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FEYNMAN CLOCKS, CAUSAL NETWORKS, AND THE ORIGIN OF HIERARCHICAL "ARROWS OF TIME" IN COMPLEX SYSTEMS
PART I. "CONJECTURES"

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Feynman Clocks, Causal Networks, and the Origin of Hierarchical 'Arrows of Time' in Complex Systems. Part I. 'Conjectures'

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Abstract

A theory of **time as information** is **outlined using new tools such as Feynman Clocks (FC), Collective Excitation Networks (CENs), and Sequential Excitation Networks (SENs)**. Applications of this approach are illustrated with examples ranging from the Big Bang to the emergence of consciousness in the Brain.

Keywords: the 'problem of time', the 'direction' and 'dimension' of 'time', emergence of complexity, causal networks, entangled states, decoherence, excitons, time reversal, time travel, photosystems I and II, the double slit experiment, quantum computers, 'unification' of the fundamental interactions of matter, neural networks, CMB radiation, quantum cosmology, time 'travel', the 'anthropic principle', the 'Quantum Brain' and 'consciousness'.

Contents

1 Introduction

Should we be prepared to see some day a new structure for the foundations of physics that does away with time?... Yes, because "time" is in trouble.-John Wheeler [1].

'Physical time' will emerge as a sort of secondary collective variable in the network, i.e. being different from the clock time (while being of course functionally related to it)- Manfred Requardt [2].

It has been suggested by Julian Barbour that 'time' does not exist [3]. It is the position of this author that 'time' does 'exist' and is a different 'property' of evolving systems than has been previously assumed.

Conventional 'time' is *functionally related* to the *signals created by reconfiguration or 'decoherence'*[4] *transitions between the physical states of clocks.* These signals are *detected* by the conversion of a signal into an excited state in a detector. This process produces *state information* (e.g. *configuration* observables such as energy) in the detector connecting it to the source and its signal on an 'arc' between two nodes of a *causal network.*

The detector states can be sequentially 'clocked' into ordered memory registers through a process of **'signal mapping'**. The state information stored in these registers can be used to create a 'time dimension' by *mapping* the ordered set of memory states onto the real number line. *Information processing systems* (e.g. quantum computer 'gates', neurons, the brain etc.) are an integral part of the creation of 'time' as a measure of the difference between configurations of a system with respect to a 'standard clock'.

Much of the confusion about the *nature of time* is connected with the *spatialization* of 'time'. The use of 'shift' vectors and 'lapse' functions [5] takes 'explicit' clock time and masks it in an implicit form of 'distance' between 'universal state configurations'. These are specified by the distribution of matter and energy in 'space' (vacuum).

The 'problem of time' is primarily about the emergence of macroscopic irreversibility (e.g. entropy) from reversible microscopic symmetries (the 'T" of CPT invariance). The *quantum arrow of time* is defined by the *irreversible* 'decay of a discrete state resonantly coupled to a continuum of final states' [6] observed in various nuclear and atomic processes. We will see that apparent 'time' reversibility and irreversibility are compatible and necessary aspects of quantum systems. The '*Program of Decoherence*', the entanglement of quantum states, and the emergence and decay of novel collective excitations provide tools [7], [8], [9] for understanding the common roots of all arrows of time for unstable configurations of hierarchically scaled clusters of matter in an evolving universe. This scaling leads to 'classical' or macroscopic aspects of reality that are in fact special cases of a 'quantum universe' [10].

We begin with the premise that **time is a number created by the processing of information**. Scalar division of this information by Planck's constant creates a real number with units of 'time' (seconds). The information (in this context has units of 'energy') is propagated by **signals** between **Feynman Clocks (FCs)** to **Feynman Detectors (FDs)**. The FD is the signal absorption mode of the FC and unless indicated, 'FC' will be used to represent these two modes of a single system. The conversion of this state information into numbers provides the basis for building the 'time dimension' of space-time by measurement of the differences between two numbers. The creation of these numbers from the detection events is accompanied by the loss of information about the states of the signals and clocks. The increase in information entropy will be important in understanding the 'lifetimes' of local and distributed information structures in quantum computation.

The **special theory of time** describes how the fundamental quantum mechanisms involved in the reconfigurations of unstable systems generate information states defining an irreversible 'quantum arrows of time'. The **general theory of time** describes how the quantum arrow of time can be used to define macroscopic arrows of time associated with transfer of state information in complex systems and causal networks [11]. It is the author's position that unified or comprehensive 'theories of everything, everywhere, at anytime' require a *deep* understanding of 'time'. Conventional ideas of 'time' have been the implicit and explicit source of many contradictions and paradoxes in physical theories.

The purpose of this paper is to examine the premise that all temporal processes in macroscopic complex systems can be understood as being generated by a microscopic **irreversible quantum arrow of time.** The *correspondence* between the various separate biological, cosmological, psychological, radiative, and thermodynamic '*arrows of time*' [12], [13], [14], [15] is achieved with *causal networks* built up hierarchically from the quantum arrow of time. *Preliminary* and *speculative* ideas and tools are presented in order to see if a 'deeper' descriptive and computational 'language' of 'time' as 'information' is possible. Brief examples and applications are explored from the Big Bang to the Brain.

2 Time: Conjectures

The new description of 'time' is built on the following conjectures:

Conjecture 1 *'**Time**' is a **form** of '**information**'.*

Conjecture 2 ***Information** is created by **reconfigurations** of unstable states of systems.*

Conjecture 3 ***Reconfigurations** of systems produce or process '**signals**'.*

Conjecture 4 ***Signals** connect **clocks** to **detectors**. A **Feynman Clock (FC) or 'gate' (FG)** is a generalization of a **quantum clock** [16] with multiple signal input and output 'processing' capabilities. Signals are essential for the creation of causal networks. Signals are 'quantum' in nature but may appear 'classical' as a result of their collective scale, statistical entanglement, or intensity. They may be identified with a transition in a macroscopic Plateau of Complexity or 'POC' (see below).*

Conjecture 5 *The **Quantum Arrow of Time (QAT)** is a **pointer**. It is a function mapping the **irreversible** transition from an excited or unstable configuration to a coupled 'stable' one in a FC or FG system. The 'direction' and 'magnitude' of these 'arrows' are specific to the quantum system being observed. The general QAT is really a statement about unstable states of system coupled to one or more states from within a set of all possible reconfigurations of that system. These pointers are '**information vectors**' in an '**information space**' [17]. The state information transfer between clocks and detectors by the signals can be mapped by these vectors in the information space. All QATs for various localized systems in the current universe are 'traceable' back to the fundamental QAT mapping the decoherence and decay of the initial excited state of a FC-Universe at the beginning of the Big Bang.*

***Conjecture 6** The **creation** of an **unstable state** in a system by the **detection** of one or more simultaneous or staggered **signals** is the '**detector' mode** of a clock.*

***Conjecture 7** The 'decay' or '**decoherence**' of this state with the emission of one or more **signals** is the '**clock' mode** of the system.*

Remark 1 ***Note*** *that the term* ***'clock'*** ***or FC*** *will be used to represent any system that has* **both** *detector and clock modes unless otherwise noted. A* ***Feynman Detector (FD)*** *is the* ***input*** *or* ***detection mode*** *of a Feynman Clock.*

Conjecture 8 ***Causal Networks (CNs)*** *are* **built** *from locally* **connected** *sets of clock (and detector)* **nodes.** *These CNs map the sequential progression of information or signal flow from node to node. CNs may also act as* ***'temporal interferometers'*** *acting on or creating* ***entangled signal*** *states [18].*

Conjecture 9 *Causal networks of signal linked FCs processing signals* ***sequentially*** *are* ***Sequential Excitation Networks (SENs).*** *These systems treat the signals between nodes as distinct 'classical' objects which are decoupled from the clocks and detectors along their trajectories. We will see that the distinction between quantum and classical objects is conceptually artificial. It arises when systems exhibit collective properties that can be described without direct reference to the complex quantum causal networks underlying them. 'Classical' methods are clearly appropriate for the application of classical physics and engineering principles in macroscopic systems where their possible disruption by underlying quantum CEs is negligible. .*

Conjecture 10 ***FCs*** *can be* ***"synchronized"*** *by* **entangled** *signals by generalizing the* ***"Quantum Clock Synchronization Scheme (QCS)"*** *[18]. The FCs may be separated by 'classical' distances but act as a single quantum system. The spatial 'distance' between two coupled or entangled nodes is a 'weak' measure of the quantum or classical nature of the combined system. The 'distance' which distinguishes the two nodes may be more properly 'measured' by their* ***degree of entanglement*** *[19].*

Conjecture 11 ***Collective Excitations (CEs)*** *(e.g. phonons) of* ***synchronized*** *sets of Feynman clocks in causal networks result from reconfigurations of excited state of the whole system. These CEs occur as novel behaviors of these* ***Collective Excitation Networks (CENs).***

Conjecture 12 ***Plateaus of Complexity (POCs)*** *are the* ***physical states*** *of complex systems (CENs) that support* ***CEs*** *and the* ***collective signals*** *that are detected and emitted by the collective state of the components acting together as a single 'clock'. Signals are essential for the creation of causal networks. Signals are always quantum in nature but may appear classical as a result of the identification with a macroscopic POC.*

Remark 2 *These CEs are perturbations of POC n-body states. They may be multipole oscillations of nuclei shifted energetically away from the mean POC energy states associated with 'stable' configurations. These stable nuclei occur at "**magic**" total nucleon numbers given by the proton and neutron sum A, where* $A = 2, 8, 20, 28, 50, 82, or\ 126$ *calculated using the 'Shell Model' of nuclear structure[20].*

Conjecture 13 *The **spatial direction** of the **flow of information** via signals in networks defines **'arrows of time'** specific to the **signals** and their **information content.***

Conjecture 14 *The emergence and decay of **CEs** in **POCs** generate signals that can be used to create **hierarchical 'arrows of time'** associated with a system at a given level of complexity.*

Conjecture 15 *Complex systems* **composed** *of other complex systems can generate **POCs within POCs**. POCs can act as* **clocks** *forming* **networks** ***of POCs** which in turn can support new CEs. This '**nesting**' of clocks and signals provides the basis for scaling from quantum clocks to neural networks. The signals between such systems that are* not acting collectively *form hierarchical **SENs**.*

Conjecture 16 ***All 'arrows of time'** defined for various POCs are **traceable** back to fundamental QATs.*

Conjecture 17 *The '**direction**' and '**dimension**' of 'arrows of time' are created through a process of **Signal Mapping** in which the detection of non-simultaneous signals is **causally ordered** in a **memory register** by **coupling** the detector states to signals generated by an **internal** or **standard clock** [15]. The set of ordered states can then be transformed by a computer (e.g. neural network) to the set real numbers for the construction of a 'timeline'. This timeline can then be converted into the* spatialized *'time' parameter of relativistic 'space-time'.*

Conjecture 18 ***QATs are irreversible** since they are defined as originating from unstable configurations.*

Conjecture 19 *'Time' or more properly **Configuration State Information is reversible** or **restorable** [15]* only if an unstable state of a system can be recreated *by work (injection of the wave-function information specific to the desired state) done on the system by an external 'agent'(signal). This* *work may be done as a quantum computation on* ***reconfiguration signals*** *by the* ***FD 'gates'****. This can create a* ***local*** *'reversal of entropy' leading to an* ***excited*** *configuration of matter with the same properties as the atemporal 'previous ' state of the system. The creation or re-creation of an unstable state of a system requires input information from the systems environment and is not associated with an internal QAT but with the signals QAT..*

3 The Quantum Arrow of Time (QAT)

The decay of *ensembles* of identical radioactive nuclei can be described in the 'bulk' or statistical perspective with the '**exponential decay law**' [21]. We will see that the system as a whole can be thought of as decaying form the initial collective excitation of a 'network' of acausal but 'connected' set of quantum systems. The 'decay law' in the ensemble paradigm is;

$$N_\tau = N_0 e^{-k\tau} \tag{1}$$

where N_0 is the number of identical radioactive 'clocks' that we start with, k is the 'decay constant' specific to the type of clock and represents the magnitude of the 'instability' of the system, τ is the 'elapsed time' for the transition from an *initial system configuration state* of N_0 clocks to a *reconfigured state* of the system where N_τ clocks remain at 'time' τ. Since the unstable nuclei of this system are quantum clocks, we can view this equation as the recipe for a 'collective' or 'statistical' clock built from an ensemble of quantum clocks. Solving for 'time' we have;

$$\tau_{edl} = \frac{1}{k}\left(\ln \frac{N_0}{N_\tau}\right) \tag{2}$$

which can be thought of as the *transformation* of *'reconfiguration information'* on the right into the '**lifetime**' of the transition from the unstable state of the initial system to a 'more stable' state with N_τ clocks. The 'detection' of the N_τ 'signal' results in a real number created by the *dimensional conversion* factor k^{-1}. This number is interpreted as an 'event time' for the state of a statistical clock built from many quantum clocks.

First we observe that the decays of radioactive nuclei, excited electronic states of atoms through 'autoionization' (emitting a 'free' electron) or photon emission, are described with '**time-independent**' perturbation theory;

"For example, a system, initially in a discrete state, can split, under the effect of an internal coupling (described, consequently, by a time-independent Hamiltonian W), into two distinct parts whose energies (kinetic in the case of material particles and electromagnetic in the case of photons) can have, theoretically, any value; this gives the set of final states a continuous nature...We can also cite the *spontaneous emission* of a photon by an excited atomic (or nuclear) state: the interaction of the atom with the quantized electromagnetic field couples the discrete initial state (the excited atom in the absence of photons) with a continuum of final states (the atom in a lower state in the presence of a photon of arbitrary direction, polarization and energy)." [6]

These decay modes are not restricted to atoms and nuclei. We will see that these *quantum clocks* are *time-independent irreversible systems* that can be created in space by *apparently* 'time' reversible particle collisions. *The key to the irreversibility in quantum systems is the creation of an* ***unstable*** *configuration of matter and energy in space.* This is the *'first cause'* for decay. The decay of an unstable state creates a 'local' arrow of time pointing to more stable states for the system. *Instability* is a measure of the *geometric asymmetry* of the mass-energy distribution of the 'components' as they are driven to 'more stable' configurations by the fundamental interactions (forces) between each other.

The apparent 'reversibility' of clocks or any other complex system is an phenomena created by the interaction of spatially distinct signals and detectors. Reversibility is a collective property of a composite system formed with 'free' signals, the vacuum, and quantum detectors and clocks. 'Entropy' is a convenient mapping tool or system pointer indicating the direction of evolution of the total system while preserving the reversibility of detectors and the irreversibility of clocks.

4 Collective Excitations

The key to hierarchical systems of quantum systems acting as 'classical' objects is the concept of **collective excitations (CEs)** of **quasiparticles** (also called 'elementary excitations') [22], [23], [20]. **Phonons, excitons**, and **plasmons** are examples of CEs that exhibit mesoscopic system behaviors but are still quantum phenomena [24], [25]. Superconductivity represents an important quantum macroscopic behavior in the CE model. The concept of CEs as links between hierarchical plateaus in complex systems as a source for 'consciousness' as an ultimate expression of a CE state is being explored by the recent work of *Alex Kaivarainen* [26]. His approach has similarities (CEs at various plateaus of complexity) and differences (i.e. Bose-condensation mediated CEs *versus* CEs resulting from quantum 'entanglement', *self-measurement*, and *decoherence* processes) with the approach taken by this author. More work needs to be done to see how these ideas can provide a clearer model of complex states in systems like the brain. Other helpful approaches to this problem include CEs in the form of chemical waves [27] presenting another possibility modeling for the transition (if any) between the 'quantum' processes in neurons and 'classical' collective states such as thought. Other models of collective excitations in networks of neurons have provided theoretical support for the emergent CE behaviors in 'Cortical Tissue' [28]. These ideas will be examined briefly in the Examples section later in this paper. The focus of this paper however is on the *quantum source* and *hierarchical* nature of *'time'* as *information* as it is *processed* at various POCs in systems ranging from minimal (e.g. particle collisions) to maximal complexity such as the brain.

If spatially extended quantum CEs can be shown to exist in complex 'classical' systems, then CE emergence and decay can define the 'lifetime' of the reconfiguration process involved with transitions between specific states. Collective excitations represent new properties of n-body aggregates of matter that are not a mere sum of the individual properties of the individual components. The emergence of these novel behaviors creates the opportunity for new 'signals' to be emitted and absorbed as resonances of the new energy eigenstates. The state information transported by these signals is also new. These signals allow identification of the transitions between states in the spectrum of CE states of a complex system. These phonon or phonon-like signals can link other CE systems in hierarchical causal networks.

One of the fundamental questions about collective excitations is what are the maximum distances between CEN components that will still support collective behavior? The emergence of 'quantum' excitations in mesoscopic (quasi-classical) and macroscopic CEN systems requires resonant communication or *'synchronized' entanglement* of the states of all the relevant components. **Entanglement** of the quantum states of two or more components provides a composite complex state that can represent a collective excitation of two 'isolated' but 'historically' coupled signals.

Recent work on the synchronization of quantum clocks provides a model for CEs as entangled states in widely separated systems through a "*quantum clock synchronization scheme*" (QCS) [18]. This model can be expanded for

Feynman Clock Synchronization (FCS) over 'classical' distances where the FCs are virtual clocks (entangled 'time' independent *signals*) until 'measured' or decohered from an atemporal global CE state into 'actual' FC states of the nodes in a causal network. These synchronized nodes create a CEN without the exchange of 'timing information'. Evidence of CEs over great distances is found in photon entanglement experiments.

Experimental observation of two 'energy-time' entangled photons separated by more than 10 Kilometers [29] provides an example of the *decay of a collective excitation* of a vary large spatially extensive quantum system *if* we look at the entire experimental setup as a 'SEN' system from the 'Geneva FC' to the Bellevue/Bernex 'CEN'. The 'Geneva FC' produces two 'coherent' photon signals that traverse large distances on separate fiber optic paths (8.1 and 9.3 km). The 'transit lifetimes' of the signals are functions of the velocity of the signals in the medium and their distances to the FDs in the Bellevue/Bernex CEN. Signal mapping of the FD/FC detection events in the CEN via a 'clocked' memory system linking the two 'node' leads to causal ordering. The entangled photons remained 'correlated' even though separated by 10.9 kilometers, upon their detection 'decohere' with the production of 'classical' information (i.e. the emission of 'signals' or the creation of 'states' in memories) upon measurement.

The existence of spatially extended quantum states in networks depends on the entanglement of the states of the components. Entanglement allows CEs to emerge and decay. The lifetimes of these states is controlled by environmentally induced decoherence. *Decoherence lifetimes* can be extended by 'self-measurement' or 'feedback' with the CE or environment. This allows for the existence of macroscopic quantum states of networks. The lifetimes can also be shortened by decohering signals causing 'feedforward' of the evolution of the system. If the interaction extends the lifetime of the state then entropy in minimized. If the lifetime is shortened then entropy is maximized. Information loss is a measure of the entropy of the system. It is lost via emitted signals to the environment.

Quantum entanglement of the states of many components of a network can then 'define' the collective excitation as the *resultant state* of the coupled interactions of all the nodes. CEs may also interact with each other. This may lead to entanglement of various states of a plateau of complexity creating a higher order CE. Nesting of sets of entangled states within causal networks can lead to an entangled state composed of entangled states. This may provide a basis for the existence of spatially extended complex higher order CEN quantum states over 'classically' separated nodes of a causal network.

The emergence of classical systems as collective effects of networks of quantum systems through a process of collective excitation state signal production and the 'decoherence' of quantum superpositions of states into 'classical' signals and systems calls for a description in which the lifetimes of unstable states of systems of all sizes 'correspond' in a logical way to the reconfiguration processes of their subsystems. For an 'open' system, such as an atom with an electron in an excited state, the decoherence of the excited state can be induced its coupling to its 'environment'. The environment in this case is the 'vacuum' plus the QED 'self-interaction' field of composite system.

The definition of a systems' environment depends of the specific property or state of the system is interacting with the 'external' space in which it is embedded. For example the 'vacuum' may not be the relevant environment for the chemically driven metabolic activities of a cell although it 'exists' between the chemicals. However it is an essential 'environment' for virtual particle production and decay and the 'Casimir' forces of attraction between two flat parallel plates in it [50]. The initial state of the universe can be considered to be self-contained 'closed' system with no 'external' environment. It can however have a coupled 'environment' composed of primordial density perturbations in the form of CE 'cosmic phonons' (see **Figure 1**). These 'sound waves' may be the result of a Casimir effect of the expanding 'boundary' of the universe [51]. The phonon states may have been frozen out as hierarchical clusters of matter or 'caused' the decoherence of the initial state of the Universe driving inflation and the Big Bang.

In collective modes of n-body nuclei [20], the CE 'environment' is the phonon field with a characteristic multi-phonon spectrum. The 'boundary condition' acting as an apparatus 'measuring' the nuclear configuration state of the system is the 'surface tension' due to the binding energy of the strong interaction between nucleons in the nucleus. The phonon resonances of the nucleus and its 'surface' represent a prototypical collective excitation that emerges at a plateaus of complexity for this CE. 'Giant resonance' collective excitations of nuclei emerge from the coherent states of the nucleons. The resulting decay of the resonance by decoherence of the CE is caused by its coupling to the non-coherent modes of motion for the nucleus resulting in the 'damping' of the collective motion. If the CE has enough energy to exceed the stationary state equilibrium energy, then the system 'decays' irreversibly into a new configuration.

The interaction of the CE with the internal configuration states of the system is a time independent '*self-measurement*' [30] which causes the system to 'decay' or decohere irreversibly. The CE acts as the '**environment**' coupling the present configuration to all the possible 'future' reconfiguration states. In the case of the universe the difference between the non-stationary 'closed' initial state and the 'open' expanding system is the creation of the 'vacuum' as a decay product. The **expansion** of the universe is now a *collective excitation* of the mass-energy plus gravitation system.

The CEs of systems may act as measurements on the internal states by the surface environment. This surface represents a plateau of complexity for these systems. These plateaus have collective behaviors including irreversible transitions to new configurations of matter and energy in expanding space. One can artificially ascribe scaled arrows of time for these plateaus. These system dependent arrows are derived from the quantum arrow of time. They '*correspond*' to the quantum arrow through the collective excitations and behaviors of the networks of clocks and signals throughout the hierarchical clusters of information processing subsystems.

5 Signals

A signal is any 'system' that conveys information from one system (e.g. FC) to another (e.g. FD) (see **Figures 2 and 3**). The creation of a detector state from a signal state is the end process of information transfer originating in a spatially distinct FC. The state information transfer causes the reconfiguration of the detection system resulting in an unstable state of 'excess' information.

This local perturbation mapped in an **information space** [17] can be used to define the entropy of a memory state in a FC 'gate'. The significance of these information states at points along causal networks charted as functions of an information space is found in the mapping of configuration observables of the gates, register, and memories to 'numbers' (e.g. ordered sets of binary,...,*n-ary*, and modulo elements of the sets of Integers, Real numbers, and in special cases Complex numbers (absolute magnitudes)). The numbers are used to represent ordered 'event times' in observer systems. The 'numbers' form the language of causality for physical information in quantum computers ranging from particle collisions to consciousness. These numbers are one of the final forms of information generated by signals. The perception of a 'number' representing a signal induced state in a detector or memory is an artifact of the signal mapping process. The importance of this relation of numbers to **pointer states** is non-trivial:

> "...the states of the system used to represent numbers are those stabilized by the interactions with the environment, the

"pointer states"..." -Paul Benioff [31]

'Quantum' information is the 'value' of a pointer state or the 'magnitude of an observable' of that state induced in a detection system by a *pointer signal* from a FC to a FD. Entropy is a measure of the decreasing likelihood of state information transfer from a signal to a detection system. We will see that the thermodynamic interpretation of entropy is a result of the propagation of the quantum arrow of time through complex systems with plateaus of complexity that can experience irreversible configuration changes. This is analogous to the process of 'information erasure' in which the decay of an unstable state to a 'standard' state transfers information to the environment via a 'signal'.

'Classical' signals are decoupled from their sources and propagate through a vacuum or other medium with a velocity, v, over a distance, d. The 'velocity' of a signal can be understood in terms of time-independent energies and directions giving momentum in signal spectrometers. Spectrometer gates (e.g. gratings, prisms, slits etc.) process and disperse the signals (e.g. photons) as functions of their energies and trajectories. This spatial relation of the detectors with respect to the spectrometer 'gates' can then in turn be used to derive the 'momenta' associated with the signals. From this a 'velocity' can be *calculated* based on the understanding of the dispersion interaction of the spectrometer gate and the signals. Spatial, energy, and state information from the signals can be converted in a time-independent way into the classical velocities of the signals.

The signal path length, d, combined with this 'derived' velocity, v, (at this point assumed constant) can be used to find the *'lifetime'* of the signal from its creation by an FC to its annihilation by a FD. This 'lifetime' is the classical transit 'time' of the signal given by the macroscopic or classical relation:

$$\tau_{signal} = \frac{d}{v} \tag{3}$$

For any 'classical' arbitrary trajectory of a signal in space with a non-constant velocity function of 3-space position $\vec{\mathbf{r}}$, the classical velocity function $\vec{\mathbf{V}}(\vec{\mathbf{r}})$, and the differential signal direction, $d\vec{\mathbf{r}}$, are dependent on a fundamental interaction of the signal with the medium/environment through which it passes. The net 'lifetime' of the signal is found by integrating over the path from source clock position, $C(\vec{\mathbf{r}}_0)$, to detector position, $D(\vec{\mathbf{r}}_l)$. The 'classical' lifetime of the signal is then:

$$\tau_{signal} = \int\limits_{C(\vec{\mathbf{r}}_0)}^{D(\vec{\mathbf{r}}_l)} \left(\vec{\mathbf{V}}(\vec{\mathbf{r}})\right)^{-1} \cdot d\vec{\mathbf{r}} \tag{4}$$

The 'classical' and 'quantum' lifetimes of signals overlap for cases. The first case is when the signal trajectory path length is of the order of collective excitation modes of the system and is bound to the system. This means that the 'signal' does not propagate 'freely' as in the case of photons created by decay processes inside a star. This is a 'quantum' signal if it is trapped between quantum systems and interacting with them through absorption-emission or scattering processes.

It becomes a 'classical signal' if it propagates 'freely' in space. The decoupled photon escaping the surface of a star (subject to gravitational redshift effects) carries state information about its 'last' source in a networks of sources. A photon can be a quantum or classical signal depending on the environment in which it propagates. This is really an artificial separation that is intended to illustrate the subtle nature of the correspondence principle connecting the quantum description of signals with the 'classical' electromagnetic wave formalism.

The lifetime of a signal from emission (excited state), propagation (decoherence or decay lifetime), to its detection ('ground state') can be viewed as the decay of a single collective excitation of a s-FC system composed of original source FC, the vacuum or other signal medium, and the FD. The FC and FD at either ends of the signal trajectory 'bound' the s-FC. The 'quantum lifetime' of the 'signal' or its *equivalent* s-FC system is:

$$\tau_{C \to D} = \frac{\hbar}{\langle \Psi_{(D(\vec{\mathbf{r}}_l))} \mid H_{C \to D} \mid \Psi_{(C(\vec{\mathbf{r}}_0))} \rangle} = \tau_{signal} \tag{5}$$

This seems artificial, but it shows that a fully quantum description of the 'classical' aspects of the universe is possible by considering signal trajectories in space as the decay process of a collective state of a *quantum* clock-signal-environment-detector system. This will be useful later when considering quantum computation and *the universe as a quantum computer* [32].

6 Feynman Clocks (FCs)

Feynman diagrams are the source of Feynman clocks created by transforming the 'time' component (dimension) of the incoming and outgoing signals into the state information content of those signals. The interaction (collision or scattering) of the incoming signals creates a Feynman clock for the case in which there was no pre-existing matter in that volume of space. For the case of a 'target' interacting with incoming signals, the system composed of absorbed or scattered signals and the target form a Feynman detector in that volume of space. The target 'detects' the signals in the process of interaction with them in which new states of the composite system are created. If this system is unstable, then the Feynman detector mode of the target has become a Feynman clock. Generally the incoming particles create a clock where there was no clock before. FCs may be 'open' or 'closed' in relation to the incoming and outgoing signal trajectories.

For incoming signals whose total momentum is;

$$\mathbf{p}_0 = \sum_{i=1}^{m} \mathbf{p}_i \tag{6}$$

resulting in the creation of outgoing signals whose total momentum is;

$$\mathbf{q}_0 = \sum_{j=1}^{n} \mathbf{q}_j \tag{7}$$

A 'transient' clock system is created through reconfigurations of the matter and energy in the signals via the strong, electromagnetic, weak, and gravitational fundamental interactions (indexed by $I = s, em, w, g$ respectively). The **net** Feynman clock 'lifetime' from the system state created by the interacting incoming signals (FD mode) through the 'decay' process (internal 'decoherence' mode collective excitation state decay) to the state in which the outgoing decoupled signals are emitted (FC mode) is given by;

$$\tau_{FC_{net}} = \frac{\hbar}{\int \cdots \int_{q_n \cdots q_1} \left[\frac{V^{n+1}}{(2\pi)^{3n+4}} \mathbf{P} \cdot |\mathbf{M}_I|^2 \delta_4(\mathbf{p}_0 - \mathbf{q}_0) \right] dq_1 dq_2 \cdots dq_n} \tag{8}$$

$$= \frac{\hbar}{\int \cdots \int_{q_n \cdots q_1} \left[\frac{V^{n+1}}{(2\pi)^{3n+4}} \mathbf{P} \cdot |\mathbf{M}_I|^2 \delta_4 \left(\sum_{i=1}^{m} \mathbf{p}_i - \sum_{j=1}^{n} \mathbf{q}_j \right) \right] dq_1 dq_2 \cdots dq_n} \tag{9}$$

which is *nearly equivalent* to the entire system treated as a 'particle' that decays with a 'lifetime' [6]:

$$\tau_{FC_P} = \frac{\hbar}{\mathbf{F}_I} = \frac{\hbar}{\langle \Psi_{(E_0,\mathbf{q}_j)} \mid H_{E^* \to E_0} \mid \Psi_{(E^*,\mathbf{p}_0)} \rangle} \tag{10}$$

the difference between the net lifetimes of these representations is primarily due to the 'excitation lifetime' of the detector mode, generally absent in the treatment of the decay process of an unstable particle in the second equation. This will be clarified later when the 'three-stage' decoherence process for the internal reconfiguration of 'closed' quantum systems is explored. If there is no reconfiguration of the incoming signals and target (if any) in this region of space, then a clock has not been 'created' and the reduced fundamental interaction matrix element M_I (Note: equal to the S-matrix (the 'scattering' matrix) except for the δ-function for overall energy-momentum conservation) [33] is zero:

$$\mathbf{M}_I = 0 \tag{11}$$

The above equations for the Feynman diagram method for FD/FC 'lifetimes' represent the creation of 'lifetime' information from a scattering process that in general is very difficult to compute for complex systems. The idea here is that a 'collective excitation system' is created by the incoming signals leading to an irreversible decay with the production of outgoing signals. The transformation of the incoming signals by collisional 'processing' in a target 'gate' creates new information in the form of the novel emergent signal states.

Feynman clocks are quantum clocks with multiple inputs and outputs. These 'time-independent' quantum systems are modeled from techniques used in Feynman Diagrams. The **lifetime** associated with the Feynman clock **reconfiguration, τ_{FC}**, is:

$$\tau_{FC} = \frac{\hbar}{\Gamma_I} = \frac{\hbar}{\langle \Psi_f \mid H_{i \to f} \mid \Psi_i \rangle} \tag{12}$$

Note that the denominator is usually referred to as the 'decay rate', Γ_α, which represents the reconfiguration process in the term, $\langle \Psi_0 \mid H_\alpha \mid \Psi^* \rangle$ with unite of 'energy'. This energy divided by the 'temperature' of the system represent the decrease in entropy of the system due to the decay from an excited state accompanied by the emission of a signal. This loss of energy via a 'signal' is equivalent to the loss of **information** carried by the signal into the environment. This energy of reconfiguration is a measure of the entropy of the system at a constant 'temperature'. The lifetime of the unstable state is approximately the 'decoherence lifetime' for a system of 'diameter', L , caused to 'decay' by interaction with the environment.

$$\tau_{FC} = \frac{\hbar}{\Gamma_I} = \frac{\hbar}{\Delta E_S} = \frac{\hbar}{(T\Delta S)_{FC}} \approx \left(\frac{2L}{cTn}\right)_\delta = \tau_\delta \tag{13}$$

The **classical time** is the *'measured' difference* between the *detection event 'times'* connected with *two independent signals* from the two separate events **as seen** by a detection system. For event α and event β the observed 'lifetime' or 'elapsed time' between these two (signal detection) events is the 'difference' or 'classical' time between signal detections;

$$\tau_{\alpha\beta} = \Delta\tau = \left|\frac{\hbar}{\Gamma_\alpha} - \frac{\hbar}{\Gamma_\beta}\right| = \left|\frac{\hbar}{\langle\Psi_0 \mid H_\alpha \mid \Psi^*\rangle} - \frac{\hbar}{\langle\Phi_0 \mid H_\beta \mid \Phi^*\rangle}\right| \tag{14}$$

A Feynman clock with multiple simultaneous incoming input signals with a total momentum;

$$\mathbf{p}_0 = \sum_{i=1}^{m} \mathbf{p}_i \tag{15}$$

which decays or decoheres resulting in the creation of outgoing signals with total momentum;

$$\mathbf{q}_0 = \sum_{j=1}^{n} \mathbf{q}_j \tag{16}$$

is a 'transient' clock system created through reconfigurations of the matter and energy in the 'detection' space. This can occur via the strong, electromagnetic, weak, and gravitational fundamental interactions (indexed by $I = s, em, w, g$ respectively) between the signals and the resident detection system.

The **net** Feynman clock 'lifetime' from the system state created by the interacting incoming signals (FD mode) through the 'decay' process (internal 'decoherence' mode collective excitation state decay) to the state in which the outgoing decoupled signals are emitted (FC mode) is given by;

$$\tau_{FC_{net}} = \frac{\hbar}{\int\limits_{q_n \cdots q_1} \cdots \int \left[\frac{V^{n+1}}{(2\pi)^{3n+4}} \mathbf{P} \cdot |\mathbf{M}_I|^2 \delta_4(\mathbf{p}_0 - \mathbf{q}_0) \right] dq_1 dq_2 \cdots dq_n} \quad (17)$$

$$= \frac{\hbar}{\int\limits_{q_n \cdots q_1} \cdots \int \left[\frac{V^{n+1}}{(2\pi)^{3n+4}} \mathbf{P} \cdot |\mathbf{M}_I|^2 \delta_4 \left(\sum_{i=1}^{m} \mathbf{p}_i - \sum_{j=1}^{n} \mathbf{q}_j \right) \right] dq_1 dq_2 \cdots dq_n} \quad (18)$$

which is *nearly equivalent* to the entire system treated as a 'particle' that decays in with 'lifetime' [6]:

$$\tau_{FC_P} = \frac{\hbar}{\mathbf{F}_I} = \frac{\hbar}{\langle \Psi_{(E_0, \mathbf{q}_j)} \mid H_{E^* \to E_0} \mid \Psi_{(E^*, \mathbf{p}_0)} \rangle} \quad (19)$$

where the small difference between the net lifetimes of these representations is primarily due to the 'excitation lifetime' of the detector mode, generally absent in the treatment of the decay process of an unstable particle in the second equation.

If there is no reconfiguration of the incoming signals and target (if any) in this region of space, then a clock has not been 'created' and the reduced fundamental interaction matrix element M_I (Note: equal to the S-matrix (the 'scattering' matrix) except for the δ-function for overall energy-momentum conservation) [33] is zero:

$$\mathbf{M}_I = 0 \quad (20)$$

The above equations taken from the Feynman diagram method can be used to determine for FC 'lifetimes'. 'Lifetime' information from a scattering process is in general is very difficult to compute for 'real' complex systems. The idea here is that a 'collective excitation' of all the entangled components is created by the incoming signals leading to an irreversible decay with the production of outgoing signals. The transformation of the incoming signals by collisional 'processing' in a target 'gate' creates new information in the form of the novel emergent signal states.

Incident signals in region I of a FD node or gate in a causal network are detected or processed (region II) as signal state information by the irreversible 'internal' evolution of the three configuration states of the FD/FC modes of the quantum system (see **Figures 4 and 5**). These are; coherent excitation of configuration modes by signal detection (IIIa), 'self-measurement' or 'adiabatic' entanglement [8] of CEN internal resonances

(IIIb), and environmentally induced decoherence, disentanglement and 'decay' (IIIc) of system CEs with finite 'lifetimes'. NOTE: This three stage process of detection, CE resonance self measurement, and CE decay is conceptually similar to the three stages of decoherence defined by Dodonov, Mizrahi, and de Souza Silva [34]. The reconfiguration proceeds as an irreversible 'decay' of the excited state (region IV) accompanied by an emitted signal (region V) which propagates away from the FC. This may 'reconfigure' the FC to its 'ground state' FD mode. This provides a basic repeatable 'cycle' from which 'atomic' and other clocks are built if input signals or states can be provided by the 'classical' environment . *The decoherence and decay process of an excited state are irreversible* even though the 'system' may be put into a state identical to the pre-excitation state allowing the creation of standard clocks. This should not be confused as a 'reverse' QAT since QATs are 'irreversible' since they point from an excited or unstable single state (e.g. atomic electron transition creation of photons) or CE state (e.g. nuclear n-body multipole or 'phonon' transitions) to 'reconfigured state'.

For region I we have an incoming photon (e.g. γ-ray) approaching a target (e.g. nucleus) in a system that is composed of a distinct quantum state of the signal separated from the distinct quantum state of the target by a 'classical' environment (e.g. vacuum). The 'lifetime' of the signal is the classical 'transit time' from its source to the FD mode of the target. This can be thought of as the lifetime of FC plus vacuum plus signal plus FD combined system. A sort of virtual internal decay of a signal in an extended node to node system.

The 'lifetime' of the signal (region I) is given by:

$$\tau_{\mathrm{I}} = \frac{d_{\text{source to this detector}}}{v_{\text{signal 'velocity}}} = \frac{\hbar}{F_\lambda} = \frac{\hbar}{\langle \Psi_{FD} \mid H_\lambda \mid \Psi_{FC} \rangle_{in}} \tag{21}$$

The 'lifetime' of the signal 'annihilation/absorption/detection' process (region II) in which the signal and the detector form one 'closed' system excited 'discrete' and coherent state is given by:

$$\tau_{II} = \frac{\hbar}{\langle \Psi_{(E^*)} \mid H_{II} \mid \Psi_{(E_0)} \rangle} \tag{22}$$

The system becomes a superposition of the signal induced collective excitation on the n-target states (assumed to form an n-body system such as that created by n-nucleons in a nucleus) of the detector. The lifetime of the signal conversion process into a collective excitation of the n-body detector is given by:

$$\tau_{IIIa} = \frac{\hbar}{\langle(\Psi_1^* \Psi_2^* \cdots \Psi_n^*)\,\Psi_{CE}^* \mid H_{IIIa} \mid \Psi_{(E^*)} \cdot \Psi_S^*\rangle} \tag{23}$$

The superposition of the collective excitation and the components states decouples from a coherent collective discrete system configuration state into a set of coherent unstable states with a CE lifetime given by:

$$\tau_{IIIb} = \frac{\hbar}{\langle(\Psi_1 \Psi_2 \cdots \Psi_n)_d^* \mid H_{IIIb} \mid (\Psi_1^* \Psi_2^* \cdots \Psi_n^*)\,\Psi_{CE}^*\rangle} \tag{24}$$

'Interferences' between the states of the components of the system cause the coherent states to 'decohere' with the loss of quantum information. This decoherence *to* FC mode transition has a '*lifetime*' given by:

$$\tau_{IIIc} = \frac{\hbar}{\langle\Psi_{(E^*)} \mid H_{IIIc} \mid (\Psi_1 \Psi_2 \cdots \Psi_n)_d^*\rangle} \tag{25}$$

which leaves the system in a discrete unstable state coupled to a continuum of decay states in the environment. This system is now 'open'. It is composed of the FC, the vacuum and coupled signals and decays in a finite lifetime with the emission of signals. The 'lifetime' of this stage is given by:

$$\tau_{IV} = \frac{\hbar}{\langle\Psi_{(E_0)} \mid H_{IV} \mid \Psi_{(E^*)}\rangle} = \tau_{II} \tag{26}$$

Finally we have the emitted signal lifetime equal to the classical transit time or the lifetime of a composite system of the FC, the signal, the 'environment', and the FD at the end of the signal trajectory:

$$\tau_V = \frac{d_{\text{from this source to next detector}}}{v_{\text{signal 'velocity}}} = \frac{\hbar}{\langle\Psi_{FD'} \mid H_{\chi'} \mid \Psi_{FC'}\rangle_{out}} \tag{27}$$

7 Collective Excitation Networks (CENs)

Collective behaviors of systems composed of discrete but connected components need to be characterized in order to understand how 'arrows of time' emerge at POCs in complex systems. The concept of 'collective excitations' in the many-body problem [22] and in phonon behavior in solids [24], [25] provides the basis for modeling reconfigurations in POCs. When a set of subsystems (local networks) in a complex system are 'wired' together in a network, they can support coherent superposition of states capable of new collective system behaviors (see **Figure 6**). These collective states have finite lifetimes and decay with the production of 'signals' (e.g. phonons, solitons, plasmons, 'sound waves', etc.).

The first level of complexity emerges when sets of *coupled* Feynman clocks act collectively as a single system with new system energy eigenstates (e.g. molecular spectra) whose unstable excitation modes decay with finite lifetimes. This system is a **Collective Excitation Network** or **CEN**. These CENs can support new *collective excitation states and signals.* They can also act as 'gates', memories, or registers creating and processing signals (information) when embedded in larger networks. This process of 'nesting' of subsystems with collective excitation states provides a means for deriving various hierarchical 'arrows of time' connected with plateaus of complexity. Individual Feynman clocks and CEN units can interact to form higher level CEN 'circuits'. These CEN circuits can become 'gates' with *multiple signal inputs and outputs.* These 'integrated' CEN circuits now generate new POC states.

The 'lifetime' of the 'clock' mode of a general CEN is given by:

$$\tau_{CEN} = \frac{\hbar}{\Gamma_{CEN}} = \frac{\hbar}{\langle \Psi_{CEN_0} \mid H_{CEN} \mid \Psi^*_{CEN} \rangle} \tag{28}$$

where the excited 'clock' state of the CEN decays via the reconfiguration transformation function, H_{CEN}, with the creation of a signal, S_{out}.

The initial state of the CEN in the above equation is created by the detection of an incoming signal, S_{in} , by the CEN composed of a set of j-coupled FCs. This 'system' configuration state, $\mid \Psi^*_{CEN} \rangle$, is the *direct product* of the states of each of the components:

$$\mid \Psi^*_{CEN} \rangle = \left[\bigotimes_{i=1}^{j} \mid \Psi^*_{FC_i} \rangle \right] \bigotimes \mid \Psi_{S_{in}} \rangle \tag{29}$$

The state of the CEN after decoherence ('decay' or 'decoupling') of the CE over the set of FCs results in the emission of a signal, S_{out} . The 'reconfigured' state of the system is:

$$| \Psi_{CEN_0}\rangle = \left[\bigotimes_{i=1}^{j} | \Psi_{FC_i}\rangle\right] \bigotimes | \Psi_{S_{out}}\rangle \tag{30}$$

The decohered FCs may still be bound in a lattice or other n-body configuration ready to detect the next phonon-like signal.

8 Sequential Excitation Networks (SENs)

A SEN is a composite network of FCs and CENs coupled in such a way that information and signals moves from node to node sequentially (see **Figure 7**). The SEN has 'lifetime' representing the sum of all the of the FC, CEN and signal transit 'lifetimes from an initial signals input to a final signal output. The SEN 'lifetime' for this process is given by:

$$\tau_{nsum} \equiv \sum_{j}(\tau_{FC_j} + \tau_{S_j}) \tag{31}$$

where, τ_{FC_j}, is the lifetime of an FC or CEN in the sequence, τ_{S_j} is the signal lifetime between the j-th and $(j+1)$ node.

Feedback, feedforward and **cyclical flow of signals (information)** is also possible in the SEN. This provides a mechanism for the resetting of unstable configurations necessary for quantum computational algorithms. It also provides for adaptive behavior in relatively closed systems like cells. These 'control' mechanisms can be realized by defining signal trajectories or 'circuits' connecting various nodes into hybrid linear and cyclical causal networks. All of the combinatorial possibilities for 'connecting' systems and subsystems together by signal loops provide a means for modelling complex self-adjusting or adaptive behaviors. The transformations of the local states or network configurations in the component FD/FC, CEN, and SEN nodes produce different computational 'lifetimes' for the information 'currents' propagating through them.

9 The 'Special' Theory of Time

Once we have identified quantum clocks as the source for temporal directionality, we can then examine their range of features. We will show how these 'clocks' in communication with each other can form networks in which larger and more complex systems can emerge with system arrows of time emerging from the quantum arrows of time of their components. At increasing levels of hierarchical complexity there are *POCs* such as cells, organs and organisms each with a characteristic arrows of time for the various metabolic activities.

The general equation for the *lifetime* of a system in which the quantum arrow of time is generated by the decay of an unstable configuration to another state representing an 'event' is given by [11]:

$$\tau_{qc} = \frac{\hbar}{\Gamma_I} = \frac{\hbar}{\langle \Psi_f \mid H_{i \to f} \mid \Psi_i \rangle} \tag{32}$$

The **'master arrow'** giving the direction of time for any system is defined by a **time-independent QAT** originating in Feynman clocks and **'pointing'** *from the unstable configuration,* Ψ_i*, to a 'more stable' (intermediate) state or ground state reconfiguration,* Ψ_f *.*

The **quantum time** associated with the quantum clock **'event'** α (lifetime of the *clocks* transition) coupled with the creation of one or more signals is the **'reconfiguration lifetime',** τ_α,

$$\tau_\alpha = \frac{\hbar}{\Gamma_\alpha} = \frac{\hbar}{\langle \Psi_0 \mid H_\alpha \mid \Psi^* \rangle} \tag{33}$$

Note that the denominator is usually referred to as the 'decay rate', Γ_α, which actually represents the reconfiguration process as $\langle \Psi_0 \mid H_\alpha \mid \Psi^* \rangle$. The value of this lifetime is a 'bit' of 'energy of reconfiguration' information.

The **classical time** is the *'measured' difference* between the *detection event 'times'* connected with *two independent signals* from the two separate events **as seen** by a detection system. For event α and event β the observed 'lifetime' or 'elapsed time' between these two (signal detection) events is the 'difference' or 'classical' time between signal detections;

$$\tau_{\alpha\beta} = \Delta\tau = \left| \frac{\hbar}{\Gamma_\alpha} - \frac{\hbar}{\Gamma_\beta} \right| = \left| \frac{\hbar}{\langle \Psi_0 \mid H_\alpha \mid \Psi^* \rangle} - \frac{\hbar}{\langle \Phi_0 \mid H_\beta \mid \Phi^* \rangle} \right| \tag{34}$$

This is the 'time' interval between signal detections form 'events' by an observer. This is the 'classical' 'time' of space-time. This 'time' information 'bit' is a *parameter* in quantum mechanics and not an *observable* like 'energy', 'momentum', and 'position'.

10 The 'General' Theory of Time

Now that we have a 'source' for the quantum arrow of time hypothesized in the special theory of time, it is possible to construct networks mapping the causal relationships between two or more interacting systems (see **Figures 8 and 9**). The general theory of time is a causal network model in which information flow between systems causes the reconfigurations of matter and energy that support evolutionary processes at all spatial scales from microscopic to cosmic.

The network model is built using nodes (Feynman detectors and clocks) and arcs (signals and their trajectories). We will see later that ensembles of nodes can form sub-systems from which new collective excitation modes and behaviors emerge. These behaviors can also be modeled as unstable states of collective excitation network (CEN) detectors and clocks that 'decay' with finite lifetimes. These aggregate clocks produce signals representative of the collective system configuration state transformations (e.g. phonons, plasmons, excitons, solitons, and 'classical' states resulting from the decoherence of sets of interacting quantum states). These clocks can be built using local causal networks embedded or nested within larger complex systems (e.g. organelle 'clocks' within a cell 'clock' in an organism 'clock'). It should be apparent that there is no absolute clock and that the nature of time for a given causal network is dependent on it's structure. All changing systems described with causal networks have the quantum arrow of time in common at their primitive foundations. The various lifetimes of unstable configurations of matter at all levels of complexity are the result of the geometry, composition and energy of their configurations. Feynman nodes (detector and/or clock modes) are the building blocks of causal networks.

11 Plateaus of Complexity (POCs)

As we have seen above collective excitations are the markers for new levels of complexity in hierarchically connected systems. Solitons represent 'classical' wave packet signals in macroscopic scale systems. Their origins are found in the plateaus of complexity of the subsystems from which they are composed. Since CEs are the result of the superposition of *quantum states resulting in another quantum state,* classical states emerge as the result of the interaction of this system with an *environment.* Plateaus of complexity are the interface between the quantum properties of the system and its environment. This is how quantum systems in CENs and SENs can create 'classical' signals and behaviors as a result of the environmental measurement by an observing system in which it is embedded. The environmental component makes the quantum system 'open' to classical signal production. If the environment is the boundary condition on the quantum system it may be 'closed' but still act like an open system which can decohere (e.g. decay of FC mode of the initial state of the universe in Big Bang scenarios).

Feedback, feedforward and **cyclical flow of signals (information)** is also possible in the SEN. This provides a mechanism for the resetting of unstable configurations necessary for quantum computational algorithms. It also provides for adaptive behavior in relatively closed systems like cells. These 'control' mechanisms can be realized by defining signal trajectories or 'circuits' connecting various nodes into hybrid linear and cyclical causal networks. All of the combinatorial possibilities for 'connecting' systems and subsystems together by signal loops provide a means for modelling complex self-adjusting or adaptive behaviors in which the continual transformations of the local states or their relative network configurations of FD/FC, CEN, and SEN nodes produce different computational 'lifetimes' for the information 'currents' propagating through them.

12 Signal Mapping

Signal mapping is the process by which signals carrying state information are detected and their 'information content' (induced state in detector) put into ordered sets with respect to a standard or internal clock (see **Figure 10**). This involves creating states in a 'memory' so that their causal relation to other events can be 'read' and interpreted. 'Time' emerges as the functional value of the energy eigenstates in the detectors as information 'bits' assigned to a detected signal from an 'event' (FC created signal) in 3-space (possibly n-space at the Planck scale for higher dimensional quantum modes of 'strings' etc.). The magnitude of the states (in 'bits') are determined by the conversion of state information by a detector and kept in a memory register as a mirror state of the original source state created by the decay of the signal generating FC. The state in the memory can be 'scanned' (measured) by a shift or parallel data register through the action of an internal or standard clock. This is similar to data ordering in classical computational hardware. The key point here is that all of the systems (FC, Signal, FD, Memory and cyclical data sequencing clock) may be 'quantum' systems with microscopic or classical sizes. In this way the relative order and magnitude of the conventional 'time' interval *between events* is the result of the processing of state information in the 'gates' of a *quantum computer.*

The **temporal correspondence principle (TCP)** briefly hinted at in a previous paper [11] is now easier to see using the tools developed above. We can see that the various 'arrows of time' in complex systems arise naturally from collective behaviors in the subsystems in the systems causal network. The emergence and flow of information created at these various plateaus of complexity defines the evolutionary 'pointers' used to conceptualize these macroscopic arrows. Ultimately all of these arrows can be traced back to irreversibility at the quantum level.

The TCP states that all macroscopic arrows of time are *collective arrows of time* created from the *fundamental quantum arrow of time* defined by *information flow* in causal networks of FCs, CENs, and SENs, and the signals between them at *discrete plateaus of complexity* for material systems. The signals emerging from the decoherence induced by a CE-environment transport 'information' from the 'boundary' represented by the system geometry for a given plateau of complexity. The creation of information in the CE-apparatus-system excited 'boundary' configuration by decoherence represents all the information that can be obtained about the evolution of states. This is similar to the 'quantum holographic principle' for open systems [9] except that we treat the 'environment' of a closed system as the set of 'collective excitations' causing decoherence of the initial unstable set of coherent configuration states and the boundary apparatus (surface 'tension' due to internal interactions and forces) into one of all the possible reconfiguration states.

13 Examples

The following examples indicate the range of possible applications for microscopic to cosmic systems. These 'sketches' will be examined in more detail in future papers.

13.1 The 'Neutral Kaon' Feynman Clock

The observation of time-reversal non-invariance in the neutral kaon system [37], [38], [39] by the CPLEAR collaboration provides an example of a decay process that was expected to be symmetric (reversible) in time where the 'forward' or 'backward' reactions in space would occur with equal probability (see **Figure 11**). The fundamental asymmetry is deduced for the quantum superposition state of the neutral kaon and its anti-particle system:

$$K^0 \rightleftarrows \overline{K}^0$$

using intermediate reactions and decay rate asymmetry relations[37]. There is a bias of about 6.6 parts in 1000 towards the $\overline{K}^0$ configuration.

The coupling of the two coherent states $|K^0\rangle$ and $\left|\overline{K}^0\right\rangle$ can be thought of as forming a two level metastable oscillating Feynman Clock. The state of the initial kaon-Feynman detector mode of the system is:

$$|K_{FD}\rangle = |K^0\rangle \otimes \left|\overline{K}^0\right\rangle \tag{35}$$

The composite state of the system upon detection of a decoherence initiating signal, $|\lambda_\delta\rangle$, ('measurement' by another system or the 'environment') is:

$$|K^*_{FC}\rangle = |K^0\rangle \otimes \left|\overline{K}^0\right\rangle \otimes |\lambda_\delta\rangle = | K^0, \overline{K}^0, \lambda_\delta\rangle \tag{36}$$

After decoherence the state of the system is a sum of two decoupled states:

$$|K_{FC_\delta}\rangle \approx (0.9934)\,|K^0\rangle + \left|\overline{K}^0\right\rangle \tag{37}$$

This decays further to either the kaon or its antiparticle:

$$|K_{FC}\rangle = |K^0\rangle \tag{38}$$

or

$$|K_{FC}\rangle = \left|\overline{K}^0\right\rangle \tag{39}$$

With two distinct lifetimes of the decoherence process is:

$$\tau_{K^0} = \frac{\hbar}{\Gamma_{K^0}} = \frac{\hbar}{\langle K^0 \mid H_{FD\to FC} \mid K^0, \overline{K}^0, \lambda_\delta\rangle} \tag{40}$$

or

$$\tau_{\overline{K}^0} = \frac{\hbar}{\Gamma_{\overline{K}^0}} = \frac{\hbar}{\langle \overline{K}^0 \mid H_{FD \to FC} \mid K^0, \overline{K}^0, \lambda_\delta \rangle} \tag{41}$$

where the experimental *asymmetry* in terms of decay rates we might expect that the *temporal asymmetry* is:

$$A_T^{\exp} = \frac{\Gamma_{\overline{K}^0} - \Gamma_{K^0}}{\Gamma_{\overline{K}^0} + \Gamma_{K^0}} = \frac{\frac{\hbar}{\tau_{\overline{K}^0}} - \frac{\hbar}{\tau_{K^0}}}{\frac{\hbar}{\tau_{\overline{K}^0}} + \frac{\hbar}{\tau_{K^0}}} = \frac{\frac{1}{\tau_{\overline{K}^0}} - \frac{1}{\tau_{K^0}}}{\frac{1}{\tau_{\overline{K}^0}} + \frac{1}{\tau_{K^0}}} \cong 0.0066 \tag{42}$$

This indicates that we might expect the $\overline{K}^0$ to have a shorter decoherence 'lifetime' relative to the K^0. It is important to understand that the lifetimes of these particles is defined from the point at which an induced excited collective state is created by a **classical intervention 'signal',** $|\lambda_\delta\rangle$ [40]. In is case the intervention triggers the decoherence of the composite coherent system into one of two possible particle identities. Treating the oscillating neutral kaon 'current' as a Feynman detector prior to a classical intervention and transforming it into a Feynman clock upon the intervention, there is the possibility of observing different decoherence lifetimes for the neutral kaon and its antiparticle. This will be explored further in a later paper.

13.2 The 'Double Slit' CEN-SEN System

We can recast the '*double slit*' experimental apparatus [41] into a SEN (see **Figures 12, 13**). The 'information' input to this SEN originates in a signal source (FC). A set of *coherent* signals (e.g. photons of wavelength λ_{signal}) is incident on two slits (FCs) which collectively form a CEN 'gate'. The incoming 'signals' are processed by the CEN gate creating an entangled set of outgoing signals. A 'measurement' by the 'environment' (e.g. an observer or a 'CE-self-measurement') on the CEN gate while the 'signals' are being processed can cause *decoherence*. This destroys the quantum interference pattern and gives 'classical' probability distributions over the detector array. The signals are then 'disentangled'.

The detector array is coupled to 'memory' registers. The superposition of *entangled* signals in the FD array create the interference '*collective excitations*' of the *entire system*. The *coupled* slits can be treated as a CEN source for the FD array.

13.3 Photosynthesis and SENs

Photosynthesis is part of the 'energy processing' causal network essential to all life [35] (see **Figures 14-19**). The conversion of starlight into usable biological energy begins with photosynthesis. A dual network of Photosystem I and Photosystem II form a coupled hybrid CEN/SEN in the surface of the thylakoid membrane of grana in the cells of plant and some bacteria. The simplified model used here does not account for real details such as the cyclic behavior of complex chemical pathways controlled by feedback mechanisms.

Photon absorption triggers atomic and molecular reconfigurations transitions expressed as many different types of physical and chemical processes in the photosynthetic SEN of events. Some of the energy conversions occur by dissociation ionization, direct reactions, charge transfer, excitons, isomerization, intermolecular energy transfer, intramolecular or radiationless transfer, luminescence, fluorescence, phosphorescence, diffusion, physical quenching, resonant chain reactions (SENs), internal conversion (e.g. decoherence) and 'thermal' effects in unstable systems [42].

The photosystems in light harvesting purple bacteria [36] have been examined with the quantum description of **excitons**. The lifetimes of states and configurations involved in the conversion of photons into various forms of exciton and chemical signals in the Photosynthesis network in plants can be mapped as a causal network composed of Feynman detectors and clocks, CENs, and SENs with both quantum and 'classical' aspects.

The chloroplast is a metabolic causal network of chemical and physical FCs contained by a **membrane.** The membrane defines a chemical POC. The 'lifetimes' of the states of the configurations of the FCs imbedded in the membrane contribute to the overall processing time of photons through the electron transport chain (SEN) to end products such as ATP.

The exciton transfer time or signal lifetime in an **antenna complex** is modeled from the work done on **purple bacteria** with peak LHC-I photon absorption at 875 nm and two LHC-II photon absorptions of 850 nm at the 'top' and 800 nm at the 'bottom' of the thylakoid membrane with respect to the center of the granum. This example is in principle like the PS I and II systems in plants that absorb at 700 nm and 680 nm respectively. The following example of energy flow in the Antenna complex of purple bacteria is used due to the fine use of quantum methods by the authors; *Thorsten Ritz, Xiche Hu, Ana Damjanovic,* and *Klaus Schulten* [36] for the description of a complex quantum process.

Exciton transfer in an initially *absorbing* LHC (type II) state to an *accepting* LHC (type II) state (sequential sets of LHC-IIs form a SEN connected to the Reaction Center (RC) inside the antenna complex) is given by:

$$\tau_{II} = \frac{\hbar}{\Gamma_{II}} = \frac{\hbar}{\langle \Psi_{II_2} \mid H_{II_{1\to 2}} \mid \Psi_{II_1} \rangle} \approx 6.21\,\mathrm{ps} \tag{43}$$

for the case of purple bacteria where $H_{1\to 2}$ is the effective Hamiltonian for the excitation transfer between LHC-1 and LHC-2 for example. Once the excitation has traversed some hundred ('n') similar LHCs (each with a lifetime of about 6.21ps) it arrives at a LHC (type I) ring surrounding the central Reaction Center molecule. The LHC-II to LHC-I transition is more complicated due to the four degenerate energy states of the LHC-I. The spread in coupling energies gives signal transition lifetimes in a range of 3.27 to 3.42 ps.

$$\tau_{II\to I} = \frac{\hbar}{\Gamma_{II\to I}} = \frac{\hbar}{\langle \Psi_{I_{(2,3)}} \mid H_{II\to I} \mid \Psi_{II_n} \rangle} \approx 3.42\,\mathrm{ps} \tag{44}$$

for the pair of degenerate states $\mid \Psi_{LHC_I}\rangle = |\Psi_{I_2}\rangle, |\Psi_{I_3}\rangle$. For the other pair of degenerate states $\mid \Psi_{LHC_I}\rangle = |\Psi_{I_4}\rangle, |\Psi_{I_5}\rangle$ we have:

$$\tau_{II\to I} = \frac{\hbar}{\Gamma_{II\to I}} = \frac{\hbar}{\langle \Psi_{I_{(4,5)}} \mid H_{II\to I} \mid \Psi_{II_n} \rangle} \approx 3.27\,\mathrm{ps} \tag{45}$$

Now we have a transfer from the LHC-I lowest energy excitons to the central RC. Ritz et al calculated the exciton transfer time as 52 ps compared with an experimental value of 35 ps. The sum of the lifetimes for each of the transitions (FC 'lifetime' + 'exciton signal lifetime' together) gives the net SEN 'lifetime' associated with the energy flow through the antenna complex.

The *state information* is transferred from FC to FC which can then be converted into 'time' by comparison of signal induced detector event correlations with the observers standard clock using the method of signal mapping. The general principles of the causal network approach created by information flow through various levels of organizational complexity lead to 'arrows of time' defined for specific CE behaviors of POCs in those systems.

The QATs originating in the FC, CEN and quantum SEN processes in a cell are the building blocks of larger biological networks such as trees with their energy and chemical fluid transport systems creating daily and seasonal 'arrows of time' for overall complex system configurations of a superposition of various metabolic causal networks. This naturally leads to animal control and transport systems derived from the FC level to the central nervous system and the brain.

13.4 FCs and Gravitational Effects on Signals

Nuclear Feynman clocks in a strong gravitational field can emit redshifted signals (see **Figure 20**). This shift in the energy states (by 'equivalent mass' shifts) lead to delayed decay times of excited unstable nuclear configurations [43]. The increased lifetimes of these states are recorded as the frequency shifts of emitted photons as detected by a Feynman clock in a weaker region of the gravitational field. The SEN of information flow as determined by signal trajectories from an FC in a strong gravitational field to a detector at 'o' (the point of cancellation of the two fields) appears sequential unless the entire system is viewed as the internal decay of a state in a single CEN formed by the central source, signal and detector.

Either description should yield the same lifetime for the process. The situation becomes more complicated if the second 'orbiting' system form a massive gravitational 'dipole' CEN. The red and blue shifting of a signal between the two masses is a electromagnetic resonance. One can envision a source system decaying due to strong or weak interactions orbit around the mass on the left. The signals may not be photons but other particles representing a possible link of the fundamental interactions from which they were created to gravitation. Since these systems are intrinsically 'quantum' they can be thought of as a mediating strong, weak and electromagnetic information flow inside a gravitational CEN. This information flow generates the 'lifetimes' of the 'unified' states of the collective system. In this sense the information state of the system represents a possible avenue for the creation of a quantum gravity and a context in which the fundamental interactions of nature are unified by novel states created in CEN or SEN systems. The 'lifetimes' derived from state information created by reconfigurations of unstable systems may be 'independent' of the fundamental interactions driving them. They might provide a context in which fundamental interactions can be unified as some form of 'information field' or 'info-space'.

The lifetimes of signals created in and travelling through gravitational fields are red or blue shifted depending on their directions. The shift originates at the point of emission (G_1) or detection (G_2). The common interpretation of the energy shift in a photon is that it is due to 'continual' energy loss due to the work done by the photon in escaping out of a potential well. However, the photon (signal) energy (frequency) is *conserved* as it propagates in a static gravitational field [43].

The energy shift of an emitted or absorbed photon by a 'mass shifted' FC source in a gravitational potential provides a key to forming a 'quantum gravity' theory. It is at this level that the gravitational interaction with signal production due to the strong, weak or electromagnetic interactions in 'orbiting' FCs are coupled to gravity. This coupling can be viewing in the finite decay 'lifetime' arising from the decoherence induced mass-energy shift created by the gravitational 'environment' on an n-body FC.

Using special relativity, the 'proper time' or gravitationally shifted FC decay 'lifetime', τ_{FC_G}, of the intrinsic decay or decoherence lifetime, τ_{FC_0}, due to a potential ϕ at the 'location' of the FC is:

$$\tau_{FC_G} = \tau_{FC_0}\sqrt{1+\frac{2\phi}{c^2}-\frac{u^2}{c^2}} \tag{46}$$

$$= \frac{\hbar}{\Gamma_{FC_0}}\sqrt{1+\frac{2\phi}{c^2}-\frac{u^2}{c^2}} \tag{47}$$

$$= \frac{\hbar}{\langle FC_0 \mid H_{FD\to FC} \mid FD_0\rangle}\sqrt{1+\frac{2\phi}{c^2}-\frac{u^2}{c^2}} \tag{48}$$

where u is the relative velocity of the FC system at the point of signal emission. This can be interpreted as the shift in the decoherence lifetime of the unstable state of the FD decay to the FC signal emission state and not due to the 'attraction' of the signal (photon) to the gravitational mass. In a modified general relativity framework for a 'static' potential without a 'time' dimension ($i, k = 0$ is the temporal component) the time-independent metric is $g_{ik}(x)$,where $i, k = 1, 2, 3$ and the 'signal' transit interval (spatial) is :

$$ds^2 = g_{ik}(x)dx^i dx^j \tag{49}$$

the usual 'proper time interval', $d\tau$, is :

$$d\tau = \frac{ds}{c} \tag{50}$$

and the shifted lifetime of 'at rest' FC lifetime, dt , is:

$$dt = \frac{dx^0}{c} \tag{51}$$

we have the relationship between the two is

$$d\tau = \sqrt{g_{00}}dt \tag{52}$$

where $g_{00} = 1 + \frac{2\phi}{c^2}$. In the static case (weak gravity approximation) integrating the equation above we have:

$$\tau = t\sqrt{g_{00}} = t\sqrt{1 + \frac{2\phi}{c^2}} \tag{53}$$

which is the same as for the special relativity case where the FC velocity is zero, $u = 0$, with respect to the gravitational mass creating the potential. We now have the decoherence lifetime shift for a composite system in which gravitation is coupled to the quantum FC:

$$\tau_{FC_G} = t_{FC_0}\sqrt{g_{00}} = t_{FC_0}\sqrt{1 + \frac{2\phi}{c^2}} = \frac{\hbar}{\langle FC_0 \mid H_{FD \to FC} \mid FD_0 \rangle}\sqrt{1 + \frac{2\phi}{c^2}} \tag{54}$$

This can be interpreted as the lifetime of the collective excitation state of an unstable system whose energy is:

$$E_{FD_G} = E_{FD_0} - E_\phi \tag{55}$$

and

$$E_{FC_G} = E_{FC_0} - E_\phi \tag{56}$$

where the resulting shifted signal (photon) energy is:

$$\Delta E_{\lambda_G} = h\Delta v_{\lambda_G} = \frac{h}{\tau_{FC_G}} \tag{57}$$

where the lifetime of a cyclical clock between decay and the 'immediate' resetting of an excited state is τ_{FC_G} for an unstable state of an FC orbiting in a gravitational field with a 'gravitational shift' in frequency Δv_{λ_G}.

The shift occurs at the point of emission. At the zero-field point 'o' between the two masses M_1 and M_2 a detector sees the signal S_1 redshifted relative to its own inertial frame. If it can absorb and re-emit this red-shifted signal, S_2 , (at the same frequency) towards the second orbiting mass M_2 then it will appear to be blue-shifted relative to the target FD/FC.

The placement of a FD/FC at 'o' illustrates each point of space can be thought of as a system through which information passes. This leads to the possibility of quantizing gravity by treatment of points in space as non-zero energy (Higgs vacuum energy) 'virtual Higgs FCs' whose 'lifetimes' are the same as the signal transmission lifetimes 'shifted' by gravity through that 'point'. A quantized gravitational field could be created by a CE-bounded infinite set of virtual Higgs FCs forming a CEN along an information (signal) trajectory. The SEN formed by the causal network of virtual Higgs FCs is a 'source to detector' CEN whose CE 'lifetime' is equal to the classical signal transit time.

13.5 Quantum Computers

Quantum computers and computation provide a new area of research in which the flow of state information (signals) through 'quantum' gates, registers, and memories [44], [45], [46], [47] can be modeled using causal networks of FCs, CENs, and SENs. The Feynman clock is a general signal processing gate in which physical logic is applied to states created in its FC mode. Sequential excitation networks formed with these gates are used to build quantum computers. The signals are processed by Feynman detector modes of a quantum gate. Feedback and feedforward of signals in these systems are used for algorithmic computations and the creation of new information structures distributed in quantum and classical registers and memory. The quantum computers when generalized for the multi-state input and output capabilities of Feynman node detectors, clocks, CENs, and SENs can define more complex computational networks with local continua of information spectra. These systems are **'FC-computers'.**

The Photosystem II example above represents a form of FC-computer in that the causal networks in the thylakoid membrane process 'quantum' signals of various chemical and physical forms within larger cellular and organismic networks.

13.6 The Universe as a Feynman Clock

The discrete initial excited state of the Big Bang singularity can be thought of as the unstable state of a Feynman Clock. It is generally assumed the initial state of the universe was 'closed' due to the presumed definition of the 'universe as all that there is'. A collective excitation or perturbation (due to an 'interference' effect of the energy modes of the initial state) can be an '*environment*'. If this environment decoheres due to a process of 'self-measurement' then the tools of '*decoherence*' [10] can be applied. A 'cosmic' QAT emerges from the decoherence induced by the CE-perturbations causing the 'decay' of the system.

This state is created by a global Planck collective excitation due to the 'constructive interference' of all the possible initial coherent energy states of the universe coupled to a continuum of 'decay' modes. These decay modes include the creation of expanding space (vacuum) via inflation, the decoupling (freezing out) of the fundamental interactions of matter [5], [48], [50] and the creation of causal networks through gravitationally induced aggregation of information, signals and FCs.

The 'holographic' nature of information flow and 'storage' in the early universe explored by Paola Zizzi [49] provides us with tools to help connect the decoherence in quantum microsystems in the present epoch with their sources in the decoherence processes of the early universe. The collective excitation of the universe 'measures' the internal coherent superposition of energy configurations causing decay via 'decoherence' into an inflationary epoch of decohered states. These states create the 'vacuum' as they lose coherence with the initial CE of the universe.

The decay process is then a CE of the boundary conditions of the initial state of the universe. The CE may in fact be the hypothesized 'quintessence' created to account for 'missing energy' [53] needed to account for the difference between the matter density and the critical density of the early universe. This missing energy may be resident in the 'ground states' of the virtual Higgs FCs forming the 'vacuum'.

The superposition of energy states of the unstable configuration of the FC-universe combined with a CE-phonon boundary perturbation is:

$$\mid \Psi_{U_{CE}}\rangle = \left(\bigotimes_{i=1}^{\infty} \mid \Psi_i\rangle \right) \bigotimes \mid\Psi_{CE}\rangle \qquad (58)$$

decohering into the Big Bang FC:

$$| \Psi_{U_{FC}}\rangle =| \Psi_{VAC}\rangle \bigotimes | \Psi_{Mass-Energy}\rangle \bigotimes |\Psi_{Gravity}\rangle \qquad (59)$$

with 'decay' products such as 'space' (with a non-zero energy density Higgs vacuum), fundamental FC-particles, and 'frozen' POC-phonon mass density perturbations. The fundamental interactions between particles emerge from the decoherence of 'interference terms' between topological inhomogeneities in the energy density function forcing a 'phase transition' with a 'decoherence lifetime':

$$\tau_{\delta_{BB}} = \frac{\hbar}{\Gamma_{CE}} = \frac{\hbar}{\langle \Psi_{U_{FC}} \mid H_{CE \to FC} \mid \Psi_{U_{CE}} \rangle} \qquad (60)$$

If the energy of the initial CE of coherent energy states remains below the threshold for expansion (i.e. decay) then the universe remains in a 'stationary' state and no evolution (i.e. Big Bang) is possible. Since the initial state must be unstable with at least enough collective excitation energy to create the global phase transition then the universe would have originated from a **non-tunneling decay** of an unstable *non-stationary* discrete state. This FC mode of the universe is *coupled* to a continuum of possible reconfiguration states (e.g. inflationary transition, freezing out of fundamental interactions, and biochemical evolution). This *coupling* is the '**first cause**' of all subsequent reconfiguration processes and the emergence of POCs throughout the vacuum of space.

13.6.1 The FC-Universe as a 'Quantum Computer"

The evolution of the FC-universe into a hierarchy of complex systems of causal networks forming a 'quantum computer' is a topic for further speculation [32]. The quantum computer analogy may be explored by taking the position that the initial early universe was a FC or CEN that decohered to a configuration of matter and energy that then 'decayed' in an inflationary SEN of branching, subdividing, and hierarchically connected FC, CEN and SEN 'gates'.

As the mass-energy-information density 'locally' increases in the form of galaxies, stars, planets and humans, we see that the density of 'signals' and therefore available information (states) forming causal links between these spatially distinct systems decreases as particle, atomic, and molecular *FC density* of space declines due to expansion of the universe. The increase in local POCs is in stark contrast with the increasing unavailability of energy sources in an expanding universe.

The continuous evolution and branching of causal networks of matter and signals makes it difficult to treat the universe as a 'single' quantum computer system representing all of the emergent structures in the universe throughout its reconfiguration history. This does not mean that the universe itself is not a 'quantum computer', but that it might be a FC-quantum computer which can accommodate the complex hierarchical causal networks and the signal mediated information flow in them.

13.6.2 The 'Cosmic' QAT and CMB-Phonons at the Beginning of the FC-Universe

Understanding the origins of the QAT associated with the initial state of the FC-universe provides an opportunity to understand the critical 'Hubble Flow' parameter determining the 'past' and 'future' expansion rate of the universe as mapped by mass distributions in the form of clusters and super-clusters of galaxy 'signals' originating in the decoherence (or decoupling) of cosmic microwave background (CMB) photons from matter. This 'freezing out' epoch marks the emergence of remnant thermal signals [56] mapping the primordial quantum density perturbations caused by global CE-phonons in the 'quantum' universe.

These temperature maps of the microwave sky indicate the approximate angular separation between two 'hot spots' on these maps is of the order of 2^0 to 5^0. When the Universe was about 300,000 years old a 'global' POC emerged where the **cosmic phonons** associated with the **CE density perturbations** *'froze out'* in a process of 'decoherence' of the previously entangled matter-energy states. The Universe had a 'diameter' of about 10^{-3} cm at this point. Using the approximate angular separation between 'hot spots' as indicators of phonon density 'wave' maxima, the 'wavelengths' of these CE perturbation cosmic phonons at the point of photon-matter decoupling is in the approximate range of 1.7×10^{-5} to 4.3×10^{-5} cm.

This FC transition resulted in 'decay' products like the CMB radiation, the 'vacuum', and the gravitationally driven hierarchical clustering of matter and energy seen in the large scale structure of galaxy distributions around 'bubbles' and 'voids' [55]. These gravitational 'POCs' are a historically connected to the **entangled** quantum CE perturbations (quintessence? [53]) in the initial state of the FC-universe.

13.6.3 The 'Anthropic Principle' in a FC-Universe

The 'anthropic principle' implies that what we observe today in the evolving universe 'appears' the way it does because we are here only as a result of the special initial conditions or 'fine tuning' at the beginning of the universe that causally *directed* our emergence as an end result. Causal networks can be formed with open or closed signal connections between all the nodes. The open nature of space allows for signals to create open networks between distant systems as the universe evolves. Locally 'closed' systems are formed by gravitational clustering of matter and energy. As long as signals from clocks can reach detectors, then new systems can emerge without 'fine tuning'. The stochastic signal trajectories involved in open causal networks may be *backwards traceable* to earlier configurations of the universe but this 'after the fact' approach is retrodictive and can produce fallacious historical causal networks where there were none. This limits the usefulness of the anthropic principle as a tool for exact determination of the initial conditions of the FC-universe. It may however remain useful for understanding the 'cosmological constant' if for nothing else [52].

13.7 'Unification' of the Fundamental Interactions

The strong, electromagnetic, weak and gravitational forces can drive reconfiguration processes in FCs, CENs and SENs. In this sense all of these interactions have 'lifetimes' and therefore information generating capabilities in common and are therefore 'unified' in a information space. The 'emergence' of the 'separate' fundamental interactions during the evolution of the FC-universe at **POC 'phase transitions'** is accompanied by the creation of open and closed 'branch' systems of causal networks of interacting matter and signals. The systems can decouple in space (the vacuum) and connect to other systems in later stages of evolution by gravitational cluster and the process of energy and information transfer via signals.

For a FC reconfigured by the strong interaction we have a decay or decoherence lifetime τ_U :

$$\tau_U = \alpha \tau_{strong} = \frac{\hbar}{\Gamma_{strong}} = \frac{\hbar}{\langle \Psi_{S_f} \mid S_{i \to f} \mid \Psi_{S_i} \rangle} \tag{61}$$

For a FC system driven by the weak interaction (or 'electroweak') we have:

$$\tau_U = \beta\tau_{weak} = \frac{\hbar}{\Gamma_{weak}} = \frac{\hbar}{\langle \Psi_{W_f} \mid W_{i\to f} \mid \Psi_{W_i}\rangle} \tag{62}$$

For a FC system driven by the electromagnetic interaction we have:

$$\tau_U = \delta\tau_{em} = \frac{\hbar}{\Gamma_{em}} = \frac{\hbar}{\langle \Psi_{EM_f} \mid EM_{i\to f} \mid \Psi_{EM_i}\rangle} \tag{63}$$

and for a gravitational FC system we have:

$$\tau_U = \epsilon\tau_{grav} = \frac{\hbar}{\Gamma_{grav}} = \frac{\hbar}{\langle \Psi_{G_f} \mid G_{i\to f} \mid \Psi_{G_i}\rangle} \tag{64}$$

where the lifetimes are related by real scalar constants α, β, δ, and ϵ. The unified 'lifetime', τ_U is then:

$$\tau_U = \alpha\tau_{strong} = \beta\tau_{weak} = \delta\tau_{em} = \epsilon\tau_{grav} \tag{65}$$

These four prototypical systems are reconfigured by different forces but their signals provide a rather obvious and perhaps trivial way of establishing an ad hoc unification of the fundamental interactions of matter in an *information space* [17]. The key to this type of unification is recognizing the dimensional equivalence of the 'lifetimes' and therefore the source 'information' common to all the fundamental interactions.

Signals generated in the decay processes above carry state information to detection systems where the signal generating events can be 'measured' with respect to each other as functions of 'arrival times', signal spectra energy distributions, and spatial directions. This process of signal mapping by an observing system creates the 'times' in the ordered sets of sequential events. The ordering is with respect to an internal or external standard 'cyclical' FC system. The *differences* in the order of the detected signal states can be used to create the 'difference times' or secondary 'event times' used in the 'coordinates' and time dimension of the space-time of special and general relativity.

At a subtle level it is the *information* (e.g. specific energy states associated with 'signals') flow between these systems that may ultimately provide a context for working 'backward' from collective features of systems to the unification of physical laws in the microscopic domain of particle physics.

This represents a rather obvious and perhaps trivial way of viewing the unification of the fundamental interactions of matter from the information and 'lifetime' frame of reference. The key to unification may be seen in the 'lifetime' or information terms common to all theses interactions. This occurs in the dynamic transfer of state 'information' flowing between the casual network 'gates' of the universe modeled as an evolving Big Bang Feynman Computer.

13.8 Neurons and Neural Networks

Neurons represent a challenging example of clock and gate properties (see **Figure 21**). The detailed physiology is beyond the scope of this paper. A drastically simplified model of neurons as a FD/FC system with internal SENs and CENs is presented to illustrate that POC properties such as 'action potentials' can be modeled from the FC-causal network approach. '*Orderparameters*' [64],[65] as configuration 'information' can be used to characterize differences between collective excitation states of neural network system POCs. Irreversible state transitions in neuron POCs have finite 'lifetimes'.

The 'direction' of a POC transition from collective excited state with the decay of a CE can be *interpreted* as an 'arrow of time'. The coupling of the open quantum system like the brain to external (environmental) stimuli (signals) via sensory (detector) systems reproduces the microscopic behavior of Feynman clocks at a 'classical' scale. The spontaneous shift in collective states of neural networks in the brain is caused by the 'measurement' of these states by the signals sent to it by sensory detectors. Sense signals can 'decohere' some of the stored memory states by overprinting them with new state configurations.

The transport of state information as a CE [28] along the axon of a neuron is a SEN of 'nearest neighbor' Na^+ and K^+ ion FDs and FCs forming a local CEN *across* the axon plasma membrane. The surface of the axon is a cylindrical causal network with approximately a 75 millivolt potential normal to the membrane [58]. An annular CE propagates along the axon as an 'action potential' where an excess positive charge in the interior of the axon forms a depolarized collective excitation in the form of local concentrations of entangled Na^+ ions. The propagation of a 'classical' electric field in this case may be decomposed into the sequential emergence and decay of CEN states fixed with respect to the axon. The CEN is created as a transient structure by the 'entanglement' of ion quantum states acting as a single mesoscopic quantum system. The CE action potential is a mesoscopic 'soliton' but it is also a quantum CE state of the quasi-particle CEN whose position is defined by the centroid of the ion current distribution inside the axon.

Modeling neuron behavior by analogy with discrete electrical components and circuits [60] is useful for the description of network components when considering the CEs as 'classical' signals. We propose that the FC causal network model may help to clarify the transition (if any) from the microscopic quantum origins of 'time' and information through various biological plateaus of complexity upwards into the macroscopic or 'classical' scale. At each new level of complexity, new signals and information can emerge that are connected in a fundamental way to the network of quantum systems from which they are built. The details of the causal network approach to signal processing properties of various structures in the neuron are beyond the scope of this paper and will be addressed in a later paper.

13.9 CEs and the Emergence of Consciousness

How does *consciousness* emerge in the complex neural networks of the brain? Various approaches to look at the question of whether the state of consciousness is a fundamentally a 'quantum' or 'classical' phenomena [66],[57], [61], and [62]. An approach to this problem is to see what may be learned by using the tools outlined in this paper. Starting with quantum sources of primary (FC), secondary (CE, CEN, or SEN) and tertiary (POC) 'information' states at the microscopic atomic and chemical scale can configurations of these systems emerge such that a CE over many neurons can be generated? Can this CE or a series of CEs produce 'consciousness'?

The source of QATs at the chemical level in neurons provides foundation for building causal networks leading to POCs ranging in scale from mesoscopic processes in neurons to neural SENs (e.g. central nervous system) with 'memory' ('read/write' POCs) upward to larger biological features of the brain like the cerebral cortex. The brain is therefore a hierarchical system which spans a range of complexity from photon detection in the eye at the FD/FC level to the complex 'classical' POCs associated with 'brainwaves'. Electromagnetic brainwave 'signals' can act a source of decoherence on a CE consciousness state in a neural network. They can also coordinate the transition process from one CE state to another by *entanglement synchronization* of neuron states. At each level there emerge characteristic collective behaviors or excitation states with specific lifetimes .

CEs in the brain (see [26], [28], [27]) present a challenging problem since the 'discrete classicality' of the neurotransmitter biomolecules and their transport mechanisms between neurons complicate any coherent description of coordinated and synchronized states of neurons in a CEN. These entangled states of neurons are necessary for the creation of the SEN processing of CEs triggering a *resultant* CE state identified with global neural behaviors such as '**attention**' [67] and consciousness.

In this model '**attention**' is the same as consciousness if the neural network is a SEN of a linear progressions of CEs. An **attention state** of a network is the resultant meta-CE superimposed on the network. Attention is 'lost' or diluted by entanglement of more than one concurrent CE states superimposed on the same networks responsible for consciousness. These competing CEs can interfere, decohere, amplify, and create novel local or distributed CE states in the various overlapping and contiguous networks of the brain. The hierarchical superposition and interference properties of the CEs provide a mechanism for building the complex and perhaps 'single' CE states emerging and decaying in a quasi-continuous SEN of consciousness.

The overlap of local (lobe specific functions) and global CEN states of the brain can give rise to 'perceptions', thoughts and the sense of time. The internal clock of the brain may be a hybrid system of heart beats and CEN decay rate controlling neurotransmitters. The internal sense of time derived by the mapping the brains SEN 'processing rates' of sequential CEN states relative to external environmental processes can give the sense of 'time' speeding up or slowing down. The brains SEN processing rates can be delayed or sped up with drugs, adrenaline and 'sleep' for example. The collective SEN state of evolving CEN states may decouple into disordered superpositions of internally 'unclocked' CEN thoughts resulting in the 'non-sense' of dreams.

The 'processing rate' is really a measure of the 'lifetime' of the **transition** from a CEN state to another one in a SEN **POC state of consciousness**.. This transition or SEN processing 'lifetime' is:

$$\tau_{SEN} = \frac{\hbar}{\Gamma_{SEN}} = \frac{\hbar}{\langle \Psi_{CEN_2} \mid B_{1\to2} \mid \Psi_{CEN_1} \rangle} \tag{66}$$

The brain is 'quantum' in the sense that complex states (e.g. consciousness) can be viewed as collective excitation states of casual networks built from Feynman clocks. Neurons display both CEN and SEN properties as does the network built from them, the brain. The building of these complex interacting neural networks has a 'classical' description in the 'discreet wiring' sense, but global collective excitations such as brain waves have both 'classical' and 'quantum' aspects. This distinction is delineated by the weak differences between CEN and SEN aspects of a macroscopic system. It remains possible that the *coherence* of aggregate network states (CEN aspect) or their *decoherence* (SEN 'classical' collective state transitions from one 'quantum' CEN state to another) determines whether the 'brain' is viewed (as 'measured') as a quantum or classical system respectively. The collective SEN state created by the sequential shifting and overlap of emerging and decaying CEN states may form the ultimate 'collective excitation' of the brain known as consciousness (see **Figure 22**). The brain has both 'quantum' and 'classical' properties. Planck's constant provides a way to map 'change' into 'time'.

The classical aspects such as brain waves, action potentials, and localized activity in specialized brain lobes as observed with electroencephalography (EEG), magneto encephalography (MEG), and functional magnetic resonance imaging ('functional' magnetic resonance imaging or fMRI) are generally considered to be measuring 'averages' of electromagnetic fields for groups of neurons [59]. These 'averages' are 'macroscopic' collective excitations of neural networks. The sum of the 'disjoint' individual neuron fields can give a non CE field, but for causally connected neurons the collective behavior may be not a sum but the direct product of all the quantum states of the neurons. The sum leading to an 'average' classical field for n-disjoint (non-causal network) neurons would be:

$$\left\|\vec{E}\right\| = \sum_{i=1}^{n} \left\|\vec{E}_i\right\| \tag{67}$$

for the individual electric fields due to ion or action potential propagation, and

$$\left\|\vec{B}\right\| = \sum_{i=1}^{n} \left\|\vec{B}_i\right\| \tag{68}$$

for individual magnetic field generation due to the electric component of charge flow from or to the neurons.

In the quantum case, the collective excitation state of the coupled FC, signal, and FD components of a CEN is a product of all the states of the neurons involved. The 'measured' collective excitation state of this CEN is:

$$| \Psi_{EM_{CEN}} \rangle = \bigotimes_{i=1}^{n} \left\{ | \Psi_{FD_i} \rangle \bigotimes | \Psi_{signal_i} \rangle \bigotimes | \Psi_{FC_i} \rangle \right\} = \bigotimes_{i=1}^{n} | \Psi_{FD_i}, \Psi_{signal_i}, \Psi_{FC_i} \rangle \tag{69}$$

which allows for interference and superposition effects in an extended quantum system. The quantum nature of the collective state of activity in a CEN of neurons should lead to distinctly different net fields with a CE signature. The collective states of neurons in causal CENs should have a different net state signature than that of the classical average of disjoint neuron states. A **sequential excitation program (SEP)** of induced CEs in a neural CEN can give a 'resultant' **POC state of consciousness (see Figure 22).** This will be explored in more detail in a later paper.

13.10 Time Travel

'Time Travel' into the 'past' or 'future' is one of the persistent obsession of popular culture. It is also of concern to those who want to understand the universe and the apparent irreversibility of processes such as aging. What is meant by 'time travel'? It is generally though of as 'going' to a 'past or 'future' configuration of all or part of the universe. An 'ideal' standard clock *appears* to return or 'travel' to a 'past' configuration with each cycle. The universe at large however does not appear to be returning to any of its past configurations. Travel to a *local* 'past' really means the 'recreation' of a 'previous' configuration of a system.

The fundamental arrow of time at the microscopic level (QAT) is defined by unstable systems. This is not reversible even though the FD mode of a FC can be 'reset' if there is available 'information' in the form of work done on the system by an agent in the environment capable of reproducing a 'previous' state. For example, we look at the case of 'squeezing' of an observable state of a system [71]. The 'arrow of time' is a QAT associated with the process of an 'apparatus' or 'environment' acting on the unstable but coherent initial state of a FC. This results in the loss of 'coherence' (decoherence) and causes the 'decay' of the FC state accompanied by the creation of 'signals' (and therefore information). Squeezing is not a reversal of an irreversible QAT but the 'resetting' of a system configuration through the action of an external system on a 'measured' or 'squeezed' FD.

If a system does not 'change' then there is no time information created by it. This system is 'timeless' with respect to other evolving systems. The 'past' and 'future' of an isolated unchanging system has no meaning by itself. In this sense 'travel' to its past or future is indistinguishable from the point of an observer. The past and future are separated by the irreversible information flow in dynamic systems. The 'one way' sign is locked into the unstable state of any system. All causal networks are built from unstable systems (of varying degrees and lifetimes). So it seems that all hierarchical systems that are traceable to their QAT roots make travel back in time impossible since the global increase in information entropy at the cosmic level limits the amount of information and energy available to reconstruct large enough systems of matter and energy into a 'recognizable' historical configuration.

In the case of travel to the 'future', the configurations yet to be realized that one may want to 'travel' to do not exist until the causal networks of the 'present' universe generate them. They will only do this following evolutionary patterns emerging from the 'past'. To get to a future state, one either has to let the hierarchical causal networks in the universe make them, or one has to again 'construct' a future configuration. Calling a constructed 'future' a future presents us with a colorful tautology.

The 'future' may be accessed by 'waiting' in a state with a 'slowed' observer lifetime (quantum Zeno effects via 'cryogenic' delay of unstable configuration decay?) relative to the system configuration that one is 'traveling' to in the observers 'future'. The 'future' in this case represents the observed world due to the extended 'lifetime' of the observer, not a superposition of the possible reconfigurations of the universe coexistent with the observers 'now'. In conclusion, time travel into the 'past' may be *locally* possible but globally improbable. Travel into the future requires the slowing down of an observers metabolic clock or 'movement' through the evolving causal networks of the universe at relativistic velocities until the desired 'future' has been created. High speeds are expensive in energy terms. It may be that cryogenic or other biological clock slowing techniques are the 'cheaper' way to 'wait' until the future emerges.

14 Summary

The location of the fundamental irreversible quantum 'arrow of time' can be found in microscopic Feynman clocks (FCs). The origin of FCs can be traced back to the irreversible decay of the initial 'cosmic' collective excitation state of the Big Bang-FC. Collective excitations of coupled sets of FCs can form CENs inside larger networks where sequential signal transfer between mixtures of these FCs and CENs define larger causal networks (SENs). These building blocks provide the basis of a hierarchical network approach to causality in complex systems. The emergence of 'information' from unstable configurations of matter in the form of signals can be used to define the 'lifetimes' of reconfiguration processes in evolving systems.

The 'lifetimes' can then be used to create space-time maps of events. The 'direction' and 'dimension' of time in these maps can be constructed from the information flow in causal networks. The nodes of these networks can act as FCs or Feynman Gates (FGs) acting on incoming information and creating new information and signals which are propagated to other components of the system. Information storage in quantum 'memory' registers provides state information which can be mapped to numbers ('real' clock time). The emergence of complex information structures as POCs of collective memory systems provides a mechanism for 'language'. The language in turn can act as an information transfer interface between complex systems. Hierarchical information structures and languages can then map to hierarchical 'arrows of time' as a general indicator of the direction of evolution in 'classical' systems. These general properties allow the observer to 'pragmatically' ignore the details of the underlying quantum causal network by focussing on the POCs created by them. The macroscopic behaviors then exist as CEs of POCs regardless of the physical scale.

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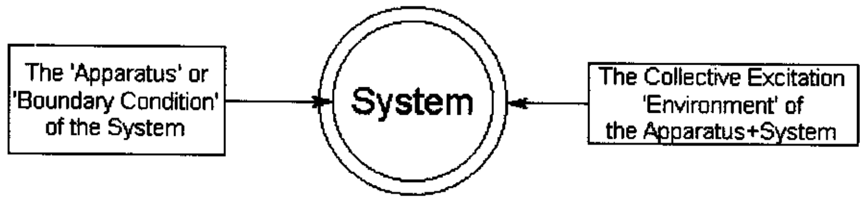


Figure 1: Collective Excitation Environment as the superposition of the Apparatus and the System. This is an excited state of a Feynman Clock or CEN, which decays, in a finite 'lifetime' into one reconfiguration state from the set of all possible reconfiguration states to which it is coupled. Quantum gravity or a quantized gravitational field and phonon-like CE perturbations causing inflation may be are found in the CE-environment of the system and its surface (boundary) 'apparatus'. CEs in or on the system induced at the boundary may give rise to 'internal' energy density perturbations that differentiate matter from the vacuum. These CE 'signals' may freeze out during phase transitions of the entire system leaving the density perturbations to evolve as local systems giving rise to the non-homogenous distribution of matter today. Note that 'CE-environments' are coupled to the system forming a hybrid CE-environment plus FD/FC system within larger 'environments' (e.g. the 'vacuum' of space) that may or may not interact with the specific unstable state.

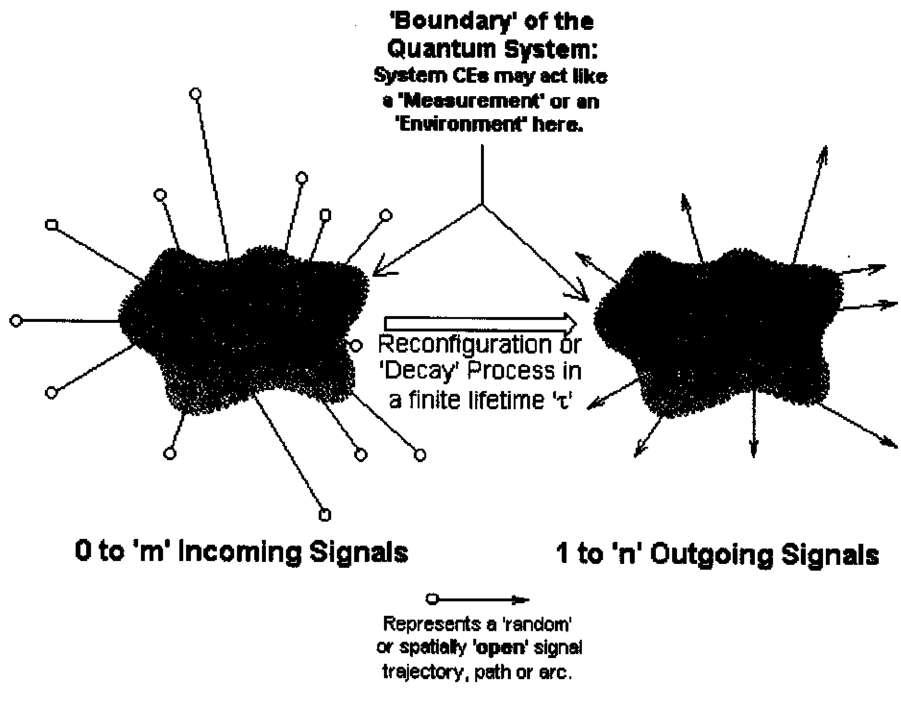


Figure 2: Feynman Detector and Clock States of an 'open' or 'random' signal trajectories in and out of the system in space. The left figure illustrates the 'initial' FD configuration of the quantum system and the right is the FC configuration (at the same 'spatial location' in the center of mass frame of the system).

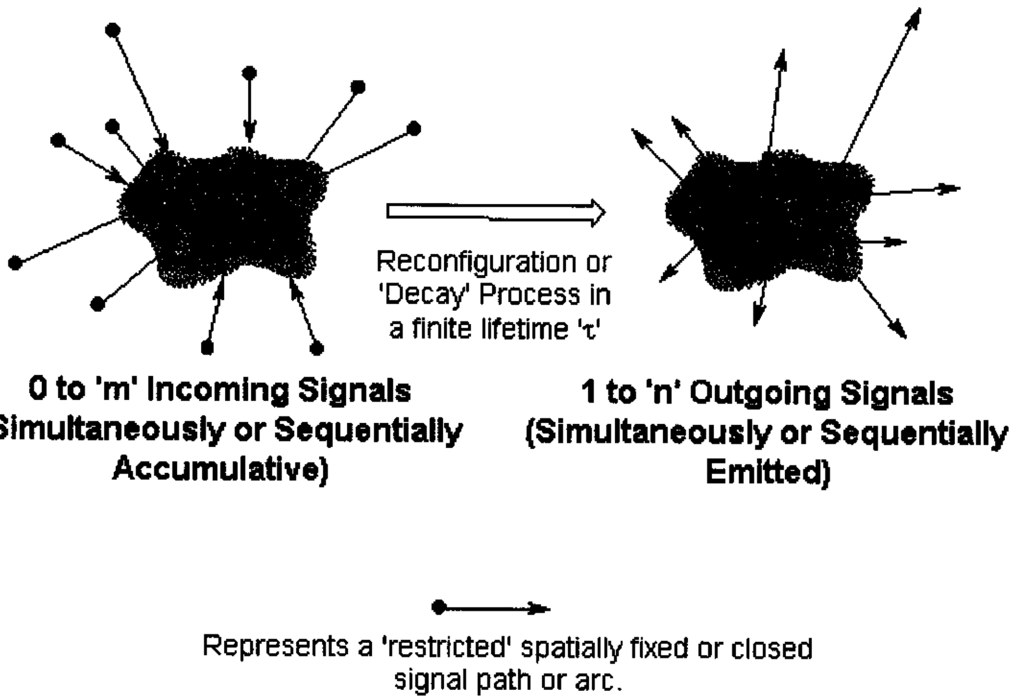


Figure 3: Feynman Detector and Clock States of a 'closed' with 'fixed' ('circuit') signal trajectories in and out of the system in space. The left figure illustrates the 'initial' FD configuration of the quantum system and the right is the FC configuration (at the same 'spatial location' in the center of mass frame of the system).

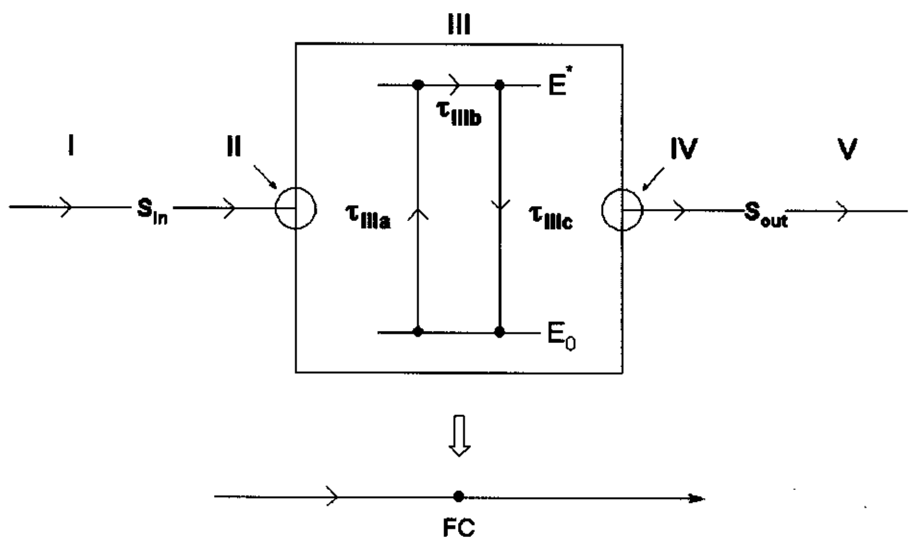


Figure 4: A Simple Feynman Detector/Clock (Gate) with one incoming 'trigger' signal and one outgoing 'decay' signal. The 'node' and 'arc' representation for causal network maps is illustrated below. The 'information' flow from left to right through the various regions of this node are discussed in the text.

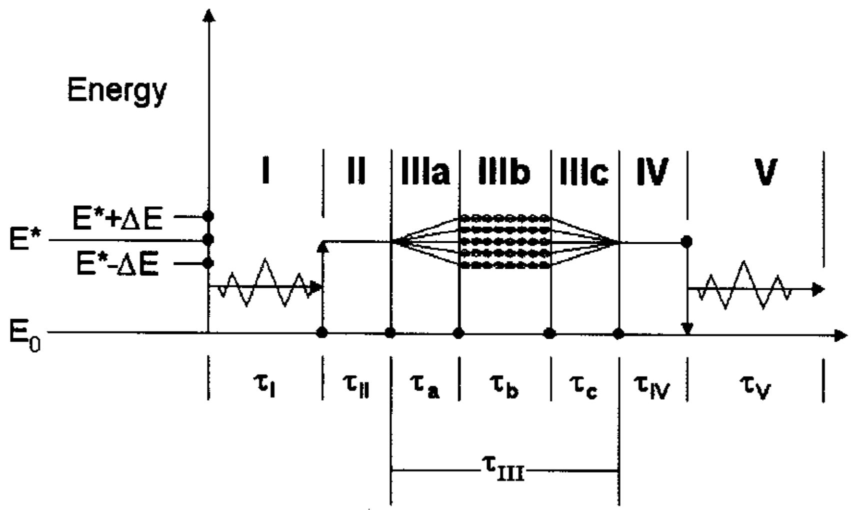


Figure 5: The "Lifetimes' of configuration states associated with Feynman Detector/Clock nodes.

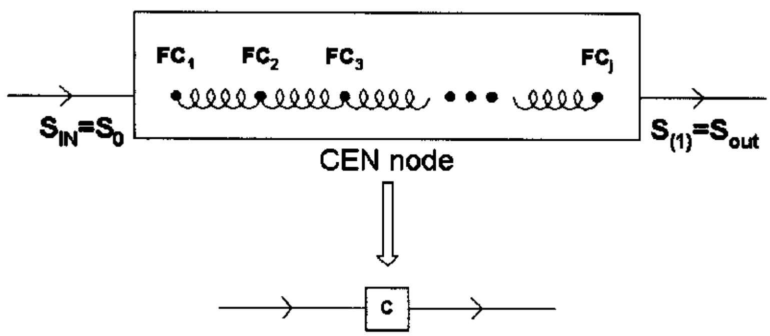


Figure 6: A CEN composed of coupled FCs. Below is the representation of the CEN node for mapping information flow in causal networks.

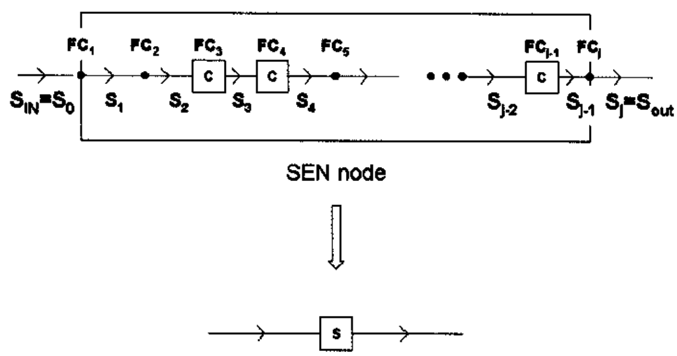


Figure 7: A SEN composed of FCs (could also be embedded CENs) and their signals. Below this is the condensed SEN node representation for use in mapping information flow in causal networks.

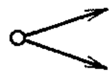
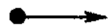
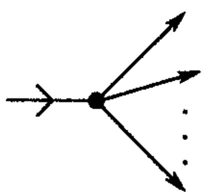
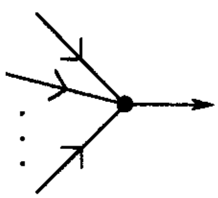
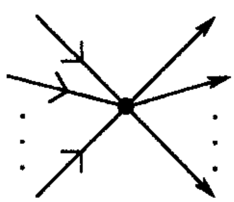
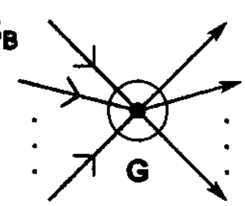
Causal Network Node Symbol:	Feynman Operator, F:	Example:
m = 0 ○ n = 0	$F = \langle 0 \mid H_{0,0} \mid 0 \rangle$	'Vacuum', Equivalent 'mass' = 0
m = 0 ● n = 0	$F = \langle 0 \mid H_{0,0} \mid 0 \rangle$	Stable Particle or System Equivalent 'mass' ≠0
m = 0  n = 2	$F = \langle 2 \mid H_{0,2} \mid 0 \rangle$	Vacuum Fluctuations; Virtual Pair Production
m = 0  n = 1	$F = \langle 1 \mid H_{0,1} \mid 0 \rangle$	Simple Decay; Fluorescence, Relaxation of Collective Excitations
m = 1  n = 1	$F = \langle 1 \mid H_{1,1} \mid 1 \rangle$	'Linear' Transmission of Signals, Logic Gates
m = 0,1  n	$F = \langle n \mid H_{0,n} \mid 0 \rangle$	Multiparticle 'Spontaneous' Decay of a Nucleus, Big Bang
	$F = \langle n \mid H_{1,n} \mid 1 \rangle$	Scattering, Stimulated Decay or Emission through Collisions
m  n = 0,1	$F = \langle 0 \mid H_{m,0} \mid m \rangle$	Fusion, Creation of System in an Excited State, With or Without a 'Target Mass'
	$F = \langle 1 \mid H_{m,1} \mid m \rangle$	Neurons, 'Irreversible' Quantum or Classical Logic Gates, Information 'Funnels'
m  n	$F = \langle n \mid H_{m,n} \mid m \rangle$	The General Form of the Feynman Clock, Node, or Gate
S_B m_B  S_R n_R	$F_G = \langle n_R \mid H_G \mid m_B \rangle$	A Feynman Clock in a Gravitational Field with blue(m) and red(n) shifts of in/out signals respectively

Figure 8

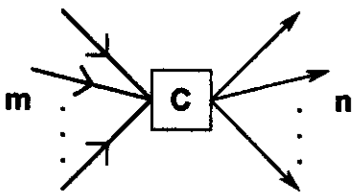
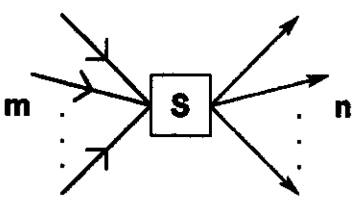
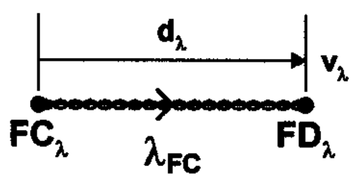
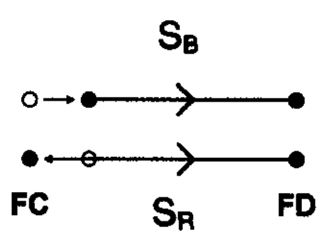
Causal Network Node Symbol:	Feynman Operator, F:	Example:
	$F_{CEN} = \langle n \mid C_{m,n} \mid m \rangle$	**CEN** or **Collective Excitation Network**; Crystals, Lattices, DNA,etc., with collective rotational, vibrational, and translational modes. Signals: EM waves, Photons, Plasmons, Excitons, Phonons, and Solitons etc.
	$F_{SEN} = \langle n \mid S_{m,n} \mid m \rangle$	**SEN** or **Sequential Excitation Network**; Photosystems I and II, Cell Life Cycles, Quantum Computers, Neural Networks, Central Nervous System etc., Signals and States can be a mixture of FCs, FDs, CENs and sub-SENs with Quantum and Classical Collective Excitations.
	$F_\lambda = \langle \Psi_{FD} \mid H_\lambda \mid \Psi_{FC} \rangle$ $= d_\lambda / v_\lambda$	A **signal trajectory FC:** where the 'path' between a FC node and a FD node is treated as a decay of a single FC system. The signal 'lifetime' is equal to a 'classical' free particle traversal or transit time for an average velocity 'v_λ' over a total distance 'd_λ' **(Note that the path may be curved and the velocity may vary, see text).**
	$F_{FD} = \gamma^{-1} F_{FC}$ $= (1-(v^2/c^2))^{1/2} F_{FC}$ $= \gamma^{-1} \langle 1 \mid H_{m,1} \mid m \rangle_{FC}$	**Emission of a Signal from a FC (or CEN) in motion Relative to a FD (or CED)**; Doppler blue shifted and red shifted signals for FC moving towards and away from the FD respectively. The FC may have a velocity, v, where γ is the relativistic correction term for the Feynman Operator acting on FC as seen by FD.

Figure 9

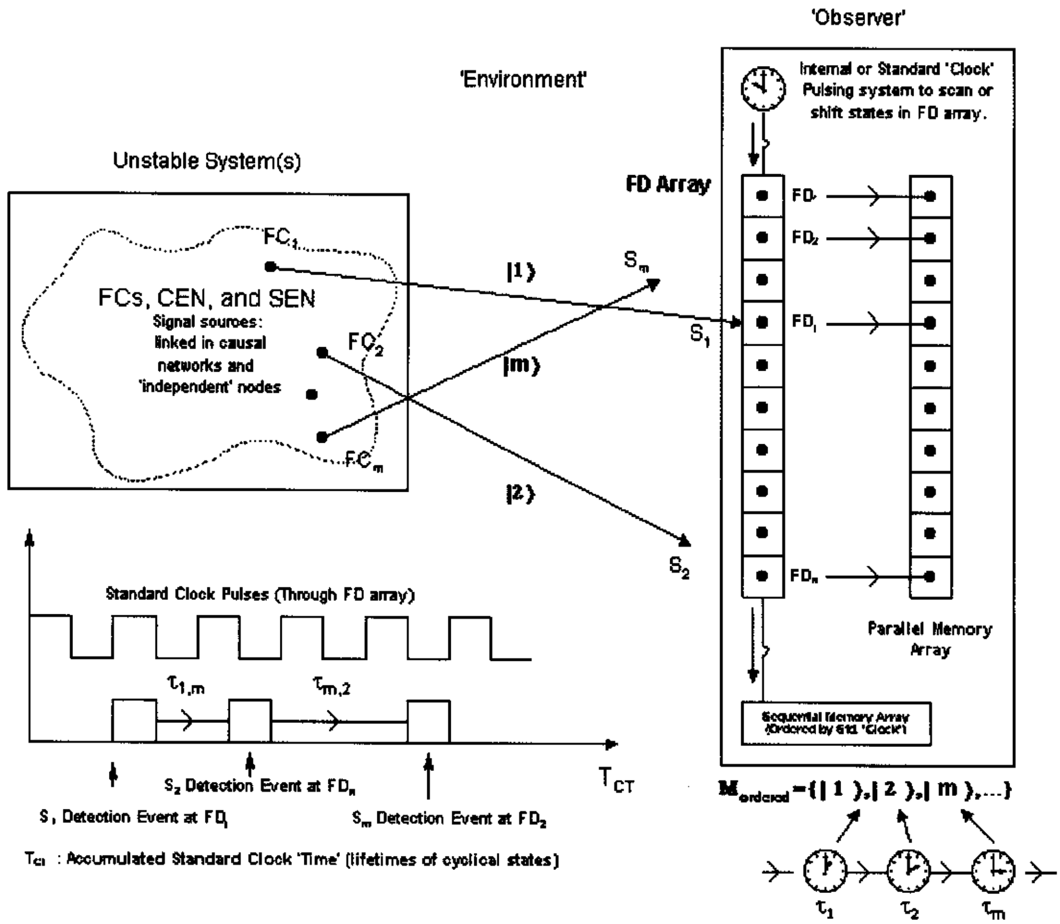


Figure 10: The Signal Mapping Process in an Observer System for the temporal ordering of signal detection events by an internal standard clock. The conversion of decay information in an unstable system into signals propagating through an environment and ending in the creation of mirror states in the detection system is the source for the creation of 'event time' and the 'dimension' and 'direction' of time by the processing of states in the observer system.

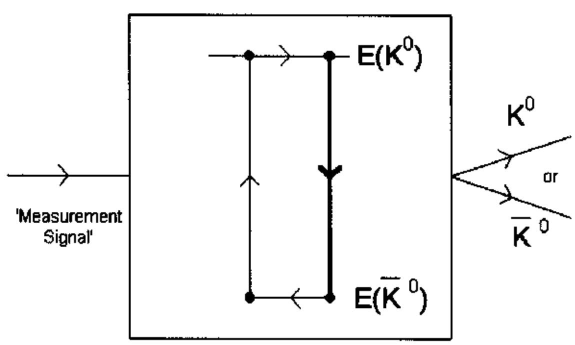


Figure 11: The Neutral Kaon as a FD/FC system. The asymmetric 'decay' of the coherent binary resonance state of the CEN particle/anti-particle modes by decoherence is induced by a 'measurement' signal driving the system into a classical outcome of weighted probabilities for the decay of ensembles into distinct particles.

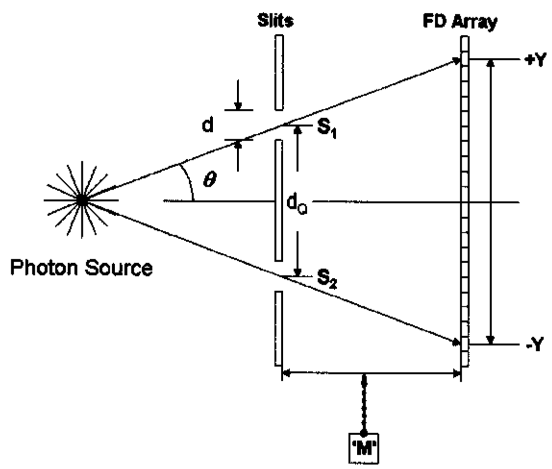


Figure 12: The 'physical' Young's double slit experiment simplified layout. A measurement 'M' on the signals emerging from the double slit can decohere the pattern at the FD array on the right. This results in 'classical' scattering distributions of the signals on the detectors.

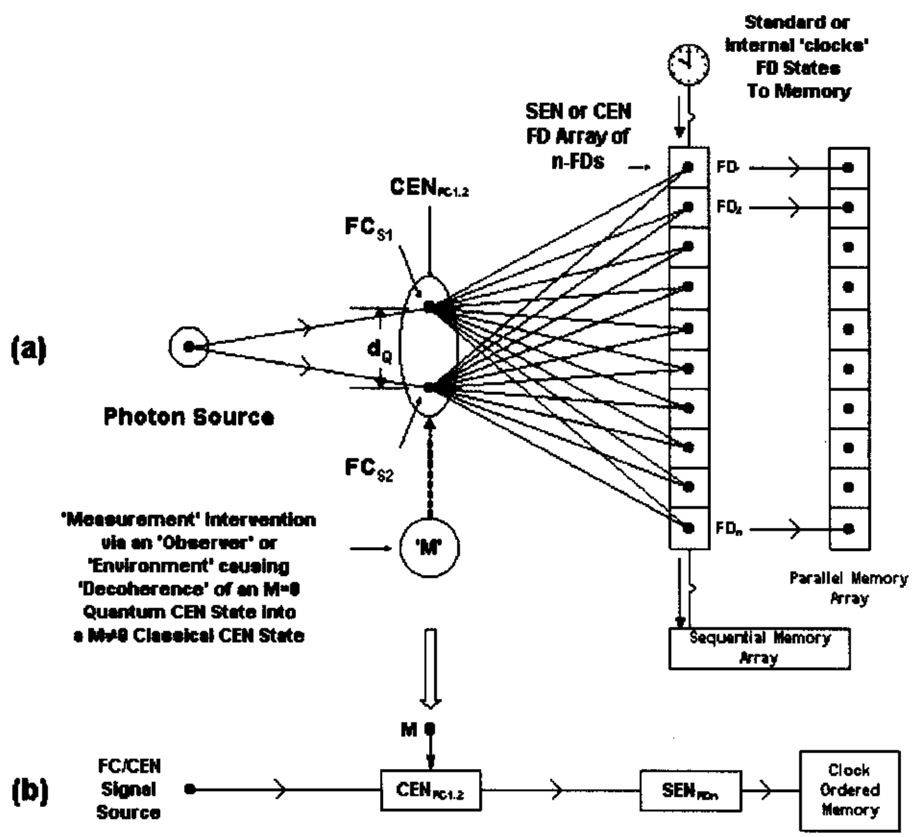


Figure 13: The FD/FC, CEN, SEN node or 'information processing' representation of the double slit experiment. (a). This system illustrates the process of signal mapping at the quantum/classical transition for 'time' information derived from signals processed by a CEN 'Double-slit' gate. Measurements by an 'observer' or 'environment' system on the quantum interference patterns of signals emitted CEN gate induce a quantum to classical transition resulting in non-interfering

superposition of signals detected by arrays of FDs. (b). The Feynman 'Node' notation for this process.

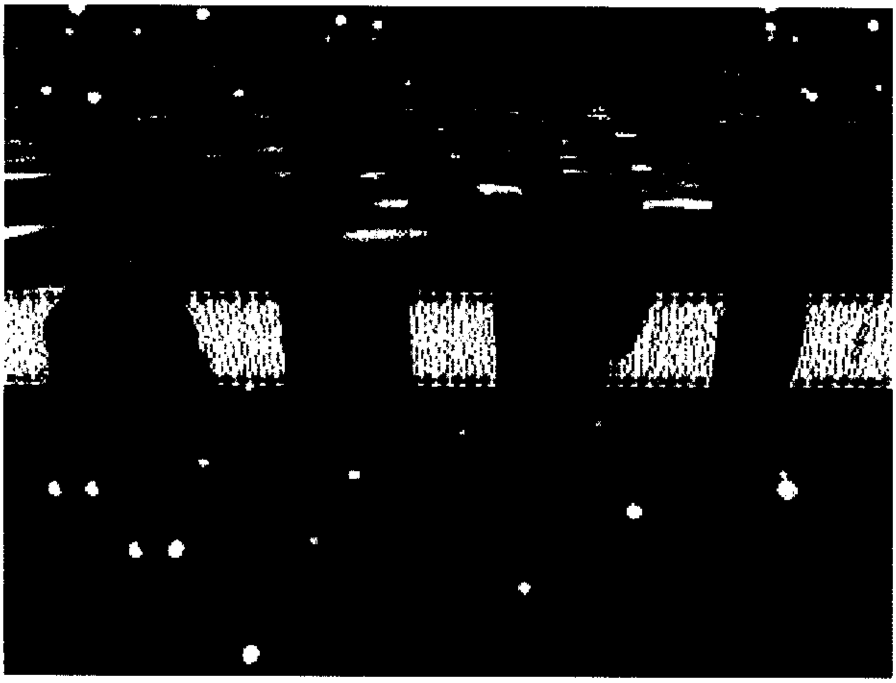


Figure 14: Photosystems II and I in the thylakoid membrane. From left to right; PSII, Cyt Bf, PSI, and ATP Synthase systems. See figures below for details. (figure used with kind permission of J. Whitmarsh and Govindjee).

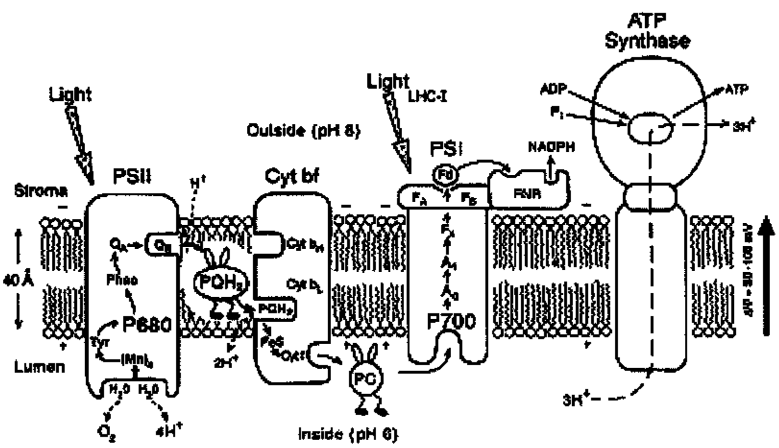


Figure 15: Photosystem II (PSII) and I (PSI) components in the photosynthetic causal network of the Thylakoid Membrane of a granum inside a plant cell.

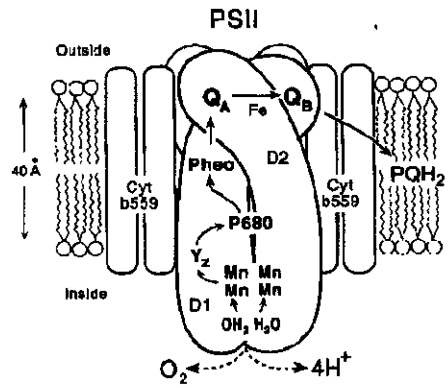


Figure 16: Schematic Details of the PSII site (figure used with kind permission of J. Whitmarsh and Govindjee).

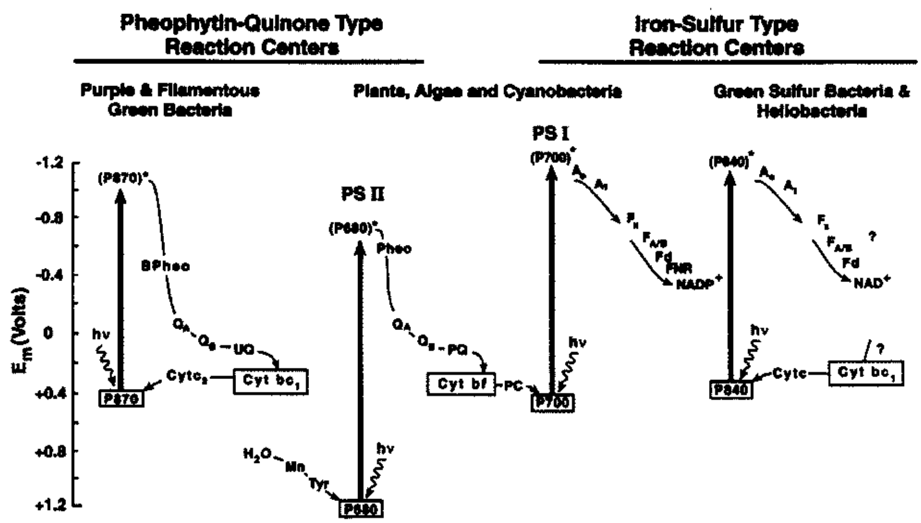
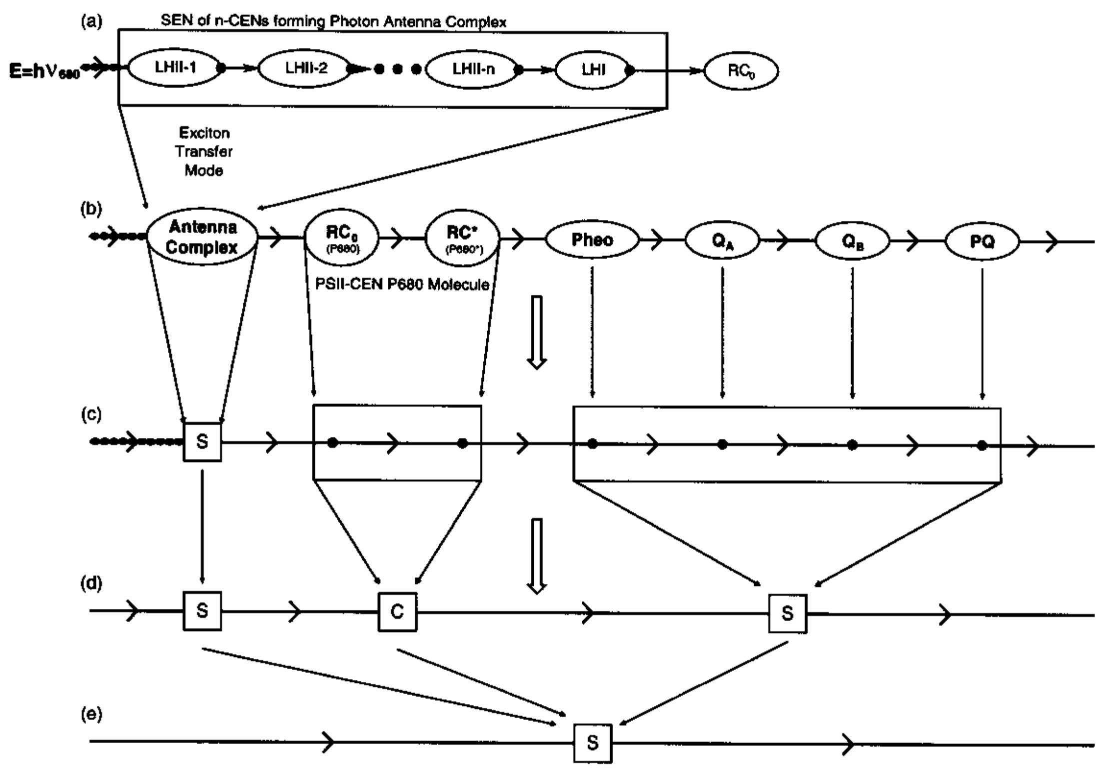


Figure 17: Photosystems I and II relative energy of configuration for various stages in the energy transfer process. The 'lifetimes' the 'signals' are summarized below (figure used with permission of J. Whitmarsh and Govindjee).

Initial State	Final State	"Lifetime' of Transition (approximate)
Photon	Antenna-Light harvesting complex molecule (LHC)	2 fs
Initial exciton of Antenna LHC Molecule resonance transfer through network of antenna LHC molecules	Exciton transfer to Reaction Center Molecules P680 (and P700)	<100 ps
P680	P680*	2-3 fs
P680*	Pheo	3 ps
Pheo	QA	150 ps
QA	QB	150-300 us
QB	PQ	1 ms
PQ	Cyt Bf	5 ms
Cyt Bf	PC	500 us
PC	P700	200-300 us

Figure 18: Lifetimes of 'signals' in the energy conversion and transfer process in the Photosystem II (PSII) network. For simplicity a causal network is illustrated from initial photon detection in the Antenna complex of the P680 Reaction Center (RC) to the creation of an excited state in the P700 (RC) of the Photosystem I (PSI) site.



SEN Node Reduction for Photosystem II

Figure 19: Feynman Node representation of Photosystem II components in a causal network or FC-computer. (a) photon detection and exciton creation in the antenna complex in thylakoid

membrane as a SEN of light harvesting molecules. (b) Photosystem II energy path of electrons from the antenna complex. (c) Feynman clock and SEN node notation representing this section of the energy path. (d) further reduction to CEN/SEN nodes. (e) single SEN node simplification. Each of the nodes in the above figures represents a 'plateau of complexity' with an 'arrow of time' indicated by information (signal) flow from right to left. Note that 'time' is not a graphical dimension (axis) here. The signals can point to any location in plane of the map, as may be need for complex networks with feedback or spatial branching.

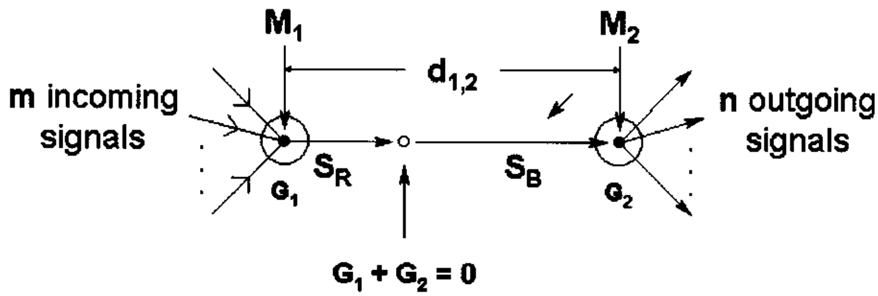


Figure 20: A multiple mass gravitational system. Red and Blue shifted signals propagate from left to right. The point at 'o' represents the 'zero-gravity' coaxial location between the masses M1 and M2. A virtual FD/FC system at this node can be thought of as a Feynman Gate with no action on the signal. Other points on the signal trajectory can be thought of as virtual FD/FCs or 'Higgs clocks'. See Text for details.

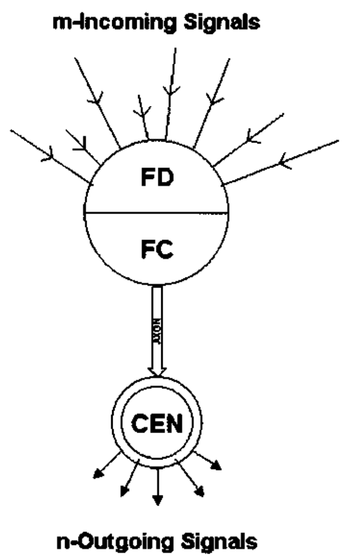


Figure 21: The Feynman Clock/CEN Neuron as an information processing gate with an Axon signal transmitting conduit, and CEN neurotransmitter signal emission gate. The m-incoming signals from other neurons propagate along dendrites into the neuron cell body. These 'signals' may be non-simultaneous or staggered. The FD mode of the cell body accumulates signals until a trigger threshold is reached. A non-threshold state dissipates if the necessary signals for firing are not obtained within the decoherence lifetime of that state. The Axon can be thought of as a SEN of Schwann cell FCs that 'detect' an incoming CE signal and then 'decay' in a finite lifetime emitting a 'signal' (ion mediated potential) across the Nodes of Ranvier ('arcs' in our notation) to the synaptic bouton. Here n-neurotransmitter molecules are released by fusion of synaptic vesicles to the plasma membrane releasing the chemical 'signals' to diffuse across the synaptic cleft to FD receptor sites on the post synaptic dendrite of the next neuron or cell in the neural SEN.

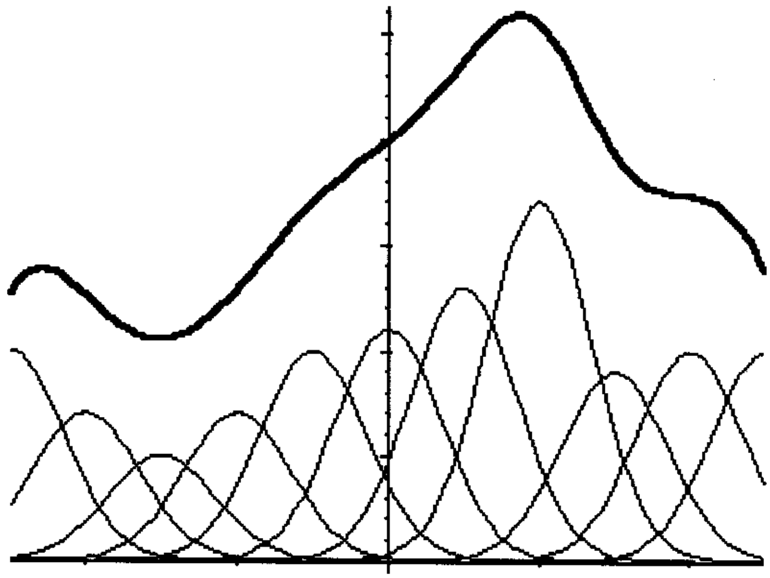


Figure 22: The resultant CEN state due to a SEN progression of CEs through a neural network. The vertical axis represents the current state of a neural network as CEs emerge and decay 'moving' from the 'future' through the 'now' to the 'past' from right to left with respect to the 'timeless' perspective of the 'observer state'. One can also view this as the 'movement' of the observer state from left to right. The intersection of the top curve (a direct product of the overlapping CEs) with the vertical 'now' axis gives the meta-CE state of the observer. This state is analogous to a single collective state of 'consciousness' in the CEN. The CE curves represent the probability that the CEN in a given state. The FWHM values of these curves indicate the decoherence lifetimes of the individual CE states being processed by the CEN (see text). The widths of the CE states can vary due to 'environmentally' (e.g. chemical or physical quantum Zeno effects) dilated or contracted decoherence lifetimes.