Quantum Structure

Jonathan Tooker[1]

[1]*Occupy Atlanta, Georgia, USA, 30338*

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The logical structure of the standard model is isomorphic to the geometric structure of the modified cosmological model (MCM). We introduce a new particle representation scheme and show that it is invariant under CPT. In this representation spin arises as an ordinary physical process. The final character of the Higgs boson is predicted. Wavefunction collapse, the symmetry (anti-symmetry) of the wavefunction and some recent experimental results are discussed.

> *"Everything should be made as simple as possible, but not simpler."*
>
> $\sim$ Einstein

As the story goes, Oersted observed deflections of his compass needle in a thunderstorm and went on to discover the first hints of electromagnetism. The theory of this phenomenon was developed over the years culminating in "the best theory we have:" quantum electrodynamics. The agreement of this theory with experiment is very good and many of the things in our modern technological society are built on our good understanding of electromagnetic phenomena. However, we still do not have a theory for the lightning that spurred Oersted's inquiry. It is not known what physical process can lead to large scale accumulation of charge in the atmosphere.

We know what lightning is but not why lightning is. So it is with the standard model. We know what it is but not why it is. In an attempt to answer the latter question, we offer a particle representation scheme accounting for the particle zoo as a geometric property of the modified cosmological model (MCM).

The elementary particles of the standard model are considered fundamental and they live in an artificial gravitational background. In a proper theory of everything, the members of the standard model should be described as quanta of spacetime where some particular circumstance differentiates one particle from another. The MCM quantum of spacetime is a Minkowski diagram where the extent L of space and duration D of time are related by the ratio $D = 2\varphi L$. When the specific values $D = \varphi$ and $L = 1/2$ are selected we see that Einstein's equations and the fine structure constant share a causal origin [1]. This unity is in good agreement with the expected functionality of a complete quantum theory.

To model all the particles as spacetime quanta our first consideration is on the nature of the duration D. The Minkowski diagram is spanned by $\{x^i, t\}$ but we have two candidates for the timelike vector. Should we choose the chronological time x^0 or the chirological time ξ^4? In [2] we have shown that the high-dimensional dynamics of MCM cosmology are easily visualized in a 3D Poincaré section spanned by $\{x^i, x^0, \xi^4\}$. In this representation there is no preferred choice for D so to move forward we maintain the logical program of the MCM: where multiple possibilities can exist, all possibilities do exist.

The orthogonal triad $\{x^i, x^0, \xi^4\}$ defines eight octants separated by three sets of four planar quadrants. The quadrants in the x^0–ξ^4 plane are not spacetimes because that plane is orthogonal to space. This leaves us with eight quadrants which can serve as spacetime quanta, i.e., there are eight locations to place a Minkowski diagram where x^i will run from 0 to 1/2 and t from 0 to φ. The value $x^i = 1/2$ is easily identified with spin-1/2 so we identify these quadrants with the elementary matter fermions and later we will consider the bosons.

Of the eight potentially useful quadrants four are reflections about x^i. These reflections will be associated with spin up and spin down for a particular fermion leaving us with four independent configurations: two with $t = x^0$ and two with $t = \xi^4$. Among these species, the individual quanta can be separated according to whether their axes form a left- or right-handed triad with the second temporal dimension. This is illustrated in figure 1.

A Minkowski diagram alone is useless in the pursuit of quantum gravity. Therefore, we also consider the state spaces $\{\aleph, \mathcal{H}, \Omega\}$ [1, 2]. For each quantum in figure 1 we may assign any one of the three members of the MCM Gel'fand triple. Keeping with our convention that each quantum is a matter fermion, we have generated three families of four fermions, where each family contains two

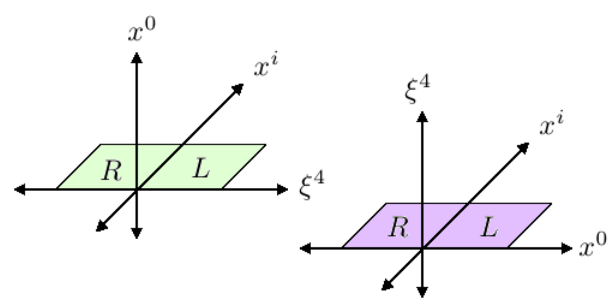

FIG. 1: Of the eight spacetime quadrants defined by $\{x^i, x^0, \xi^4\}$, reflections on x^i are associated with a reversal of spin direction. Two quanta are formed from x^i–x^0 spacetime and two from x^i–ξ^4. Within these species each of the members can be differentiated by their orientation with respect to the other time dimension.

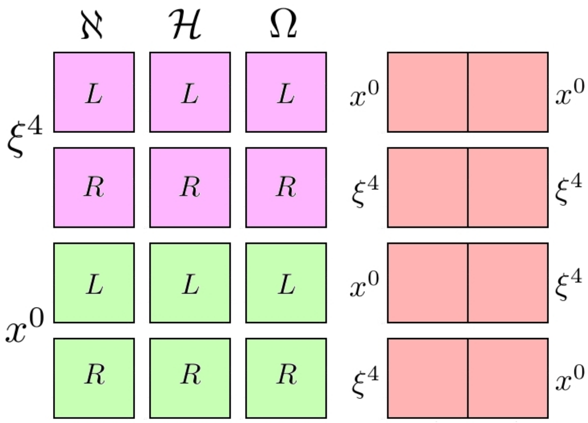

FIG. 2: Three families of spin-1/2 fermions and four spin-1 bosons. Each fermion family contains two distinct species. This representation shows the isomorphism of the MCM with the standard model of particle physics.

distinct species as seen in figure 2.

The structure of the Gel'fand triple is such that $\aleph \subset \mathcal{H} \subset \Omega$ and therein we find a motivation for the increasing masses of the particles across the families. Furthermore, the dimension ξ^4 is a composite construction readily identified with the quarks. The properties of ξ^4 are developed extensively in [2].

$$\xi^4 \equiv \xi^4_+ \otimes \varnothing \otimes \xi^4_- \tag{1}$$

The composite ξ^4 is made from three distinct pieces and it is the only "dimension" to connect the three manifolds $\{\aleph, \mathcal{H}, \Omega\}$. This three-fold structure mimics the three color charges of QCD.

Observable dynamics in Nature preferentially take place in $\aleph$ due to causality. This may have implications for the relative stability of $\aleph$ family leptons compared to their more massive counterparts in the $\mathcal{H}$ and Ω families.

One might ask the following question. What does it mean for a particle to be a little rectangle with $\aleph$, $\mathcal{H}$ or Ω defined on it when the observer is already confined to a little rectangle $\mathcal{H}$ which is the entire observable universe [1, 2]? To first order we point out that fractals are in general very complicated. A key conceptual breakthrough in formulating the MCM was to posit that quantum mechanics is bigger than the universe so that each "elementary" particle in the universe may also contain a universe or even "the universe." It is the very definition of a fractal that scale cannot be determined from internal structure alone so the fractal universe idea [3, 4] accounts nicely for little-rectangles-upon-little-rectangles.

A slightly more technical explanation invokes the holographic principle which was demonstrated in [2]. This principle states that the entire universe should be contained in every piece of it as when a holographic screen is shattered but the complete 3D image remains visible in each small shard [5]. We also make reference to the T-duality of string theory which shows that very small distances and very large distances behave similarly.

Beyond these mainstream principles, Dolce has developed a framework for QFT which strongly supports the little rectangle interpretation [6]. A key stepping stone in developing the MCM was to apply de Broglie's wave-particle duality to the entire universe. The idea was that if the entire universe-spanning hypersurface of the present is a large quantum system with a wavefunction it must also have particle-like properties. This led directly to the concept of the universe as one quantum of spacetime. Dolce includes a quote from de Broglie.

> "We proceed in this work from the assumption of the existence of a certain periodic phenomenon of a yet to be determined character, which will be attributed to each and every isolated energy parcel."

The time axis of our spacetime quantum has a periodic boundary condition [3] and qualifies nicely as de Broglie's "certain periodic phenomenon of a yet to be determined character." Dolce's great insight was to use the de Broglie relations to show that fully covariant quantum theory can be derived from nothing more than periodic boundary conditions on a classical system [6]. This is in good agreement with the idea that the quantum of spacetime is a classical system with periodic boundary conditions.

To test this geometry-based particle representation we may investigate its behavior under a CPT transformation.

$$\hat{C}:\ A^\mu \to -A^\mu \tag{2}$$
$$\hat{P}:\ x^i \to -x^i \tag{3}$$
$$\hat{T}:\ x^0 \to -x^0 \tag{4}$$

The operators $\hat{P}$ and $\hat{T}$ will operate directly on the proposed system. Equation (2) does not have a direct application and the canonical map for charge conjugation $\psi \to -i\left(\bar{\psi}\gamma^0\gamma^2\right)^T$ is beyond the scope of this article. At some point this formalism may become useful but for now we aspire toward maximal simplicity. Equation (2) can be generalized using a condition that $\xi^4_+ \to \xi^4_-$ is identified with $A^\mu \to -iA^\mu$ [2]. In this case the map $\xi^4_+ \to -i\xi^4_-$ can be taken as a substitute for (2).

It is only by convention that ξ^4_+ is chosen to be real and ξ^4_- imaginary so we may also use $\xi^4_- \to -i\xi^4_+$ for $\hat{C}$. This introduces a non-abelian quality to the geometry because once ξ^4_- is chosen to be phase shifted by i with respect to ξ^4_+, that implies an abelian relationship linking $\xi^4_- \to -i\xi^4_+$ with $A^\mu \to A^\mu$. However, that is not the result we are looking for and since SU(3) is a non-abelian group it is good that we easily see the non-commutative character of the MCM.

The condition that $\xi^4_+ \to \xi^4_-$ implies $A^\mu \to -iA^\mu$ was derived for the limiting case $\xi^4_\pm \to 0$ so there will be a rescaling included in a complete adaptation of $\hat{C}$ to the MCM. This rescaling is related to the idea that $\xi^4_+ \in (0, \Phi]$ and $\xi^4_- \in [-i\varphi, 0)$ but it is not relevant to the present discussion. It should be noted that we have preserved the $-i$ factor from the canonical charge conjugation of the wavefunction. C-conjugation is often interpreted as the process of replacing a particle with its anti-particle. This is perfectly consistent with the MCM's cosmological interpretation where the two universes involved in bouncing U and $\bar{U}$ are each other's anti-particles [3].

We have adopted the convention that $\xi^4_\pm \to -i\xi^4_\mp$ is a good representation of $\hat{C}$ in the MCM framework. Using (1), we codify the charge conjugation operator in a form useful for the present considerations.

$$\hat{C} : \xi^4 \to -i\xi^4 \tag{5}$$

Thus CPT conjugation of the system $\{x^i, x^0, \xi^4\}$ reverses the direction of each axis around the origin. The only asymmetry local to the origin is that one half of ξ^4 is imaginary and the other half is real [2]. As a consequence, the handedness of the real and imaginary parts changes. However, since a factor of i is also introduced in the conjugation of ξ^4 that will permute the real and imaginary regimes making the MCM fully invariant under CPT.

Now we discuss the bosons which were presented in figure 2 without account. The spin-1/2 quality of the fermions is related to the $L = 1/2$ property of the spacetime so spin-1 bosons should possess this property in duplicate. As force carriers the bosons can be seen as connections between fermions and thus they adopt two units of spin-1/2. This is to say that the elementary bosons acquire two units of spin-1/2 by connecting two spacetime quanta each with $L = 1/2$.

We have associated the ξ^4 fermion species with the quarks so the ξ^4–ξ^4 boson must be the gluon. There are nine possible color combinations in QCD but there are only eight gluons to allow for color neutrality. If we allow the generic gluon ξ^4–ξ^4 to be further specified, per equation (1), by the three components $\{+, \varnothing, -\}$ of ξ^4 there are nine possible gluons: $++$, $+\varnothing$, $+-$, etc... It is not immediately clear that one of these should be excluded due to geometric considerations, but we note that the gluon $\varnothing\varnothing$ is qualitatively different from the other eight.

Concerning the other bosons, there is no known particle that only interacts with the leptons as the connection x^0–x^0 implies. Still it is a reasonable ansatz to say that x^0–x^0 is the photon. We can speculate that the color confinement mechanism allows groups of quarks to interact via the x^0–x^0 connection. In this case electromagnetic interactions mediated by the photon will only involve integer charges and never the fractional charges of individual quarks.

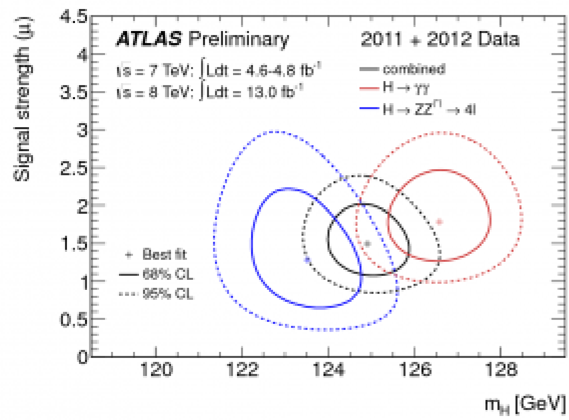

FIG. 3: Hints of two new bosons from the ATLAS experiment. If the new particles are dual to the weak bosons this data may show three new particles where two have the same mass and one lies nearby in the mass spectrum.

Following the convention for gluons, the mixed bosons x^0–ξ^4 and ξ^4–x^0 each contain three species. Let us say that one of these represents the weak bosons. We arbitrarily choose x^0–ξ^4 for this so that the W and Z particles are the connections $x^0\pm$ and the connection $x^0\varnothing$ is a non-particle analogous to the $\varnothing\varnothing$ gluon.

This leaves us with three more bosons in the ξ^4–x^0 connection. Preliminary analysis from the ATLAS experiment indicates that more than one Higgs boson may have been discovered. The data plotted in figure 3 can easily accommodate a three boson structure dual to the weak bosons. If further analysis shows three spin-1 Higgs bosons, that will be an experimental verification of the conjecture presented here. Indeed if there are three of them with spin-1 they are not properly "Higgs" and we propose to name them the G^+, G^- and ζ particles.

Now we discuss some further quantum utility of the MCM particle representation. The first non-classical consideration is spin. In the classical quantum theory state spaces are augmented to accommodate spin degrees of freedom by introducing some new dimensions that essentially lie outside the universe. For spin-1/2 fermions this looks like $\mathcal{L}^2 \to \mathcal{L}^2 \otimes \mathbb{C}^2$. As a segue into our treatment of spin consider Heisenberg's comments on the matter.

> "In classical physics the aim of research was to investigate processes occurring in space and time. In quantum theory, however, the situation is completely different. The very fact that the formalism of quantum mechanics cannot be interpreted as a visual descrip-

tion of a phenomenon occurring in space and time shows that quantum mechanics is in no way concerned with the objective determination of spacetime phenomena."

The purpose of the MCM is to return to a theory concerned with nothing other than spacetime phenomena. We must draw a diagram to show why spin arises and the spin spaces must be brought within the existing model. On the latter, we can immediately write the fermionic state space of a particle that lives in H without spin.

$$H \to H \otimes \xi^4_+ \otimes \xi^4_- \tag{6}$$

Extra dimensions are usually considered to be compactified or virtual because we do not observe them. When spin is modeled this way, we allow for real extra dimensions that may be indirectly observed as quantum mechanical spin. It is as if we are 4D "flatlanders" and do not observe extra dimensions directly because they are orthogonal to us.

It is easy to generalize equation (6) from spin-1/2 fermions to spin-1 bosons.

$$H \to H \otimes x^0_+ \otimes x^0_\star \otimes x^0_- \tag{7}$$

When we define the state spaces this way an interesting and potentially useful property is evident. The dimensions $\{x^0_+, x^0_\star, x^0_-\}$ respectively belong to the manifolds Ω, $\mathcal{H}$ and $\aleph$ which all have Lorentzian metric signature $\{-+++\}$. On the other hand, the dimensions $\{\xi^4_+, \xi^4_-\}$ belong to the spaces $\Sigma^\pm$ where the metric signatures are $\{-++++\}$ and $\{-+++-\}$ [2]. It is possible that this metric discrepancy can be linked to the symmetry and anti-symmetry of bosonic and fermionic wavefunctions. As the quantum theory stands, the asymmetrical fermion wavefunction is inserted to force agreement with experiment but there is no theoretical motivation for the Pauli exclusion principle. If this bridge can be crossed, the periodic table and general structure of large-scale reality can be attributed to $\{x^i, x^0, \xi^4\}$.

To visualize spin as a physical process in space and time, consider the action of the chirological evolution operator $\hat{M}^3$ acting on a matter fermion $|\psi\rangle$. Without specifying whether $|\psi\rangle$ is of the x^0 species or the ξ^4 species, we show that a generic state rotates naturally as times pass. This is shown in figure 4.

$$\hat{M}^3\,|\psi\rangle\,\hat{\pi} \;:=\; i\,|\psi\rangle\,\hat{\pi} \tag{8}$$
$$\hat{M}^6\,|\psi\rangle\,\hat{\pi} \;:=\; -\,|\psi\rangle\,\hat{\pi} \tag{9}$$
$$\hat{M}^9\,|\psi\rangle\,\hat{\pi} \;:=\; -i\,|\psi\rangle\,\hat{\pi} \tag{10}$$
$$\hat{M}^{12}\,|\psi\rangle\,\hat{\pi} \;:=\; |\psi\rangle\,\hat{\pi} \tag{11}$$

The MCM also provides a classical mechanism for wavefunction collapse. Consider a measurement made at

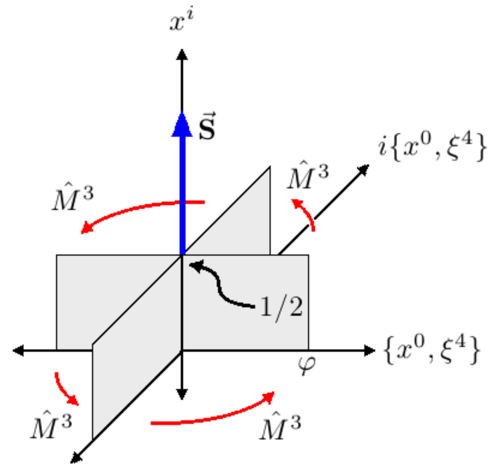

FIG. 4: Spin as a proper physical process. The operator $\hat{M}^3$ rotates quantum states through the complex plane which generates an angular momentum vector pointing in the direction of space. This is to be identified with quantum mechanical spin.

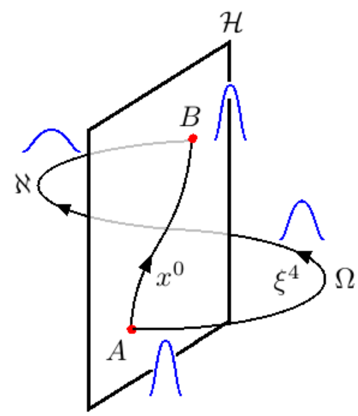

FIG. 5: Collapse of the wavefunction occurs when measurement forms a small aperture in $\mathcal{H}$.

spacetime point A. The wavefunction is sharply peaked about the measured value. After the measurement, the wavefunction begins to spread as it evolves according to the Schrödinger equation (or some other quantum evolution.) When the observer makes another measurement at B, the diffuse wavefunction collapses to the new measured value as illustrated in figure 5.

This process agrees with von Neumann's interpretation where collapse is caused by the consciousness of the observer. The act of measurement forms a small aperture in $\mathcal{H}$ which admits a small part of the wavefunction to continue into the future Ω. By choosing the specific spacetime point B to make a measurement, the observer has selected what value will pass through the aperture.

We have shown that chirological evolution is not a unitary process [1]. To preserve the probability interpretation of the wavefunction we impose unitarity preserving boundary conditions in $\mathcal{H}$. Factors of π and Φ generated by the application of $\hat{M}$ will be removed through normalization but unitary factors of i will remain so that the spin mechanism is not nullified. Artificial insertion of boundary conditions goes against the spirit of the MCM so to account for this, we may consider an inflationary scenario where $\mathcal{H}$ grows by an amount proportional to the normalization constant.

As the wavefunction evolves forward in time from A, it will not satisfy a probability condition. When the observer makes another measurement at B an infinitesimal aperture is formed allowing the wavefunction to poke through as a delta function centered on the measured value. The unitarity condition is imposed so that the wavefunction is a properly normalized Dirac delta in $\mathcal{H}$ and the probability interpretation is valid. After this, the periodic measurement process repeats. We require that the observer be fixed in the present $\mathcal{H}$ at all times but we do not require the wavefunction to obey this condition. As the observer evolves in chronos, we may have the wavefunction evolve in chiros without damaging the structure of existing quantum evolution theory. This process is in good agreement with the traditional usage of Gel'fand's formalism.

We have made the distinction that fermions are distinguished by the vector spaces $\{\aleph, \mathcal{H}, \Omega\}$ and bosons are distinguished by the components $\{+, \varnothing, -\}$ of ξ^4. Given the close relationship of ξ^4 and $\{\aleph, \mathcal{H}, \Omega\}$ [2] it may be that these are two sides of the same coin. If so, we have considered every possible choice for a particle in the MCM and shown that, pending the final character of the Higgs, the MCM particles are the standard model particles. Beyond the fermion/boson substructure choice there was no arbitrary finagling. We examined what was possible and the possibility looks very much like the standard model.

The different theories of contemporary physics are specified by minimizing the action between fixed boundaries. The act of replacing one boundary condition with another will have no impact on the validity of the dynamics between the end points. This is just what we have done with the MCM; we replaced the linear interval between the past and the future with a compact interval on $\mathbb{S}^1$. We preserve everything that we know works so well and then we also explain many other things [1–3]. It is not clear why the theory which provides a less broad explanation is the one in common usage but hopefully that will change in time.

While particle experiments at CERN and other facilities contribute to the development of the physical zeitgeist, we call special attention to a recent measurement of the proton radius at The Paul Scherrer Institute [7]. The radius of the proton in muonic hydrogen was found to be significantly smaller than the radius of the proton in ordinary hydrogen. According to the standard model, after the larger mass of the muon is accounted for, there should be no difference in the radius measured in either hydrogenic system. According to the MCM, hydrogen is an interaction of a proton with an $\aleph$ family particle but muonic hydrogen involves a proton and an $\mathcal{H}$ particle. Therein lies a potential explanation for the result: standard model leptons all live in the same state space but MCM leptons do not.

This opens many doors to new physics. For instance, the value of the fine structure constant has been experimentally determined to about 10 significant digits. Is this the same 10 digit number we would measure if the existing electron-based measurements were replaced with muon- or even tau-based experiments? If we used QED to calculate the muon magnetic moment using the value of α found from muon-based experiments, would there still be an anomaly?

The small deviation in the predicted value of α and the currently accepted value is something that will make or break the MCM. We have proposed that the increasing mass of the fermions across the families is related to the increasing volume of their respective state spaces. We have also ideated the concept that the $\aleph$ particles are more stable because everything we observe took place in the past. While the observer is permanently fixed in $\mathcal{H}$, other things are not. Given this condition on the observer it may be that measurements of α using $\mathcal{H}$ family particles will minimize the difference between the empirical and theoretical values.

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