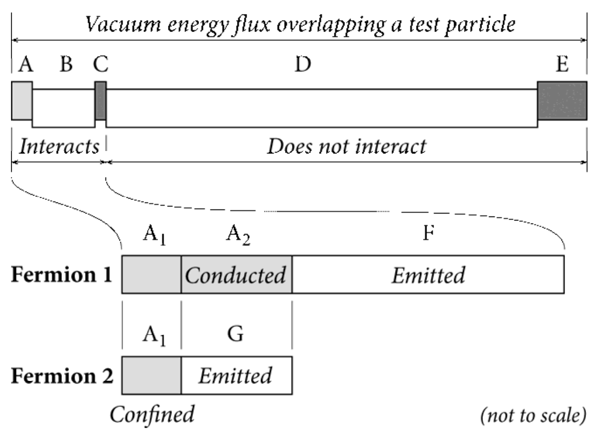

Figure 7. Attribution of unified wave sources. **C**, **E**: gravitational flux of nearby massive bodies; **A**: confined bosons; **B** and **D**: anonymous vacuum bosons.

3.8. *Neutrinos as vacuum energy*

We propose that the low mass-energy constituent bosons of neutrinos [7] are presently in a state of plasma or soup, requiring a significantly lower vacuum energy flux before the majority of neutrinos can become conserved particles in their own right.

Identity of neutrinos

Presently, neutrinos will not maintain their identity: due to their low mass-energy, they extend non-collapsed for great distances, and vast numbers of bosons will overlap and interact with bosons of higher mass-energy (3.2). This makes neutrino oscillations difficult to measure, because we are unable to guarantee that a neutrino has the same identity of bosons at successive detectors. We must instead detect and count the flavor of many instances and statistically infer flavor changes due to intermediate conditions.

Vacuum energy, dark matter, and anti-neutrinos

Neutrino constituents are a good candidate for the vacuum energy that allows fermions to reconstitute. Its plasma creates temporary fermions from vacuum energy [5], with the properties required for dark matter.

Rather than taking a field-based approach, with continuous matter propagation where events seem spontaneous, we instead specify a deterministic process for (anti-images of) fermions to interact with identifiable instances of vacuum energy. This gives us additional detail when exploring vacuum interactions. In the Standard Model, the weak interaction seems only to interact with left-handed matter, because the collapsed boson always has a particular sign for angular momentum at the point of weak interaction, so by definition, it is 'left-handed'. Doing the same for anti-matter using our mechanism, we find the weak interaction is right-handed for anti-matter. This can be seen in the diagram for fermion decay (5.2: fig.11).

3.9. *Constitution of Standard Model entities**

It is controversial enough to suggest that fermions can have sub-structure. The following hypothetical list is *highly* rudimentary and speculative, based on high-energy decay modes, and the requirements for mass-energy when creating fermions from vacuum.

Fermions

Using two boson energies, A (high mass-energy) and B (low mass energy), we compose three types of fermion: Quark (A, A); Lepton (A, B); Neutrino (B, B).

Bosons

W and Z bosons are intrinsic to the re-constitution circuit of each fermion. Given our statistical derivation of gravity (3.7), we do not need the spin-2 graviton.

Photons

We model photons as paired boson impulses, absorbed by structures like their emitters, having a frequency that may be derived from a sparse sampling of impulses (6) [7: 6.2.1.2]; compatible with creation and annihilation operators of quantum harmonic oscillators.

3.10. *Generations as n-dimensional solutions*

In previous work [7], we suggested that unique phase solutions for a fermion (3.6) may have lower spatial dimensionality than 3. This positions fermions, and by extension, a boson **B** (Table 2).

Given that the third generation requires a unique 1-dimensional solution, and only allows this when no other bosons are overlapping, their effective radius is very small. Should vacuum bosons increase the overlapping boson count for the propagating boson shell, it would introduce more constraints for the unique solution required for the next fermion event, so the bosons will radiate further.

Table 2: Dimensionality of unique fermion solutions.

Generation/Flavor	**1**	**2**	**3**	**B**
Uniqueness in dimensions	3	2	1	0
Total overlapping bosons	4	3	2	1
Lepton $(\mathrm{B}, \mathrm{A}), (\mathrm{A}, \mathrm{B})$	e	μ	τ	–
Neutrino (B, B)	ν_e	ν_μ	ν_τ	–
Quark (A, A)	d/u	c/s	b/t	–

This introduction of overlapping bosons gives opportunities for the constitutional input required to create the extra fermions of standard weak decay modes (5.2: fig.11). The high mass values of (for example, the third generation of) quarks equate to the energy required to constitute a plasma of similar fermions. In such plasmas, the quarks formed would quickly degrade from t/b, to c/s or u/d quarks, because a dense vacuum flux would cause bosons to overlap more readily, increasing the dimensionality of the unique solution, and decaying the quark when a unique solution is found.

An artificial scenario where third-generation quarks could persist is difficult to create and maintain: where a plasma of sufficient energy exists, it decreases the probability for one-dimensional solutions because of its high flux density, so its structure must be regular.

The number of overlapping bosons required to create a fermion determines the capability for a fermion to be directional, with generation-1 fermions (u/d quarks, electron-like leptons) being the most directional, due to the availability of more terms for interference.

3.11. *Computing solutions: geometry of limits*

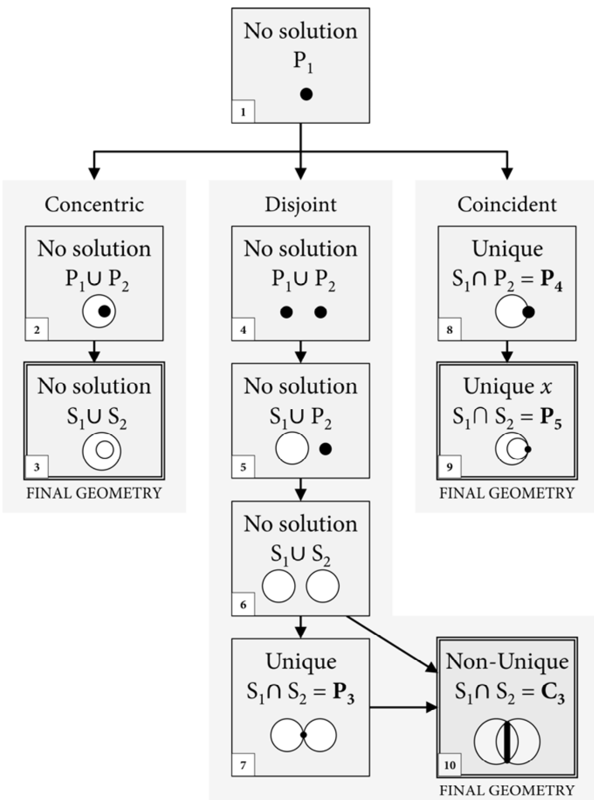

Figure 8. Evolution of wave geometry, in Euclidean space. P_3, P_4, P_5 are deterministic fermion events. "Final Geometry" is for two sources to infinity; adding a further source presents more constraints and opportunities for unique solutions.

We may quantitatively solve the unique solutions in Euclidean space, by identifying the limits where each solver equation would apply. Solutions occur only within a wave cycle of the introduction of a new intersection within the system. Fig.8 shows this evolution. The trivial case, of there being no vacuum energy, is the interactions between the known bosons/waves, which can be achieved entirely deterministically by testing whether the newly-overlapping waves (at the point directly between the sources) would be in the condition required for collapse.

Given that the active phase window of a wave is a tiny proportion of the available phase cycle, then with random phase, most waves will progress from stage 6 to stage 10, to be radiated until a vacuum wave eventually meets it at the phase required to collapse it. Self-correcting phase-coherent structures may allow more instances of state 7 than would be indicated solely by mass-energy values. Stages 8, and stage 9 (which, unlike the other states, repeats every cycle) would occur most frequently in confining structures, as in QCD.

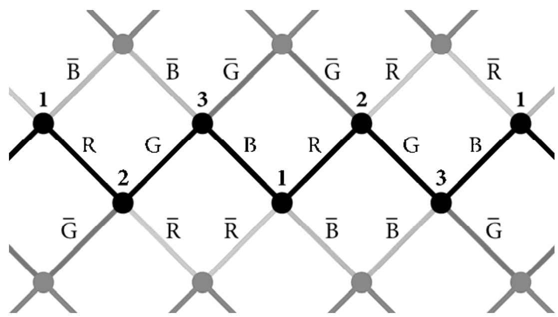

Figure 9. Quarks {1, 2, 3} in singlet, with confined RGB bosons, and anti-RGB interacting with vacuum (at grey fermion points). Time: rightwards, compacted space: upwards.

Interactions with environmental vacuum energy makes the chaotic approach non-trivial. If we concede to using statistics rather than instances of vacuum energy, we lose the deterministic view, and must instead branch each possible outcome as part of the total sum of probable events.

3.12. *Free fermion in vacuum*

We can quantify a free fermion simply by specifying $\{p_1, p_2\}$ as the mass-energies of its two bosons. To obtain a probability distribution, for the collapse of each wave, we also need a statistic of the vacuum. Assuming this be a scalar mass-energy, we can use eq.4 and map this spherically into the sample volume, for each boson.

The fermion's first reconstitution is the second collapse of the heavier fermion, combined with either the returning lighter boson, or a substituted boson from vacuum. The result is slightly skewed from the standard

$$\text{probability} = \text{amplitude}^2$$

to instead be factors:

$$\text{probability} = a_1\, a_2$$

with the a terms representing the amplitudes of the two bosons on their respective paths, including decoherence and substitution probabilities. One might want to privilege boson 1, to track the heavier boson, where it is assumed that the lighter boson could be exchanged for vacuum bosons without a macroscopic observer necessarily noticing. Using a_2 as reference is equally valid, as the formulation includes the probabilities of either or both bosons failing to collapse; the latter can be considered to be 'decoherence of the fermion'.

Obtaining a PDF for given *time* limits is less trivial, because when a collapse occurs, we must 'branch' reality in a many-worlds sense, and re-integrate results.

4. Black Hole Cosmology [9]

Recent work by S.W. Hawking [8] has led us to review our work [5, 7]. Both we and Hawking have stated requirements and principles for approaching the poorly-understood physics of black holes. Here we compare the works, and apply our previous principles to find conclusions. We propose that there is no absolute event horizon: bosons of different mass-energy value present respective effective probabilistic escape boundaries in a process of distillation that occurs in an evaporation process, driven by the flux of vacuum energy. Our foundational mechanism behaves no differently in low-energy environments than in a black hole environment, and we extract emergent effects without the effective limits of mainstream representations and their transition problems (general relativity, AdS / string / brane, QFT).

We offer our deterministic mechanism to fulfill the requirements and conclusions outlined by Hawking, using simple classical principles to produce quantum effects, in a manner that is constitution invariant, and preserves unitarity and information. We begin by comparing respective principles:

Approximations and statistical methods can fail

Both authors highlight the pitfalls of approximations that discard information and lead to misunderstandings,

H: "*…approximation of this chaotic metric by a smooth Kerr metric is responsible for the information loss in gravitational collapse.*" [8]

V: "*We lose fidelity from the physical mechanism by approximating the actual bosons as a power spectrum of vacuum energy. … We lose even more fidelity by assuming the power spectrum as a scalar flux term. … We also lose the phase coherence of any radiation, and the quantum detail for individual wave collapses.*" [7: 2.3, 3.1.1]

V: "*Conventional background vacuum energy density and its related statistics assume a uniform [continuous] or non-local field value*" [7: 1.1.3]

Boundaries: deterministic mechanisms are required

V: "*…it does not conform to a continuous function with radius, and conventional rigidity of Schwarzschild solutions is probabilistically avoided. …The unitary phase operation implies that no quantum field value may exceed unity, and the scenario of a fermion outwardly crossing the event horizon is possible.*" [5]

H: "*However inside the event horizon, the metric and matter fields will be classically **chaotic**. … The **chaotic** collapsed object will radiate **deterministically** but **chaotically**. … That is unitary, but **chaotic**, so there is effective information loss.*" [8]

V: "*Confinement, entanglement, vacuum statistics, forces, and wavefunction terms emerge from the model's **deterministic** foundations.*" [7: abstract]

V: "*We can assume that, in a massive body, a proportion of radiated bosons will interact with other quanta of radiation from the same body, … in a **chaotic** system.*" [7: 3.1.2]

V: "*When two waves … are available …, the solutions … are superimposed: **interleaved** and **ordered**.*" [7]

V: "*The history-dependent radial form of probability distribution **incorporating the failure of previous events**, and the remaining null term available to infinity tends to zero for infinite r*" [7: 2.2]

There is no 'event horizon'

H: "*…gravitational collapse produces apparent horizons but no event horizons behind which information is lost.*" [8: abstract]

V: "*The Schwarzschild radius is not privileged, but … achieved by quantum means; our event horizon is a fuzzy probabilistic boundary.*" [7: 5.1]

Information loss

We identify with the previous Hawking quote offering a context for matter (2) where no information units are lost when traversing a black hole,

V: "*We may resolve the information paradox … the 'event horizon' is not a strict barrier, but a probabilistic one, … all bosons may eventually traverse the event horizon, in a **different 'encoding'** than the matter that entered the body.*" [5: 5.7]

V: "*This model does not suffer 'information paradox' problems, because our matter is **encoded as separate bosons**, and even within the dense body of a black hole, these bosons interact as normal. However, the encoding of fermions entering a black hole is likely to be significantly **scrambled** by the interactions within.*" [7]

V: "*Convention assumes an unchanging constitution of a fermion, and that some vacuum properties are constant, whereas our model … operates on the fundamental information units: the waves of bosons, allowing fermions and the interacting elements of their environment to accountably change their constitution.*" [7: 1.1.3]

Representations need interfacing

There is an interface problem between the effective limits of established theories,

V: "*…having limited scope as effective methods that degrade at smaller scales and higher energies.*" [7]

V: "*…the constitution-invariance of the process, free of renormalization, singularity problems, and effective energy limits, is worthy of further study.*" [7]

H: "*ADS-CFT correspondence indicates that the evaporating black hole is **dual** to a unitary conformal field theory on the boundary of ADS.*" [8]

H: "*…the correlation functions from the Schwarzschild anti deSitter metric decay exponentially with real time. … the topologically trivial periodically identified anti deSitter metric is the metric that interpolates between collapse to a black hole and evaporation.*" [8]

4.1. *There are no event horizons*

In even the most extreme scenarios, a boson can collapse further away from the black hole than its own source event, allowing matter or radiation to escape over cosmological timescales (4.5). This agrees with Hawking's assertion that "*gravitational collapse produces apparent horizons, but no event horizons behind which information is lost*" [8], but contrasts with the general relativistic view that the gravitational field overcomes all outward radiation (4.3).

4.2. *The re-encoding of matter*

Fermions need external bosons to reconstitute (fig.4), but vacuum bosons of similar mass-energy can substitute themselves into the fermion structure (3.5, fig.11), 'conducting' vacuum energy, and preserving the ontology of the fermion while changing its identity. Generally though, the probability, that a stable fermion re-encodes with the same constitution, decreases as vacuum energy flux density increases.

4.3. *Unitarity and mass-dependent wave collapse*

Unitarity is preserved, because interactions continue inside the conventional Schwarzschild radius, albeit intensively and chaotically, in a manner that is difficult to calculate meaningfully for a significant duration. The deterministic calculation process is complete, and *without singularities*. With sufficient attention to detail, this applies [7: 2.1] to any system or extent, for any desired outcome to occur, with probability 0.0–1.0 (eqs.4,5). To calculate a boson's probability of collapse using our mechanism, we need to know:

(a) The phase interval for which its waves are receptive to collapse, derived from mass-energy, in turn derived from the phase interval between a boson's waves: the elliptical skew of the oscillator (2);
(b) Its propagation rate, which is universally c.
(c) Its propagation metric, which is radial, but can be applied to flat space for vacuum interactions.
(d) The vacuum energy flux, e.g. count and mass-energy values for quanta, see (a), or (less exactly) the mass-energy power spectrum of the vacuum, or (less exactly again) a scalar term.
(e) Which of the bosons' waves are not excluded (2). Where two or more waves are active on a shell, the function is a set of ordered and interleaved trials.

Taking fig.5 as a trivial example [7: 2.1.1], of one non-excluded wave propagating through vacuum, having evenly distributed quanta at identical mass-energy values (as ideally close to isotropic as discrete vacuum energy can be), we find that each wave cycle would have a probability of collapse proportional to the width of the interaction window (eq.3, Table 3), and to the flux traversed by the sweep of the growing surface area.

Limits exceeding 1.0

Another aspect of the function is the number of overlapping vacuum bosons, which converges the probability of collapse to 1.0 as the count approaches infinity. This differs from general relativity, which presents no limit to the gravitational field when the flux density approaches infinity, exceeding '1.0' in terms of fundamental effects, generating singularities, and therefore excluding all probability of emission.

4.4. *Gravitational fields generated by black holes*

Given that we define gravitation as a statistical tendency for fermions to deviate towards sources of vacuum energy flux, i.e. massive objects, (3.7) [7: 3.1], and that gravitation is wholly propagated by our mechanism (and not non-locally), it follows that any gravitational effect imposed by the black hole must be transmitted by escaped bosons. We should therefore ask: in the local context of our mechanism, if very little radiation escapes a black hole, then how does a nearby object feel its gravity?

Confined mass-energy and gravitational field

We envisage sufficiently large black holes where the probability is close to zero for any given boson to escape from far below the conventional event horizon within reasonable time limits. In other words, the boson is confined, traversing fermion events within the body of the black hole. These may eventually evaporate, but while bosons are confined like this, the overall flux contributing to the gravitational field outside the horizon will be lower than expected for the total (hidden) mass within. Objects around a black hole will not feel gravitational interactions from the mass-energy *confined* inside a black hole.

This picture implies that there are three tiers of boson *behavior*, in terms of effect and observation, which can be loosely mapped radially. We write about this in terms of fermionic matter at the interaction points, corresponding to sources of bosons. Starting with the outermost:

(a) The light-emitting matter we can see;
(b) Gravitationally-interacting dark matter at the periphery of black holes, which escapes directly, or interacts with vacuum quanta which in turn interacts with external bodies; and
(c) The matter of confined mass-energy within black holes that does not directly contribute to the vacuum energy currents outside the body.

Given time, matter evaporates to outer tiers, releasing stored mass-energy to the surrounding space, with correspondingly characteristic spectra.

Black holes as an energy store

A body's contribution to the gravitational field is derived entirely from its interaction with environmental vacuum energy, the background level (fig.10), except:

(1) when it is evaporating (gravitational flux is higher);
(2) when some of its mass is confined (flux is lower than expected for the mass of the body);
(3) when it is absorbing material (flux is lower).

In this respect, a black hole can be viewed as a store of mass-energy, and also of the flux outside the 'surface' that contributes to gravitation (3.7), and the dark matter that allows orbits to remain stable at lower velocity.

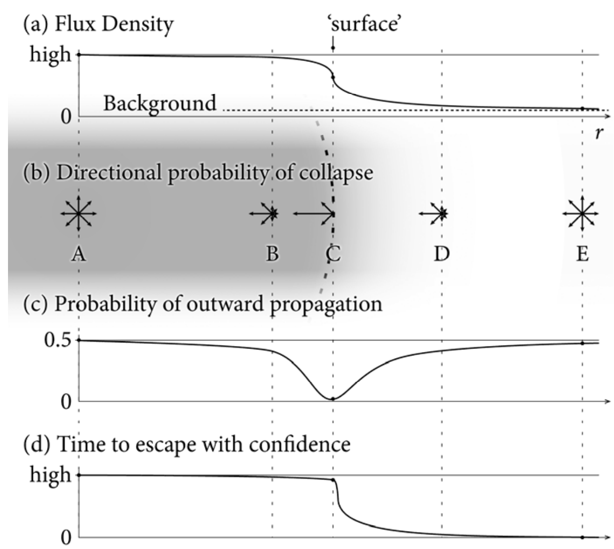

Figure 10. Deterministic black hole evaporation: simplified with all bosons having identical mass-energy value.

Prediction: radial occlusion effect; EPR variants

A large body, at radius r from a radiating source, should collapse some of the waves that would otherwise have radiated beyond the system. This occlusion effect should be a squared order smaller than direct phase modulation interaction and should be testable [7].

4.5. *No horizons: equilibrium, and evaporation*

As with the thermodynamic approach, we propose that **equilibrium** is a state of uniform flux density. Any other distribution, where environmental bosons exist, will eventually correct itself towards equilibrium with the vacuum. The vacuum erodes any hard 'event horizon' boundary towards an equilibrium state, via a fuzzy quantum boundary. Black holes are a temporary concentration, rather than a final confined singularity state; for there to be an absolute event horizon, there must be no vacuum energy flux outside it [9].

The process of filamentation and accretion will continue until no further matter is available from the environment, and the system is at thermal equilibrium with the environment, followed by the process of evaporation, to approach the background equilibrium state ("heat death").

Final evaporation

If no heavy bosons could escape for a long time, they can still interact with the vacuum quanta, which may themselves escape and interact with the surroundings, softening the flux gradient, and weakening it further. The process for final evaporation requires a gentle slope of flux density, so that bosons can more easily collapse outward. This can be provided by the absorption of lighter bosons, or environmental vacuum quanta.

5. Matter/Anti-matter: Cascading Prevalence of Dirac Images of the Fermion

In standard literature, we accept that in creating a charged particle of the Standard Model from vacuum, we also create its corresponding anti-particle in the same event. Likewise for annihilating a particle: both it and its anti-particle are converted to radiation.

We apply our deterministic physicality mechanism to find an inherent polarizing effect from exclusion in the wavefunction, leading to a prevalence of one sign of Dirac image (matter or anti-matter) as the matter state for the observable universe. This is limited to the radius of the weak interaction (fig.**4**). We offer perspectives for current cosmological hypotheses of particle genesis.

In this work, we show how exclusion applies to the waves leaving a fermion event, creating an imbalance in the probability of interaction for each of the Dirac images.

5.1. *Vacuum polarization*

Given any two matter-state waves, which are excluded from the first interaction of a fermion (fig.4), one of their anti-images will partake in the first collapse event, coupling with waves external to the fermion. For a conserved fermion, this also needs to happen to the remaining wave, making two de-localized collapsing anti-images (usually interacting with vacuum, or they may be confined in a composite structure). This process repeats, such that on their next interaction, we return to the original states interacting with the original constitution (anti-anti-states: the original fermion).

Integrated over any interval, collapse flavors the non-excluded waves, increasing the probability of removing the alternatives from future solutions. This leads to one sign of Dirac state as the matter state, especially in high-energy scenarios where matter nucleates from plasma. In our locality, we have **matter** (as conserved localized fermions) and **anti-matter** (nonconserved states, as de-localized anti-images).

The sign (matter or anti-matter state) of the bosons at the massive particles determines the polarity of matter and vacuum in that locality, leaving the lower-mass bosons to propagate further out. Because all waves of the remaining bosons on the shell are enabled after the first interaction, they carry an uncollapsed superposition of both signs, as radiation.

With their extended propagation from the source, the lighter bosons are also more likely to be exchanged (interchanged or substituted), losing coherence as they extend from the locality of their fermion sources. With untraceability or a complete loss of coherence and source identity, we may then regard the radiation as vacuum energy.

Applying this to the mechanism for fermion reconstitution (fig.4), if a boson has sign + at event **A**, then exclusion requires that the same boson's vacuum wave will be the reference wave at event **B** (the first interaction of the entangled shell of all bosons leaving event **A**), reversing the apparent angular momentum of the boson as seen from the new reference, to sign −. If the weak symmetry remains unbroken on path **BD**, then at event **D**, the boson is guaranteed to have the same sign as at event **A**.

This implies that the exclusion of identical wave phases causes polarization of matter and vacuum, because it allows the conservation of the above process to be more probable than any other outcomes.

Where external bosons (vacuum energy) interrupt the reconstitution process, they may create anti-matter, or create a condition where the bosons fail to re-collapse in the locality, defaulting to radiation (annihilation).

Polarization within the weak interaction range

Beyond the radius of the weak interaction (3.3), bosons having larger masses will likely have already collapsed. This tells us that distant radiation quanta tend to possess little mass-energy. Beyond the radius of a weak interaction, a surviving bosons' waves are both free to couple, so is equally likely to couple using either sign relative to the reference wave of its source, and thus not influence the matter/anti-matter balance. Given an unpolarized plasma, at higher energy than its weak interaction, it may slowly polarize as it condenses into independent fermions.

5.2. *Creating fermions from decay*

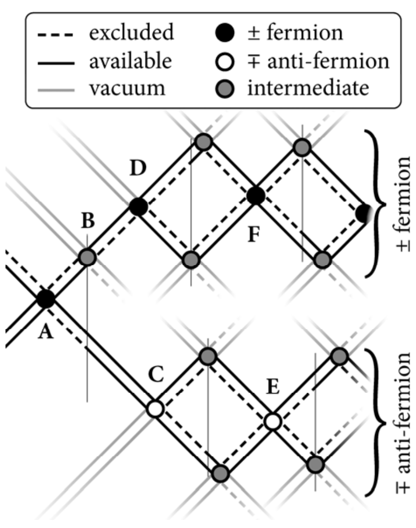

Figure 11. Decay: Fermion (**D**, **F**, …) and anti-fermion (**C**, **E**, …) are created from fermion **A** as it fails to reconstitute. Fermion **B** is not necessary, but illustrates disturbance of the reconstitution sequence for an otherwise conserved fermion. Axes: time →; compacted space ↕.

Four waves, as two bosons, radiate from a fermion event (2, fig.11), and the original fermion **A** loses coherence and fails to reconstitute.

For two new fermions **C** and **D** to emerge from the bosons emitted from **A**, a further two vacuum bosons are introduced to create **C** and **D**, and the presence of vacuum bosons is required to maintain those fermion constitutions. So rather than saying that these new particles are created from nothing, we should say that they are created from vacuum.

We may use a similar process to describe flux tubes, where the resulting new fermions confine waves between each others' anti-image events.

5.3. *Creating fermions from vacuum energy*

The previous example began with fermion **A**, but there is no reason to assume that this fermion was an unstable or conserved particle; it may be a meeting of vacuum bosons. This is how particles may be created from 'nothing' (vacuum energy).

5.4. *Cosmological interpretation: matter/anti-matter*

Although we are not ready to speculate whether the universe originated in a 'big bang', we may apply our hypothesis to this scenario. For matter and vacuum to have polarized, such that we cannot now observe any volumes of space where anti-matter dominates, the regions of prevalence must be very large, and thus have occurred at a very early stage in the story of the cosmos, before the radius of the weak interaction became a significant obstacle to cascading the polarization. This is reinforced by our assertion that the polarizing bias, created by exclusion, is ineffective beyond the radius of the weak interaction.

We speculate that there may be regions of the universe where *anti*-matter dominates, and we feel this mechanism is worthy of further study to develop it into a unifying hypothesis and a picture for cosmology.

6. Relative Redshift from the Scale of Matter in Discrete Vacuum Energy Flux

We apply our physicality mechanism [7] to QED and the emission of photons, proposing that a system's processes are accelerated and shrunk by an increase in the environmental vacuum energy flux; that varying conditions at emission and absorption are responsible for observed frequency shifting (redshift and blueshift), supplementing the Doppler shift. We offer a new cause of redshift, along with some hypotheses for the evolution of the early and late universe, suggesting flat space and removing the need for the cosmological constant.

Current hypotheses, for the observed redshift of distant objects, are problematic. When we look at the bodies around us, the current explanation for the strong bias towards redshift (the further away the object, the stronger the redshift, generally) is that there is another force at work, that space itself is expanding, and this expansion is accelerating. To fit into current models, we need to account for this acceleration using a force, a modification of a field, a new field, or an extra process. Thus far, none have proved entirely satisfactory, even accounting for gravitational redshift. When worked into Einstein's field equations as the *cosmological constant*, the term gives the vacuum a pressure value, so expanding space and providing an explanation for the distant red-shifting objects. One perceived problem with this outlook is that it needs an origin point of no acceleration, defining the region beyond which objects propagate faster than light speed.

We present, on a very basic level, a controversial proposal: rather than the universe expanding at an accelerating rate, all concentrated matter is shrinking, including that of the locality of Earth. We will not notice this near-locally, despite the physical processes contracting and progressing more quickly, because our measurement systems are also affected. However, when we look at regions that are (or were) less concentrated when their light was emitted, we see their processes running more slowly: the redshift.

Our mechanism already shows that fermions and composites will collapse and reconstitute more readily, in less time and with smaller interaction radius, if the vacuum energy flux density is higher.

Combine this with our proposal (6.1) that the photons of QED (and in particular the wavelength of photons) are the result of a sparse sampling at both source and receiver, then the frequency of photons subjectively changes from emission to absorption, if vacuum conditions differ. This may oppose the processes of discrete gravitational redshift.

We say that: (a) a de-constituted fermion requires vacuum energy to reconstitute; (b) free fundamental fermions will fail to reconstitute; and (c) vacuum energy (mass-energy) prevents infinite propagation of bosons. Thus, a complete wavefunction must incorporate both the *matter* under consideration and the external bosons (environmental *vacuum* and any confining energy).

6.1. *Reconstitution in varying vacuum conditions*

The simplest structure for the bound electron is the hydrogen atom (fig.12). Our mechanism describes the stable structure fairly conventionally, with a hadron singlet as the nucleus (not shown), an electron, and the electron's interactions with the vacuum.

Splitting the photon

We can reconstitute a single photon in a beam-splitting experiment, or cause the reconstitution to fail by closing one path. This strongly indicates that a photon has two parts. According to this mechanism, a photon is not a fundamental boson, but is instead a set of bosons in the context of the emitting or absorbing fermionic structures (fig.12). The interval is critical to its frequency. Radiation received singly (not in pairs) will be 'dark', and likely not absorbed.

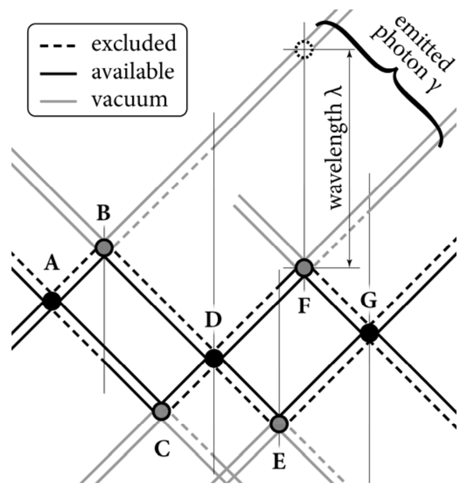

Figure 12. Reconstitution of a bound electron, at {**A**, **D**, **G**}, with photon emission. Interactions between vacuum energy and one half of the electron's constituents are shown grey {**B**, **C**, **E**, **F**}.

6.2. *Quantifying the redshift*

We interpret cosmological redshift as the change in the interaction scale for electromagnetic (and other) processes, from the distant past, to the present, due to local changes of vacuum energy density. As matter forms filaments, condenses, and clumps over time, vacuum energy density becomes non-uniform, being higher in regions of higher matter density, thereby reducing the interaction distances (fig.13).

When the light is absorbed in the present, the local interaction distance λ_a is much shorter than interaction distance λ_e when the light was emitted. Precise values for redshift could be calculated using:

(a) Mass-energy terms for the fermion's waves, and a description of the mass-energy of the environmental vacuum energy.
(b) This gives a function for the probability of collapse, and distribution of radial collapse distances from source.
(c) This is then worked into the scenario of the fermion, where the emission frequency (or spectrum) may be obtained.
(d) Do the same for the (prospective) absorption, taking the environmental vacuum conditions into account.
(e) The standard redshift z can be calculated from the ratio of the emission and absorption frequencies.

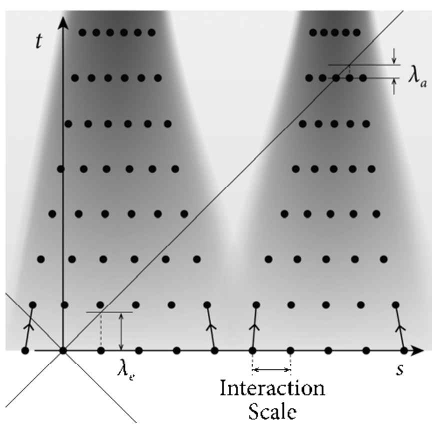

Figure 13. Emission wavelength λ_e for a process, when vacuum energy flux density J_e (shaded) is isotropic with low value, propagation time-cone, and $\lambda_e > \lambda_a$ for the same process at the absorption site: a red-shift.

For (c, d) we can take the relation $r = 6.93148/p$ (Table 3) to infer that the wavelength will be inversely proportional to the mass-energy density of the vacuum, and thus

$$z = \frac{p_a}{p_e} - 1 \tag{7}$$

6.3. *Local statistics: a constant flux density in space*

One possible objection to this hypothesis is that, according to the common interpretation of general relativity, the flux density per unit space is constant, even in the already-expanded space. We meet this objection by stating that for any given locality, the processes will be shrunk and sped up proportionally to its vacuum energy density, making the energy density seem constant for any given locality.

For vacuum energy density to become significantly increased enough to produce local shrinkage, and red-shift of distant observed emission, we propose:

(a) That a significant amount of matter is present, within a large region (galactic or cluster scale), to capture the bosons required for the matter to interact between instances and with surrounding vacuum energy.
(b) That the actual mass-energy values are very small when compared to the highest possible values allowed by eq.1 (fig.2).

One interpretation of current redshift data is that we are already experiencing the effects of vacuum flux, due to the activity around our own galaxy's black hole and the wider environment.

6.4. *Summary of redshift interpretation*

If this hypothesis holds, we may assume that our local space (or more correctly, the effective radius of the interacting particles), is shrinking in the presence of increasing vacuum energy flux. This *contraction* needn't be an accelerating process to correlate with current redshift observations. The illusion of cosmic inflation can be achieved while avoiding the difficult physical interpretations of the standard model of cosmology.

6.5. *Proof and disproof*

Our hypothesis predicts some effects to look for:

(a) Fluorescence in intermediate matter, due to local variations of vacuum energy density. Likewise, blue-shifted absorption/emission spectra from environments having high vacuum energy density.
(b) Localities where the vacuum flux density deviates from the density of matter. This scenario will be found in evolving systems, where the gradient of flux density is non-zero, having an observable effect whereby redshift remains unexplained at the point of observation. *Accreting* systems may have higher matter density; *evaporating* systems may have higher vacuum energy density.
(c) Variability of the ratio between Planck's constant and characteristic black body or emission frequencies. Given QED frequency quantization (and the constancy of the fundamental

wavelength), we should expect a universal process in space to slightly mismatch the expected frequency values $\pm\hbar$. This is separate from the redshift effect.

(d) We should see more blue-shifting than expected conventionally, due to extreme conditions existing when distant sources emitted their light.

(e) We expect a higher photon frequency when measured off-axis. If two separated sources emit bosons, then the interval between their signals will change according to the angle relative to the line joining the sources. We do not know of any such observation, but the absence of higher frequencies off-axis can be explained by a process of directionality (say intermediate interactions between the source and the receiver), whereby off-axis signals are not received. However, there could be an observable marginal effect.

6.6. *Further work on redshift*

We wrote this section (6) simply to publish the hypothesis in very broad terms. It is very speculative, and needs proof or disproof. The following should be considered in such working:

- Photons as sparsely-sampled impulses (6).
- Reconcile to a trivial standard QED case, e.g. a bound electron in hydrogen atom, and redshift data.
- How does wavelength change with vacuum energy density? (6.2). Blue-shift: high VED sources, X-rays.
- What happens when electrons change energy levels?
- What proportion of photons clear the nucleus?
- Early universe hypothesis: a condensing infinite universe, rather than a big bang? Speculation: is there a process that creates the known spectrum of mass-energy values of bosons?
- How a ‘free’ fermion interacts with vacuum energy.
- How is energy stored and confined as bosons in an atom’s reconstitution pattern?
- The interaction of vacuum energy with the nucleus and with the electrons (fig.12: C, E).
- Calculating vacuum energy density using red-shift.

7. Summary

In the introduction (1), we outlined six basic rules. Continuing with emergent details:

7) The weak interaction: breaking the symmetry and exclusion of two of a fermion’s waves, making both waves of the uncollapsed boson available to interact.
8) Implicit fermion propagation: between each reconstitution, two intermediate de-localized anti-images interact with vacuum energy.
9) A constitution-invariant process, which accounts for matter and energy in creation, propagation, and annihilation, even when the identity, type/flavour count, and make-up of fermions changes (C, P, CP violations, and baryon number violations).
10) The same process is valid for fermion generation (quarks, leptons, neutrinos), interactions in a black hole [9], QCD, strong force and nuclear residuals, QED and photons.
11) Fermion generations/flavours, as a count of the dimensions or bosons required to form the spatially-unique (localizing) solution.
12) Vacuum and matter polarization (5.1).
13) Charge, as the proportion of fermion interactions where bosons are exchanged with vacuum. This gives charged particles their currents and electro-motive force.
14) Magnetism, from coherent vacuum flux via charge.
15) Photons, terminated by pairs of radiation/absorption events, with frequency domain characteristics from sparsely-sampled intervals (6.1).
16) Gravitation [9], not as a fundamental force, but is a macroscopic statistical tendency for bosons to collapse towards sources of vacuum energy flux (3.7). Unified with forces in this hypothesis.
17) Unification energies at structural decoherence. All particles (3.1) can be modelled as black holes (4).
18) A shrinkage of the interaction radius of matter, in increased vacuum energy density, leading to frequency-shifting of photons.

8. Notes and Appendices

8.1. *Matter/vacuum and matter/anti-matter dualities*

We identify created particle pairs as corresponding to the dualled Dirac images that are present in our constitution for a fermion; for each fermion, only one image is accepted as ‘reality’ for an instance of the fermion’s matter state [3].

In previous work [2], we identified a basic algebra for discrete dualled divergences in $\{\mathrm{D}_2, \mathrm{D}_2, \mathrm{D}_2\}$ (the algebra also used in Rowlands’ nilpotent formulation [4]), as the images of creation or annihilation operations. A continuous version of these operators [3] encoded a $\{C_2, \mathcal{Cl}_{3,1}\}$ algebra from $\{C_2, C_2, C_2\}$ bases, dualling Hestenes' derivation of a $\mathcal{Cl}_{3,1}$ geometric algebra from two bases $\{C_2, C_2\}$ [1].

Our method is to use instances solely on the extra C_2 basis ("b" value) to apply determinism where quantum mechanics cannot [5, 7], using a 'two in, two out' non-rigid causal network. 't Hooft [6] proposed a similar linkage, as a discrete rigid lattice.

The "b" C_2 duality may interpolate dual $\mathcal{Cl}_{3,1}$ spaces, as an oscillation of fundamental waves between 'vacuum' and 'the condition for the fermionic matter state', for a deterministic mechanism for the physicality of matter [5]. Indeed, we may derive new statistics, and as a long-term goal we are working towards implicitly generating the free parameters of the Standard Model from the application of geometric principles.

Inherent to the structure of a fermion, as described by that hypothesis, were the additional (phase-shifted) anti-images that Dirac predicted, along with their context as states in a continuous propagation of boson waves, and their de-localized availability for coupling with other bosons.

8.2. *Cautionary note: there is no 'negative mass'*

While it is possible to have a negative value for the phase operator in eq.1, the effect for positive and negative values is approximately the same: a boson with large mass has a wide window for collapsing other bosons, regardless of its modulation sign. This assumes random distribution of phases, decoherent with the source in question. With this in mind, sign would become significant if there is a statistical tendency for phase-coherent bosons, which is likely in small systems. We leave these effects for future study.

8.3. *Problem: the emergence of Euclidean space*

Fundamentally, all solutions are based on phase alone, and we may derive further co-ordinate-free relations between entities based on that. Physically, we have no problem with the number of overlapping sources leading to the dimensionality of the unique solution, and fermion flavor. Also, we acknowledge reasons in geometric algebra for three being the maximum non-redundant dimensionality for space.

However, beyond a simple geometric approach to interactions, we do have difficulty determining when we may assume Euclidean space as a basis for positioning, and how, without this basis, radially-propagating waves can 'know' when they are overlapping. We wish to address this in future work.

8.4. *Phase coherence: opportunity for disproof*

Given that waves only collapse at phase $-b$, and the limited phase modulation that external bosons impart:

1. If most matter initially has random phase (e.g. for instances of vacuum mass-energy, p_v), then probabilistically, only a small fraction of the vacuum energy, approximately $3p_v + p_m$, interacts with matter having p_m.
2. For nearby instances of interacting matter to avoid decaying, they self-regulate their phase coherence.
3. Vacuum energy that is coherent and only slightly out-of-phase with matter, may selectively interact with bosons having large p_m while bypassing bosons of low p_m.

We treat this as an opportunity for testable disproof, and for new predictions, based on the phase coherence of matter and vacuum energy over great distances.

8.5. *Proton decay: requires phase decoherence*

We say protons can decay, but only with input from the vacuum energy that conserves the proton (fig.4).

By definition, charged composites are not totally confined, they require vacuum energy [7] to remain conserved, so we must assume a sufficient vacuum field to support the proton, rather than a strictly free proton. Yet it is this field that could disrupt the constitution of a proton. Treating the proton as a 'black hole' [9], we may calculate the chaotic probability that the proton becomes decoherent for any given vacuum conditions. This would yield the relation $f(s, v, t, p)$, where s is the structure to be decayed, v is the sustained vacuum flux, t is the time interval, and p is the confidence of decay,

Where $v > 0$, then $t > 0$, and necessarily, $p > 0$.

The only way that proton decay can be disproved in this context, is if the network is self-correcting of any deviations that could have evolved into decoherence, and that an infinite series of such corrections will overcome all expected intrusions from background levels of vacuum energy (8.4.2).

				r, for Percentile of $\int_0^\infty P_H(r)\,dr$					
Row	p	**Max** $(P_H(r))$	, r	**5**	**50**	**95**	**99**	**99.9**	**Error**
1	0.5	4.726×10^{-1}	1	1	2	5	7	10	-2.76%
2	1/3	2.723×10^{-1}	1	1	2	8	12	18	-6.11%
3	0.1	8.618×10^{-2}	2	2	8	30	45	67	-6.81%
4	0.01	9.545×10^{-3}	5	8	72	301	461	690	-2.07%
5	10^{-3}	9.883×10^{-4}	12	57	698	3,000	4,608	6,910	-0.50%
6	10^{-4}	9.972×10^{-5}	28	525	6,943	29,968	46,061	69,086	-0.11%
7	10^{-5}	9.994×10^{-6}	64	5,155	69,340	299,597	460,540	690,798	-0.03%
8	10^{-6}	9.999×10^{-7}	144	51,349	693,202	2,995,786	4,605,223	6,907,807	-0.005%
9	10^{-7}	$\sim 1.0 \times 10^{-7}$	323	513,052	6,931,591	29,957,441	46,051,819	69,077,669	-0.0011%
10	10^{-8}	$\sim 1.0 \times 10^{-8}$	721	—	—	—	—	—	—
11	10^{-10}	$\sim 1.0 \times 10^{-10}$	—	512,938,848	693,147,733	2,995,732,807	4,605,170,639	6,907,554,831	-0.00006%
12	p	p	?	$5.12939/p$	$6.93148/p$	$29.95733/p$	$46.05171/p$	$69.07555/p$	n/a
13	10^{-12}	$\sim 1.0 \times 10^{-12}$	17,398	5.1294e12	6.9315e12	29.9573e12	46.0517e12	69.0755e12	n/a
14	10^{-16}	$\sim 1.0 \times 10^{-16}$	390,115	5.1294e16	6.9315e16	29.9573e16	46.0517e16	69.0755e16	n/a

Table 3: Iterative computation of the approximation for single wave collapse (eq.4). Row 8 uses the same value for p as fig.5. Row 12 is inferred from data, and percentiles of rows 13 and 14 use the formulae of row 12.

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