**Superluminal Communication and Travel in the Quantum Temporal Dynamics Multiverse**

***Abstract:***

In the present paper, we extend previous results developed in [4], concerning the multiverse of quantum temporal dynamics. In that paper, we combined the formulation of quantum temporal dynamics with the multiverse framework arising from complex path-integral discretization, resulting in a cyclical cosmology with different cycles corresponding to alternate universes with distinct laws of physics. There, we discovered that the rate of temporal flow (the "temporal speed") depends upon cosmological cycle, and hence that access to other cosmological cycles could permit faster-than-light travel. In this paper, we expand upon the superluminal implications of this theory, determining the effective superluminal speed with which signals can propagate when these dimensions can be accessed. Furthermore, the quantum behavior of these alternate realities could allow rapid subluminal travel within each universe, thus permitting effectively superluminal travel with respect to our universe.

# I. Introduction

### *A. Overview of the Temporal Multiverse*

In [4] we considered a cyclical cosmology, comprised of a sequence of parallel universes that exist at alternate quantum phase. This theory was a result of combining multiphase discretization, as developed in [5], where the time-discretization index of the quantum functional integral is made complex, with quantum temporal dynamics, as in [3], where quantum mechanics is applied to the passage of time, and a dichotomy between time internal and external to a system is proposed. In [5], we took the standard formula for the path-integral in quantum theory,

$$P(a,b) \cong \lim_{n\to\infty} \iiint \dots \int \quad exp\left(\frac{i}{\hbar}S\right) dx_1 \dots dx_{n-1} \quad (1.1)$$

and allowed $n \in \mathbb{N} \to z \in \mathbb{C}$, yielding a spectrum of different propagators depending on how $z$ approaches infinity in the complex plane. We proposed that these propagators correspond to distinct universes. This multiverse lent itself naturally to the quantum temporal dynamics developed in [3], where we applied quantum mechanics to the passage of time, promoting time from parameter to observable. This framework necessitated the distinction between the time *internal* to a system, indexing the change of its quantum state, and *external* to a system, indexing the relationship between systems. Applying this temporal dichotomy, we developed a possible framework for the one-electron universe, where the movement of a single particle forward and backward through time produces all the particles in the universe. Thus, the potential at any point in space-time is due entirely to the influence of this single particle. The formula of the potential in this theory is given as

$$V(x,\tau) = R(\tau) + \iiint |\psi(x',\tau';t')|^2 V(x-x')\delta_\varepsilon(\tau-\tau')\, dx'd\tau'dt' \quad (1.2)$$

Where $x$ is the spatial co-ordinate, $\tau$ the external time variable, and $t$ the internal time parameter. Here, $V$ determines the standard electrostatic potential over the spatial distance, while $\delta_\varepsilon$ is a Gaussian of width $\varepsilon$. $\psi$ is a "temporal wavefunction" that determines the probability density of the particle existing, not only in a certain spatial range, but also in a range of external time. $R(\tau)$ are large temporal barriers that reflect the particle, resulting in the appearance of many particles at any given value of external time.

Using a path-integral formulation of temporal dynamics, where external time is treated as a rescaled spatial dimension, as in [4], we developed a Schrodinger equation for the evolution of the temporal state,

$$-\frac{\hbar^2}{2m}\Box_a\psi(x,\tau;t) + \left(R(\tau) + \iiint |\psi(x',\tau';t')|^2\, V(x-x')\delta_\varepsilon(\tau-\tau')\, dx'd\tau'dt'\right)\psi(x,\tau;t)$$
$$= \exp(-\mathrm{i}\mu)\, i\hbar\frac{\partial\psi(x,\tau;t)}{\partial t} \quad (1.3)$$

Where $\Box_a = \nabla^2 - \frac{1}{a^2}\frac{\partial^2}{\partial t^2}$, $a$ being a constant we dubbed the "temporal velocity." As such, the evolution of the wavefunction at any given internal time $t$ depends in principle on its value at all other times $t'$, a notion certainly consistent with our consideration of a one-electron universe, where all particles are instantiations of a single particle at distinct internal times. (1.3) readily separates as

$$-\frac{\hbar^2}{2m}\nabla^2\theta(\boldsymbol{r},t) + V(\boldsymbol{r})\theta(\boldsymbol{r},t) = i\hbar\frac{\partial}{\partial t}\theta(\boldsymbol{r},t) \quad (1.4)$$

$$\frac{\hbar^2}{2ma^2}\frac{\partial^2}{\partial\tau^2}\phi(\tau,t) + R(\tau)\phi(\tau,t) = i\hbar\frac{\partial}{\partial t}\phi(\tau,t) \quad (1.5)$$

Where

$$\psi(\boldsymbol{r},t;T) = \theta(\boldsymbol{r},T)\phi(t,T) \quad (1.6)$$

It is natural to consider the existence of space-time beyond the aforementioned temporal barriers. An intriguing possibility suggested both in [3] and in [4] is that alternate universes exist in the internal-time future and past, marked by a succession of other potential barriers $R(\tau)$.

Between any two of these barriers lies another reality. By quantum tunneling through a barrier, a particle can reach an adjacent universe. As this single particle reflects through this potential labyrinth, it systematically fills all these universes. This multiverse framework offers an intriguing system for effecting the multiverse of complex-phase discretization as in (1.1). Namely, each different universe occupying an internal-time range in this cyclical cosmology might correspond to an alternate complex phase of the discretization index.

In [4], we applied (1.1) and the framework developed in [5] to quantum temporal dynamics, resulting in the generalized Schrodinger equation

$$-\frac{\hbar^2}{2m|\exp(i\mu)|_p}\Box_a\psi(x,\tau;t)+\{|\cos(\mu)|^p - |\sin(\mu)|^p\}\left(|\cos(\mu)|^p+|\sin(\mu)|^p\right)^{\frac{1}{p}-1}\left(R(\tau) + \iiint \frac{|\psi(x',\tau';t')|^2}{\int_{x'-\tau'}|\psi(x',\tau';t')|^2dx'd\tau'}V(x-x')\delta_\varepsilon(\tau-\tau')\,dx'd\tau'dt'\right)\psi(x,\tau;t) = \exp(-i\mu)\,i\hbar\frac{\partial\psi(x,\tau;t)}{\partial t} \quad (1.7)$$

Where $\mu$ is a parameter indexing the phase of the discretization index and $p$ determines the norm used in the generalization of the functional integrand. Using an anthropic argument, concerning the structure of nucleons and the range of quantum uncertainty in quark position within the nucleon, we determined from (1.7) that the value of the temporal velocity is roughly 3 x $10^{104}$ in atomic units, that the size of the temporal barriers is roughly 2.3 x $10^{211}$, and that the number of universes in the cosmological system is on the order of $10^{43}$.

### *B. Superluminal Implications*

An interesting property of this multiverse, as we discovered in [4], is that the rate of temporal flow, the "speed" of the particle through external time, varies from universe to universe. That is, if a quantum temporal state $\psi$ is transported, instantaneously, to another reality, its evolution in internal time will exhibit a speed through external time generally less than 1. This speed is determined by the evolution of the temporal factor $\phi(\tau,t)$ in the relevant universe. In general, this "temporal speed" is proportional to

$$\frac{Re(z)}{|z|} \quad (1.8)$$

with $z$ being the complex mass coefficient $\frac{|\exp(i\mu)|_p}{exp(i\mu)}$. As such, the temporal speed in other realities is generally less than in our own, opening up the possibility of using these dimensions for superluminal travel.

For, if these universes are topologically identified so that the external-time future of one is linked to the past of the next, and the system "wraps around" so that successive universes co-exist, as proposed in [4], then travel to these other realities might be a possibility. A starship could simply enter "phasespace," a parallel universe at an alternate quantum phase, travel with subluminal velocity through phasespace, and exit at the point corresponding to its destination in realspace. Measured relative to the ship, an internal time $t$ will have passed (not the relativistic proper time, but in this non-relativistic model the time measured by all particles in that universe), and thus in accordance with the aforementioned result an external time $\frac{Re(z)}{|z|}t$ will have passed. The internal time determines the evolution of the particle's quantum state, in accordance with (1.4), and thus the distance the ship can travel, being composed of many instantiations of the particle at distinct internal times. However, external time indexes the interaction between the ship and external systems, and hence once the ship injects into "realspace," a smaller length of time will have passed for the realspace observer compared to the phasespace observer. Thus, for example, the ship could travel close to the speed of light in phasespace, travel for a hundred years, and drop out of phasespace at its destination in realspace where only a year has passed, thus effectively travelling at nearly 100c.

In addition to allowing such superluminal travel, phasespace also permits violations of the conservation of momentum, and therefore an apparatus for approaching high subliminal speeds with little energy cost. Although this model is non-relativistic, a rough consideration of special relativity would seem to suggest that the proper time relative to the ship is significantly lower than the internal time of the phasespace observer, thus meaning that both the realspace observer, and the one on the ship, experience comparatively small durations of time during the superluminal journey. In the succeeding section we consider how phasespace permits violations of momentum conservation, and the impact on intra-universe propulsion. In the following sections, we develop the specifics of the mechanics of phasespace travel.

# II. Momentum Generation in Parallel Universes

### *A. Time Reversability*

Given an initial quantum wavefunction

$$\sum \psi_i \quad (2.1)$$

in a system with energy eigenvalues $E_1, E_2$ ... , the time-evolution is given by

$$\sum \psi_i \exp\left(-\frac{i}{\hbar}\mathrm{E}t\right) \quad (2.2)$$

and we have that

$$\sum \psi_i \left(\exp\left(-\frac{i}{\hbar}\mathrm{E}t\right)\right)^* = \sum (\psi_i)^* \exp\left(-\frac{i}{\hbar}\mathrm{E}t\right) \quad (2.3)$$

Thus, this implies

$$\sum \psi_i \exp\left(\frac{i}{\hbar}\mathrm{E}t\right) = \sum (\psi_i)^* \exp\left(-\frac{i}{\hbar}\mathrm{E}t\right) \quad (2.4)$$

meaning that, in standard non-relativistic quantum mechanics, systems evolve in reversed time in the same fashion as systems evolving forward in time, but with momenta reversed. Thus, the behavior of the particle during a leg of its journey with negative temporal speed is exactly the same as those with positive temporal speed, as measured from an observer at a certain point in external time. However, this is only true in a universe with real discretization index; in a parallel universe, the relation (2.3) will generally not reduce to (2.4), as the internal-time evolution factor is given by

$$T(t) = \exp\left(-\frac{i}{\hbar}\mathrm{E}\exp(i\mu)\, t\right) \quad (2.5)$$

in this case. This is easily demonstrated by developing an analogous, complex-discretized equation for (1.4) from separating (1.7), and applying the procedure explicated in [5]. Generally, (2.5) will depress a particle's expected momentum as it evolves in internal time. However, if the particle is moving with negative temporal speed, its expected momentum will be perceived to grow exponentially, in accordance with

$$\exp\left(\frac{i}{\hbar}\mathrm{E}\ \exp(i\mu)\,\tau/v\right) \quad (2.6)$$

where $v$ is the magnitude of the temporal speed, relative to external time.

### *B. Generating Momentum in a Parallel Universe*

Let us consider, for the succeeding argument, a free particle where the potential is set to zero. Suppose that its spatial wavefunction is given by

$$\theta(\boldsymbol{r},t) = \int \sigma(E)\,\psi_E\, dE \quad (2.7)$$

where $\psi_E$ represents the eigenvector state at energy $E$. By the above, its spatial quantum state will evolve relative to external time as

$$\theta(\boldsymbol{r},t) = \int \sigma(E)\,\psi_E\ \exp\left(\frac{i}{\hbar}\mathrm{E}\ \exp(i\mu)\,\tau/v\right) dE \quad (2.8)$$

As described in [4], the actual probability density is only proportional to the wavefunction, the constant of proportionality changing with internal time so as to maintain normalization. By (2.7), however, the energy distribution $\sigma(E)$ of the quantum state will change proportionately with the factor $\exp\left(\frac{i}{\hbar}\mathrm{E}\ \exp(i\mu)\,\tau/v\right)$ as external time moves forward. Thus, for instantiations of the particle in this universe with reverse temporal orientation, the expected momentum will generally shift right, in violation of momentum conservation which holds in our universe. This property could be utilized by a starship to generate momentum at low energy cost, therefore permitting fast subluminal travel (relative to internal time) within the universe.

The starship is composed of numerous instantiations of the single particle, corresponding to distinct ranges of internal-time. As such, the internal time $t$ corresponding to the evolution of this system's state should be directly proportional to the external time $\tau$, but rescaled by the magnitude of the temporal speed as in $\tau/v$. That is, each constituent particle state evolves through external time with the same magnitude of temporal speed $v$, but different temporal directions; as such, time-reversed particles are perceived by the shipbound observer to move backward in time with a speed of 1.

Thus, we have the effective energy proportionality factor

$$\exp\left(\frac{i}{\hbar}\mathrm{E}\ \exp(i\mu)\ t\right) \quad (2.9)$$

Let us consider the behavior of a hydrogen atom with reversed temporal orientation. In atomic units, we have (2.9) reduce to

$$\exp(1000\ s^2 t) \quad (2.10)$$

using an order-of-magnitude approximation for the exponent, where $s$ is the atom's spatial velocity. Let us take an initial velocity distribution

$$\sigma = \exp(-(10^5(s - 10^{-6}))^4) \quad (2.11)$$

Corresponding to a particle whose expected velocity ranges about 10 m/s around the origin, with a maximum of the distribution slightly displaced from zero at around 1 m/s. The evolution of this distribution is almost exactly the same as that of $\exp(-(10^5 s)^4))$, except that rather than two maxima, only the rightward maximum of the evolved wavefunction is of any actual relevance. As such, we can approximate the evolution of (2.11) by examining the average velocity of

$$\exp(-(10^5 s)^4))\exp(1000\ s^2 t) \quad (2.12)$$

which is roughly $s = \frac{\sqrt{t}}{500000000}$, given by the maximum of the evolved distribution. Hence, integrating, we determine that the spatial velocity of the particle after 1 meter is roughly 7,000 m/s. Depending on the simplifying assumptions made in the foregoing calculation, and the quantum phase of the corresponding universe, the true value could be anywhere from 1-10,000 m/s. Regardless, the point is that atoms in reverse temporal orientation can be assembled in such a quantum state that they anomalously increase in momentum without an input of energy. Such a system could be used by a starship in "phasespace" to accelerate close to the speed of light within the parallel universe.

The superluminal applications of entering alternate universes arise due to the divergent temporal speed factor as expressed in (1.8); namely, that a quantum state injected into a parallel universe will generally evolve slower through external time than in our own universe. The unique properties of complex-discretized quantum theory, however, unveil further applications. By taking advantage of the violation of momentum conservation in these parallel realities, a hypothetical starship could accelerate atoms in reverse temporal orientation by preparing them in a certain quantum state as in (2.11), and simply using their natural state evolution. These particles could thus be used as a source of momentum to drive the starship forward without fuel. Not only does phasespace allow faster-than-light travel relative to realspace, but within phasespace, a ship can easily accelerate close to the speed of light.

# III. Using Alternate Dimensions for Superluminal Travel

In the cosmological model that we are envisioning, universes exist in discrete succession, following each other along the external time continuum. We imagine that the universes are topologically identified with their predecessors and successors so that they "wrap around" in external time, superimposed over the same range of external time. Thus, it might be possible for a ship to "jump" from one multiverse "layer" to another. Suppose a starship is capable of traversing N such discrete dimensional steps. Thus, it can jump through N universes when the drive mechanism is activated. It makes a subluminal journey relative to internal time in its destination universe (which, as we explained before, corresponds not to relativistic proper time, but to a stationary observer placed in that universe), and jumps back to our universe at the point corresponding to its ultimate destination, in such a fashion that very little time will have passed in our universe. Its effective superluminal speed is dependent upon the temporal scaling factor (1.8) corresponding to the relevant universe.

Let us suppose that the parameter $\mu$ has its value randomly and uniformly distributed over the constituent universes of the multiverse (in accordance with [5] its value falls between $\pi$ and $2\pi$). The parameter $p$ could have its value distributed in accordance with the geometrical distance in Fig. 1 of [5] between the boundary curves of the multiverse. Given the "dimensional capacity" N of our starship, it can be expected by the foregoing assumptions that the universe with the highest temporal scaling factor, that it can reach, has a value of $\mu$ of roughly

$$\mu \in \left(\frac{3\pi}{2} - \frac{\pi}{2N}, \frac{3\pi}{2} + \frac{\pi}{2N}\right) \quad (3.1)$$

Thus, the expected temporal scaling factor the ship can reach is approximately

$$\frac{Re(z)}{|z|} = \frac{Re(\frac{|\exp(i\mu)|_p}{exp(i\mu)})}{\left|\frac{|\exp(i\mu)|_p}{exp(i\mu)}\right|} \approx cos\left(\frac{3\pi}{2} + \frac{\pi}{2N}\right) = cos\left(\frac{\pi}{2} - \frac{\pi}{2N}\right) \quad (3.2)$$

The central principle here being that, as the values of the $\mu$ parameter are randomly distributed from universe to universe, access to more universes makes it more likely the ship can take advantage of a layer of the multiverse with very high temporal scaling factor. Indeed, $\mu = \frac{\pi}{2}$ is associated with infinite (or zero) scaling factor, and the closer the ship can approach this value, the greater will be its effective speed. In accordance with (3.2), this effective speed is

$$\frac{1}{cos\left(\frac{\pi}{2} - \frac{\pi}{2N}\right)} \quad (3.3)$$

times the speed of light.

In phasespace, as (2.9) makes clear, the standard momentum conservation is violated, and particles see their momenta anomalousy increase or decrease, relative to some external system, depending on their temporal orientation (whether their temporal speed is positive or negative). Indeed, this change in the energy profile of quantum states over internal time was used in [4] to provide limits on the value of the $\mu$ parameter in our own universe, and therefore the probable number of layers of the multiverse. As such, it is clear that normal matter will not retain its structure in phasespace, and that a ship must be protected to survive in this environment with alternate laws of physics. Projecting a bubble of normal space-time around the ship, much like the "warp bubble" used in the Alcubierre drive, could allow the ship to survive in phasespace [1]. During transit, this space-time field would be maintained and projected aroud the ship, creating a bubble of normal space where standard physical laws apply. Failure of this bubble would mean the collapse of the ship's structure at a fundamental level.

To propel itself through phasespace, a ship would rely on "momentum generators" using the same principle as that introduced in the previous Section; namely, that a particle prepared in a certain quantum state, and released into phasespace, will see its momentum increase without any energy input (provided that it exists at a reverse temporal orientation). A mechanism could prepare hydrogen atoms from a fuel store at such reverse orientation into a Bose-Einstein condensate with an initial wavefunction like (2.11), and inject them into a "field cavity" where the space-time bubble has not penetrated. In accordance with the above calculation, such a hydrogen atom, when prepared with an initial speed of roughly 10 m/s, would accelerate to roughly 5,000 m/s after 1 meter in the cavity. Once the atoms leave the cavity, a membrane or other device could be used to reflect them and extract momentum for the ship.

Some recent work suggests that wormholes might bridge universes in certain multiverse scenarios [2]. Indeed, a starship might use a wormhole or other space-time configuration as a means to reach these other realities. Injecting into phasespace would likely carry a great energy cost, as would re-emerging in normalspace. A ship would need equipment to create a gateway to phasespace, as well as technology to project a realspace bubble or field for transit, in addition to momentum generators for propulsion within phasespace itself. While these hypothetical considerations of faste-than-light travel are certainly speculative, it is intriuguing that superluminal travel seems perfectly consistent with a compelling theoretical framework.

## References

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