Appendix

Transcendence of Physical Theories

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We recognize a rather distinct pattern for major changes in physical theories: these evolutions have always been a step toward unification. The replacing theory also exhibits more stability and simplicity, with its experimental results closer to what is observed in the laboratory. Other significant features of the process include the removal of one or more infinities (singularities) from physics while new reciprocities (a kind of new symmetry) emerge accompanied by the introduction of fundamental non-commutativities. We term this process *regularization*[2]. The regular theory reproduces the singular one in the appropriate limit where a newly introduced finite parameter (*regularization parameter*) becomes infinite, and therefore, our earlier usage of the term evolution is justified. True regularizations of physics have always been the result of direct experiments or empirical investigations.

Special relativity (SR) captures concisely the essence of the regularization process: it unifies space and time while introducing a new two-way coupling (hence, a new reciprocity and symmetry) between them. SR also discards the singular idea of action-at-a-distance by introducing a finite speed for light and information transfer. SR's mathematical structure (its Lie algebra) is stable against finite changes in the speed of light. In addition, letting the speed of light go to infinity leads one back to Galileo. And finally, successive coordinate system transformations (boosts) and rotations become non-commutative. In a sense, SR transcends the Galileo relativity in that the concept of time in pre-Einstein physics, which is an absolute and independent quantity, becomes an emergent and relative quantity that is unified with space.

Building on this precedent and following this pattern, established for the previous physical evolution, towards the next big change in physics, then to unify quantum theory with gravity we are naturally led to a quantum spacetime—a quantum theory for a transcending spacetime. String theory, like other field theories, assumes a continuum spacetime background and fails almost all criteria of regularization.

Quantum theory (QT) is perhaps the most dramatic regularization of all, dethroning the Newtonian mechanical ontological descriptions of nature by taking measurement and operators as fundamental concepts. QT, however, is only partially regular and is itself ripe for regularization, as is evident from its non-simple and unstable Heisenberg algebra. Segal's proposal [1] to regularize QT has

[2] Mathematically, regularization is equivalent to what is known as *deformation*. However, deformation has never been used with the intention of creating a finite, unified, and stable physical theory.

been taken up by Finkelstein and Shiri-Garakani [2,3] and applied to the quantum harmonic oscillator (QHO). The resulting finite QT could be called *Transquantum Theory* [4]; a theory whose marriage with general relativity promises a finite unified quantum theory of spacetime.

	Galileo Relativity	**Special Relativity**
Relativization	Absolute time	Relative time
Unification	Space andTime	Space-time
Stabilization (Algebra Simplification) through new non-commutativities	$[B_x, B_y] = 0$ $[R_z, B_x] = 0$ $[R_z, B_y] = 0$ etc.	$[B_x, B_y] = c^{-2} R_z$ $[R_z, B_x] = B_y$ $[R_z, B_y] = -B_x$
Reciprocity (two-way coupling)	$x' = x - vt$ $t' = t$	$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$ $t' = \frac{t - v/c^2\, x}{\sqrt{1 - v^2/c^2}}$

Table 1. Regularization features in special relativity

Regularization	**Regularization Parameter**	**New Non-Commutativity**	**Unification**
Kinetic Theory	Boltzmann const. k	Reversible Processes	Entropy and Probability
Special Relativity	Speed of Light c	Boosts	Time and Space
General Relativity	Gravitational const. G	Translations	Energy and Curvature
De Sitter Relativity	Cosmological const. Λ	Translations	Energy and Curvature
Quantum Theory	Planck const. $\hbar$	Observables	Observable and Generators
Electrodynamics	Electric Charge e	Covariant Derivatives	Electricity and Magnetism
Chromodynamics	Strong Charge g	Covariant Derivatives	Particles and Hadrons
Electroweak Gauge	Weak const. f	Covariant Derivatives	Neucleons
Finite (trans-) Quantum Theory	Segal const. $\hbar'$ and $\hbar''$	Observables	Space-time, Fields, and Complex Plane

Table 2. Regularizations of Physics