Descriptions of Elementary Particles plus Dark Matter plus Dark Energy and Explanations for Some Related Data

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Abstract

We suggest united models and specific predictions regarding elementary particles, dark matter, aspects of galaxy evolution, dark energy, and aspects of the cosmology timeline. Results include specific predictions for new elementary particles and specific descriptions of dark matter and dark energy. Some of our modeling matches known elementary particles and extrapolates to predict other elementary particles, including bases for dark matter. Some modeling explains observed ratios of effects of dark matter to effects of ordinary matter. Some models suggest aspects of galaxy formation and evolution. Some modeling correlates with eras of increases or decreases in the observed rate of expansion of the universe. Our modeling framework features mathematics for isotropic quantum harmonic oscillators and provides a framework for creating physics theories. Some aspects of our approach emphasize existence of elementary particles and de-emphasize motion. Some of our models complement traditional quantum field theory and, for example, traditional calculations of anomalous magnetic dipole moments.

Contents

1 Introduction

This unit introduces our work and this manuscript.

1.1 Context for and scope of our work

This unit discusses context for, aspects of, and the scope of our work.

Physics includes issues that have remained unresolved for decades. For one example, describe elementary particles that remain to be found. For another example, describe dark matter.

Traditional physics theory has bases in adding quantization to classical modeling of the motion of objects. We pursue an approach that features, from its beginning, quantized concepts and that does not originally address translational motion.

The approach matches, explains, or predicts phenomena that traditional physics theory approaches do not. For example, we suggest - with some specificity - descriptions of new elementary particles, dark matter, and dark energy. The approach suggests formalism that can complement traditional quantum field theory.

1.2 Timing regarding assumptions put into the work and explanations coming from the work

This unit discusses the notion that, as of the year 2018, our work seemed to achieve a stable basis of theory centric assumptions and our work began to offer explanations for an increasing scope of observed natural phenomena that people have, starting in 2017 and continuing thereafter, reported.

In 2011, we decided to try to explain eras pertaining to the rate of expansion of the universe.

For years thereafter, we felt that the scope of major assumptions on which we based our work grew at about the same pace as the scope of natural phenomena that the work seemed to explain. (Reference [6] provides a snapshot - as of 2016 - of progress and of unresolved matters.)

In 2018, the trajectories of the two scopes seemed to decouple. The scope of major assumptions seemed to stop growing. The scope of seemingly explained natural phenomena continued to grow. Newly explained natural phenomena tend to correlate with astrophysics observations - especially, observations correlating with effects of dark matter - that people reported during and after 2017.

1.3 Scope of this manuscript

This unit discusses the scope of this manuscript.

This manuscript summarizes some aspects of our work. The manuscript does not mention some aspects of the work. The manuscript does not fully cover details leading to some of the results that the manuscript shows. Reference [7] provides some of those details. This manuscript provides more details than a conference talk provided. (See reference [8].) This manuscript augments a previous manuscript. (See reference [9].)

2 Methods

This unit summarizes some aspects - approach, in terms of some broad steps and thinking; inspirations; mathematics-based modeling; and some detailed physics modeling steps and concepts - underlying our research.

2.1 Approach

This unit summarizes some efforts and thinking underlying this research.

The following efforts and thinking contributed to our developing this research.

1. Try to explain changes in the rate of expansion of the universe.
    - Consider that the rate of expansion of the universe correlates with three eras - initial rapid expansion, billions of years of decelerating expansion, and a recent some billions of years of accelerating expansion.
    - Consider the concept that, for two objects that move apart from each other, an r^{-n} force between the two objects eventually dominates an $r^{-(n+1)}$ force. (Here, the symbol r denotes the distance between the centers of the two objects.)
    - Consider the concept that, for a scenario involving objects moving away from each other, pairs of smaller neighboring objects might undergo transitions from dominance by an r^{-n} force to dominance by an $r^{-(n+1)}$ force sooner than would pairs of larger objects.
    - Consider the concept that forces that dominate between neighboring currently very large objects might transition from r^{-5} repulsion early in the history of the universe to r^{-4} attraction for billions of years to r^{-3} repulsion for billions of recent years. (Regarding neighboring smaller astrophysical objects, transitions would occur more rapidly and the currently dominant effect would feature r^{-2} gravitational attraction.)
    - Anticipate trying to find a fundamental basis for such a phenomenological explanation of eras regarding the rate of expansion of the universe. Realize that the basis might feature a model that catalogs all known elementary particles and suggests new elementary particles. Realize that the basis might not need to depend on choosing among kinematics theories (such as Newtonian physics, special relativity, and general relativity).
2. Develop mathematics-based modeling that outputs solutions to equations, such that some solutions match all known elementary particles and some solutions suggest new elementary particles.
    - Convert a hunch about modeling for excitations of photons into a mathematics-based modeling basis that outputs all known elementary particles and that suggests new elementary particles.
    - Realize that the basis seems to be independent of the choice between classical modeling and quantum modeling and to be independent of choices among kinematics modeling bases.
    - Realize that the basis seems to obviate needs to deal with possibly infinite energies that traditional physics theory modeling might correlate with sums of boson ground-state energies or with a possibly infinite amount of matter in the universe.
    - Realize that the basis outputs some spin-2 solutions that might as easily correlate with gravity plus dark energy forces as some spin-1 solutions correlate with electromagnetic forces.
    - Realize that the basis seems to output solutions that correlate with modeling, regarding measured anomalous magnetic dipole moments, that might obviate traditional physics theory needs for mathematically conditionally convergent sums.

3. Realize that the modeling basis provides a basis for quantum field theories that might complement aspects of traditional physics theory quantum field theories. Aspects (of so-called complementary physics theory) seem to include the following.
    - Complementary physics theory embraces interaction vertices that can be volume-like (as well as point-like) with respect to spatial coordinates. Thereby, models can pertain to interactions with objects, such as protons and atoms, that include more than one elementary particle.
    - Complementary physics theory embraces symmetries that correlate with properties that add. One example of such a property is charge. Another example is excitation numbers for polarization modes of zero-mass elementary bosons.
    - Complementary physics theory embraces a symmetry that correlates with a number, three, of fermion generations.
    - Complementary physics theory embraces an approximate symmetry that correlates with a notion of somewhat conservation of fermion generation.
    - Complementary physics theory embraces symmetries that correlate with conservation of each of energy, momentum, and angular momentum.
4. Realize that the set of suggested elementary particles points to possible candidates for dark matter.
    - One candidate for dark matter is hadron-like particles (which would not be elementary particles) comprised of gluons and zero-charge analogs (which would be elementary particles) of quarks.
5. Consider the possibility that most dark matter correlates with five isomers of the combination of ordinary matter charged elementary particles and (in effect, ordinary matter) photons.
    - Realize that the mathematics-modeling basis can support the notion of six such isomers, with one isomer correlating with ordinary matter and five isomers correlating with dark matter.
    - Realize that the notion of six isomers and the notion of hadron-like particles comprised of gluons and zero-charge analogs of quarks might suffice to explain the inferred ratio of dark matter density of the universe to ordinary matter density of the universe. (Realize that traditional physics theory seems to be unable to explain that ratio.)
6. Suggest an evolution scenario, for at least some galaxies, that is based on dark matter consisting mostly of the five dark matter isomers.
    - Realize that the scenario seems to dovetail with observed ratios, pertaining to galaxies, of dark matter effects to ordinary matter effects. (Realize that traditional physics theory seems to be unable to explain those ratios. Realize that traditional physics theory might overly - compared to observational evidence - correlate with the notion that visible galaxies form based on clumps of dark matter.)
    - Realize that reuse of the scenario might explain aspects of so-called dark matter galaxies.
7. Consider the possibility that dark energy density of the universe does not necessarily correlate with dark energy forces or with so-called vacuum energy or so-called vacuum fluctuations.
    - Note that complementary physics theory does not necessarily embrace traditional physics theory notions such as vacuum energy and vacuum fluctuations.
    - Consider the possibility that the universe includes, in effect, six isomers of the combination of gravity and six isomers of charged elementary particles plus photons. (Propose using the three-word term doubly dark matter to correlate with the additional 30 isomers of charged elementary particles. Those particles would be somewhat nearly dark with respect to ordinary matter centric photons and would be dark with respect to familiar gravity plus dark energy forces.)
    - Consider the possibility that observations of non-zero dark energy density of the universe correlate with interactions between the familiar gravity-plus-six-isomers-of-charged-elementary-particles and the additional 30 isomers of charged elementary particles.
    - Note that the inferred ratio of density of the universe of dark energy to density of the universe of ordinary matter plus dark matter would grow over time from zero and would not necessarily, by now, achieve five.

2.2 Inspirations

This unit discusses two inspirations that led to our work.

One inspiration posits a non-traditional representation for photons.

Traditional physics theory describes photon states via two harmonic oscillators. Traditional physics theory features four space-time dimensions. Why not describe photon states via four harmonic oscillators?

Complementary physics theory describes photon states via four harmonic oscillators. A first hunch might be that doing so correlates with non-zero longitudinal polarization and/or non-zero photon rest mass. However, mathematics allows a way to avoid this perceived possible problem. A second hunch might be that using four oscillators adds no insight. However, using four oscillators leads to a framework for physics theories and, eventually, even to insight about a family of phenomena that includes photons.

One inspiration posits that physics theory does not necessarily have to follow the traditional path of quantizing aspects that correlate with traditional physics theory classical theories of motion.

Some data point to quantized phenomena for which models do not necessarily need to have bases in motion, even though observations of motion led to making needed inferences from the data. Examples include quantized phenomena with observed integer ratios of observed values, including spin, charge, baryon number, and lepton number; the 24 known elementary particles (assuming that one counts eight gluons) and some aspects of their properties; and some approximate ratios, including ratios of squares of masses of elementary bosons and ratios of logarithms of masses of quarks and charged leptons. Other data also might be significant. One example features somewhat-near-integer ratios of dark matter effects to ordinary matter effects. Another example features a numeric relationship between the ratio of the mass of a tauon to the mass of an electron and the ratio, for two electrons, of electromagnetic repulsion to gravitational attraction.

We strive to develop physics theory that correlates with such observations. We select modeling bases that produce quantized results. Based on quantum modeling techniques that do not necessarily consider motion or theories of motion, we develop models that match known elementary particles and extrapolate to suggest other elementary particles. Our work then continues from that point.

2.3 ALG double-entry bookkeeping

This unit discusses aspects of mathematics-based modeling that underlies our work.

We consider the left-circular polarization mode of a photon. We denote the number of excitations of the mode by n. Here, n is a nonnegative integer. One temporal oscillator pertains. We label that oscillator TA0. The excitation number $n_{TA0} = n$ pertains. Harmonic oscillator mathematics correlates a value of $n + 1/2$ with that oscillator. Three spatial oscillators pertain. Here, $n_{SA0} = -1$, $n_{SA1} = n$, $n_{SA2} = @_0$. Oscillator SA0 correlates with longitudinal polarization and has zero amplitude for excitation. Oscillator SA1 correlates with left-circular polarization. Oscillator SA2 correlates with right-circular polarization. The symbol @_ denotes a value of _ that, within a context, never changes. For left-circular polarization, $@_0$ pertains for oscillator SA2. The sum $n+1/2$ correlates with each of the one TA-side oscillator and the three SA-side oscillators. For, the SA-side oscillators, the sum equals $(-1 + 1/2) + (n + 1/2) + (0 + 1/2)$.

The following concepts and generalizations pertain.

- The above discussion correlates with the term ALG modeling. ALG is an abbreviation for the word algebraic. Later we discuss PDE modeling. PDE abbreviates the three-word term partial differential equation.
- For ALG modeling, the expression $0 = A^{ALG} = A^{ALG}_{TA} - A^{ALG}_{SA}$ pertains. The one-element term double-entry pertains. For example, increasing a TA-side excitation number by one requires either decreasing a different TA-side excitation by one or increasing an SA-side excitation by one. The two-element term double-entry bookkeeping pertains.
- The expression $A^{ALG} = 0$ provides a basis for avoiding traditional physics theory concerns about unlimited sums of ground state energies.
- Some aspects of ALG modeling include notions that people might consider to correlate with the three-word term below ground state. For example, consider the SA-side representation for the ground state of the left-circular polarization mode. The complementary physics theory ground state sum is one-half. People might think that the ground state sum for a three-dimensional isotropic quantum harmonic oscillator should be three-halves, as in $3 \cdot (0 + 1/2)$.

- For some, but not all, modeling, complementary physics theory considers pairs of oscillators. Pairs can include, for example, TA8-and-TA7, TA6-and-TA5, $\cdots$, TA2-and-TA1, TA0-and-SA0, SA1-and-SA2, $\cdots$, and SA7-and-SA8.
- The following symmetries can pertain regarding sets of oscillator pairs. For each case, at least one additive property pertains. Examples of additive properties include charge, lepton number, baryon number, and excitations of polarization modes of so-called long-range forces.
  - $U(1)$ pertains for excitations of polarization modes of long-range forces. For example, a $U(1)$ symmetry correlating with the SA1-and-SA2 oscillator pair pertains regarding photons. A $U(1)$ symmetry correlating with the SA3-and-SA4 oscillator pair pertains regarding would-be gravitons.
  - A pair of $U(1)$ symmetries can pertain regarding charge and conservation of charge. The relevant oscillator pairs are TA2-and-TA1 and SA1-and-SA2.
  - Four $U(1)$ symmetries can pertain regarding lepton number, baryon number, somewhat conservation of lepton number, and somewhat conservation of baryon number. Conservation of lepton number minus baryon number pertains.
- The following symmetries can pertain regarding oscillator pairs.
  - $SU(2)$ pertains for the fermion aspect of generations. Here the property is mass. The relevant oscillator pair is SA3-and-SA4.
  - $SU(2)$ pertains for a somewhat conservation law that pertains, for some interactions, regarding fermion generations. The relevant oscillator pair is TA4-and-TA3.
  - $SU(2)$ pertains for each of the two kinematics conservation laws conservation of linear momentum and conservation of angular momentum.
  - $SU(2) \times U(1)$ pertains for some aspects regarding the weak interaction. The relevant oscillator pair is SA1-and-SA2.
- The following symmetry can pertain regarding the TA0-and-SA0 oscillator pair.
  - $U(1)$ pertains for some binary choices, such as a choice between zerolike mass and non-zero mass. The word zerolike denotes the notion of either zero for both of traditional physics theory and complementary physics theory or zero or small for traditional physics theory and zero for complementary physics theory.
- The following symmetries can pertain regarding sets of j oscillators. Here, either all the oscillators are TA-side or all the oscillators are SA-side.
  - $SU(3)$ pertains for aspects regarding the strong interaction.
  - $SU(j)$, for $j = 3$, $j = 5$, or $j = 7$, correlates somewhat indirectly with so-called spans for long-range forces.
  - $SU(5)$ correlates with a complementary physics theory notion of conservation of energy. This notion contrasts with traditional physics theory notions of a one-generator symmetry. The one-generator symmetry correlates with an aspect of the Poincare group.

2.4 PDE double-entry bookkeeping

This unit discusses aspects of mathematics-based modeling that underlies our work.

Complementary physics theory includes modeling based on an analog, $0 = A^{PDE} = A^{PDE}_{TA} - A^{PDE}_{SA}$, to $0 = A^{ALG} = A^{ALG}_{TA} - A^{ALG}_{SA}$. Each of A^{PDE}_{TA} and A^{PDE}_{SA} is a quantum operator.

The following perspective pertains.

Equations (1) and (2) correlate with an isotropic quantum harmonic oscillator. Here, r denotes the radial coordinate and has dimensions of length. The parameter η_{SA} has dimensions of length. The parameter η_{SA} is a non-zero real number. The magnitude $|\eta_{SA}|$ correlates with a scale length. The positive integer D correlates with a number of dimensions. Each of ξ_{SA} and ξ'_{SA} is a constant. The symbol $\Psi(r)$ denotes a function of r and, possibly, of angular coordinates. The symbol ${\nabla_r}^2$ denotes a Laplacian operator. In some traditional physics theory applications, Ω_{SA} is a constant that correlates with aspects correlating with angular coordinates. Our discussion includes the term Ω_{SA} and, otherwise, tends to de-emphasize some angular aspects. We associate the term SA-side with this use of symbols and mathematics, in anticipation that the symbols used correlate with spatial aspects of physics modeling and in anticipation that TA-side symbols and mathematics pertain for some modeling.

$$\xi_{SA}\Psi(r) = (\xi'_{SA}/2)(-(\eta_{SA})^2{\nabla_r}^2 + (\eta_{SA})^{-2}r^2)\Psi(r) \tag{1}$$

$${\nabla_r}^2 = r^{-(D-1)}(\partial/\partial r)(r^{D-1})(\partial/\partial r) - \Omega_{SA}r^{-2} \tag{2}$$

Including for $D = 1$, each of equation (1), equation (2), and the function Ψ pertains for the domain equation (3) shows.

$$0 < r < \infty \tag{3}$$

We consider solutions of the form equation (4) shows.

$$\Psi(r) \propto (r/\eta_{SA})^{\nu_{SA}} \exp(-r^2/(2(\eta_{SA})^2)), \text{ with } (\eta_{SA})^2 > 0 \tag{4}$$

Equations (5) and (6) characterize solutions. The parameter η_{SA} does not appear in these equations. Equation (7) correlates with the domains of D and ν_{SA} for which normalization pertains for $\Psi(r)$. For $D + 2\nu_{SA} = 0$, normalization pertains in the limit $(\eta_{SA})^2 \to 0^+$.

$$\xi_{SA} = (D + 2\nu_{SA})(\xi'_{SA}/2) \tag{5}$$

$$\Omega_{SA} = \nu_{SA}(\nu_{SA} + D - 2) \tag{6}$$

$$D + 2\nu_{SA} \geq 0 \tag{7}$$

The following notions pertain.

- Some applications feature one temporal dimension (or, $D^*_{TA} = 1$) and three spatial dimensions (or, $D^*_{SA} = 3$).
  - SA-side aspects correlate with $D^*_{SA} = 3$ via values of Ω_{SA} that satisfy $\Omega_{SA} = \sigma S(S + D^*_{SA} - 2) = \sigma S(S + 1)$. Here, σ is one of $+1$ and -1. Here, $2S$ is a nonnegative integer. For some solutions, $D \neq D^*_{SA}$. Here, S can correlate with traditional physics theory notions of spin divided by $\hbar$. The symbol $\hbar$ denotes the so-called reduced Planck's constant.
  - Solutions for which $\nu_{SA} = -1/2$ can correlate with notions of fields for elementary fermions.
  - Solutions for which $\nu_{SA} = -1$ can correlate with notions of fields for elementary bosons.
  - Solutions for which $\nu_{SA} = -3/2$ can correlate with notions of particles for elementary fermions.
  - PDE solutions are radial with respect to t, the TA-side analog to the SA-side radial coordinate r, as well as being radial with respect to r.
  - TA-side aspects correlate with $D^*_{TA} = 1$ via values of Ω_{TA} that satisfy $\Omega_{TA} = \sigma' S'(S' + D^*_{TA} - 2) = \sigma' S'(S' - 1)$. Here, σ' is one of $+1$ and -1. Here, $2S'$ is an integer that exceeds one. For some solutions, $D \neq D^*_{TA}$.
- Some applications feature a notion of $D'' = 2$. For these cases, we, in effect, separate some PDE aspects into PDE aspects correlating with oscillator pairs. Examples of such oscillator pairs include the TA0-and-SA0 oscillator pair and the SA1-and-SA2 oscillator pair.
  - For some cases correlating with $D^*_{TA} = 1$ and $D^*_{SA} = 3$, $D'' = 2$ pertains for each of the TA0-and-SA0 oscillator pair and the SA1-and-SA2 oscillator pair.
  - Solutions for which $\nu_{TA0,SA0} = \nu_{SA1,SA2} = -1$ can correlate with notions of particles for elementary bosons.

Table 1 provides details leading to equations (5) and (6). We consider equations (1), (2), and (4). The table assumes, without loss of generality, that $(\xi'_{SA}/2) = 1$ and that $\eta_{SA} = 1$. More generally, we assume that each of the four terms $K\_$ and each of the two terms $V\_$ includes appropriate appearances of $(\xi'_{SA}/2)$ and η_{SA}. The term V_{+2} correlates with the right-most term in equation (1). The term V_{-2} correlates

Tab. 1: Terms correlating with an SA-side PDE equation (assuming $(\xi'_{SA}/2) = 1$ and $\eta_{SA} = 1$)

Term/ $\exp(-r^2/2)$	Symbol for term	Change in power of r	Non-zero unless ...	Notes
$-r^{\nu_{SA}+2}$	K_{+2}	$+2$	-	Cancels V_{+2}
$(D+\nu_{SA})r^{\nu_{SA}}$	K_{0a}	0	$D+\nu_{SA}=0$	-
$\nu_{SA}r^{\nu_{SA}}$	K_{0b}	0	$\nu_{SA}=0$	-
$-\nu_{SA}(\nu_{SA}+D-2)r^{\nu_{SA}-2}$	K_{-2}	-2	$\nu_{SA}=0$ or $(\nu_{SA}+D-2)=0$	Cancels V_{-2}
$\Omega_{SA}r^{\nu_{SA}-2}$	V_{-2}	-2	$\Omega_{SA}=0$	Cancels K_{-2}
$r^{\nu_{SA}+2}$	V_{+2}	$+2$	-	Cancels K_{+2}

with the right-most term in equation (2). The four $K_{\_}$ terms correlate with the other term in equation (2). The sum of the two $K_{0\_}$ terms correlates with the factor $D+2\nu_{SA}$ in equation (5).

The following remarks are speculative. Possibly, PDE-based modeling correlates with some aspects of unification of the strong, electromagnetic, and weak interactions. We consider modeling for which $2\nu_{SA}$ is a non-negative integer. Based on the r^{-2} spatial factor, the V_{-2} term might correlate with the square of an electrostatic potential. Based on the r^2 spatial factor, the V_{+2} term might correlate (at least, within hadrons) with the square of a potential correlating with the strong interaction. The sum $K_{0a}+K_{0b}$ might correlate with the strength of the weak interaction. (The effective range of the weak interaction is much smaller than the size of a hadron. Perhaps, the spatial characterization r^0 correlates with an approximately even distribution, throughout a hadron, for the possibility of a weak interaction occurring.) Based on the V_{-2} term, we expect that ξ'_{SA} includes a factor $\hbar^2$.

2.5 Physics modeling

This unit discusses some details regarding steps and concepts underlying our theories and models. Such theories and models suggest means to catalog and predict elementary particles and to augment and/or complement traditional physics theory aspects such as quantum field theory and quantum chromodynamics.

The following steps and concepts pertain regarding how we developed complementary physics theory.

- Develop a catalog of known and suggested elementary particles and a catalog of known and suggested so-called long-range forces. Do the following.
  - Recognize four possibly somewhat distinguishable notions - objects, forces, motion, and internal changes to objects. Focus first on cataloging elementary particles and long-range forces. For such cataloging activities, de-emphasize the notion that forces affect motion and affect internal states of objects. Postpone considering traditional physics theory kinematics conservation laws and kinematics theories.
  - Use a framework that has a basis in solutions for which, for each elementary particle or long-range force, at least one ALG $n_{\_}$ is negative and/or at least one PDE ν is negative.
  - Observe that the catalog of elementary particles suggests new particles.
  - Observe that the catalog of long-range forces suggests a description of gravity and dark energy forces. (Note that the description seems suitable for use in modeling based on classical physics and for use in modeling based on quantum physics.)
- Anticipate expanding use of the framework that the cataloging activity uses. We call the framework the CUSP framework. CUSP is an acronym for the four-word phrase concepts uniting some physics. Uses of the framework include the following.
  - Match known and predict new elementary particles and long-range forces.
  - Develop complements to traditional physics theory quantum field theory, quantum electrodynamics, and quantum chromodynamics.
  - Embrace and incorporate traditional physics theory kinematics conservation laws.
  - Bridge aspects of traditional physics theory and complementary physics theory.

- Develop aspects of a complementary physics theory QFT (or, quantum field theory).
  - Catalog interaction vertices.
    - For example, for each of some vertices, assume that the sum, over incoming objects, of the values of the SA-side field-centric ν equals each one of $-3/2$ and the sum, over outgoing objects, of the values of the SA-side field-centric ν.
    - The following symbols symbolize interaction vertices - 0f1b→2f0b, 2f0b→0f1b, 1f1b→1f1b, 1f1b→3f0b, 3f0b→1f1b, and 0f2b→0f2b. Each symbol correlates with the notion of incoming particles → (or, produce) outgoing particles. An element of the form nf denotes n fermions. An element of the form nb denotes n bosons. Regarding 1f1b→1f1b vertices, one (but not both) of the 1b states can be a ground state. An element of the form 0b denotes such a ground state. The vertices 0f1b→2f0b, 2f0b→0f1b, and 0f2b→0f2b correlate with SA-side field-centric $\nu = -1$. The vertices 1f1b→1f1b, 1f1b→3f0b, and 3f0b→1f1b correlate with SA-side field-centric $\nu = -3/2$.
  - Note that each interaction vertex correlates with a point with respect to a temporal space-time coordinate. Note that each of some interaction vertices can correlate with either a point or a non-zero volume with respect to spatial space-time coordinates.
  - Anticipate that aspects of complementary physics theory QFT do not necessarily require modeling that uses notions of virtual particles.
  - Observe that the catalog of long-range forces suggests a complementary physics theory explanation for anomalous magnetic dipole moments. Note that the explanation correlates with a sum of a finite number of terms and might avoid complexities people associate with traditional physics theory QED (or quantum electrodynamics).
  - Anticipate that complementary physics theory can embrace notions of tachyon-like behavior regarding particles within so-called confined environments. (An example of a confined environment is a proton or other hadron. The word confined correlates with the quarks and gluons in the proton or other hadron. Tachyon-like behavior correlates with modeling for which interaction vertices model as having non-zero volume with respect to spatial space-time coordinates. The two-word term free environment contrasts with the two-word term confined environment.)
- Consider a notion that nature includes nnn isomers of a set (of elementary particles) that includes, at least, all non-zero-charge elementary particles and the traditional physics theory photon. Here, $L6N = \log_6(\text{nnn})$ is a non-negative integer.
  - Traditional physics theory correlates with $L6N = 0$. Only one isomer of each charged elementary particle pertains.
  - The ratio of inferred density of the universe of dark matter to inferred density of the universe of ordinary matter is somewhat more than five. (See reference [25].) Traditional physics theory does not explain the ratio of five-plus to one.
  - We posit that a positive value of $L6N$ pertains.
  - The following thought experiment, posits an explanation for the ratio of five-plus to one.
    - Assume that $L6N = 1$. Assume that there is only one isomer of gravity. Assume that gravity interacts with each of the six isomeric sets.
    - One isomeric set correlates with ordinary matter and familiar photons. The other five isomer sets correlate with dark matter.
    - Assume that something not related to the isomeric sets also contributes to inferences that correlate with dark matter. (Below, we propose that so-called 1R⊗2U hadron-like particles are candidates for such a something.) Assume that such a contribution correlates with the difference between a ratio of five-plus to one and a ratio of five to one.
    - Complementary physics theory explains the ratio of densities of the universe.
    - Complementary physics theory might explain other inferred ratios of dark matter effects to ordinary matter effects.
  - We explore that extent to which $L6N = 1$ modeling explains other observed ratios of dark matter effects to ordinary matter effects.
    - We develop a galaxy evolution scenario that correlates with observations of ratios and with complementary physics theory.

        * We explain observed ratios pertaining to some galaxies and to some galaxy clusters.
    - We also explore notions that $L6N$ is two or three.
        * For $L6N = 2$, complementary physics theory offers the possibility that so-called dark energy density of the universe correlates with the existence, in nature, of (so-called doubly dark) isomers of the $L6N = 1$ set that includes both one instance of gravity and six instances of the set of, at least, non-zero-charge elementary particles.

- Catalog contexts that correlate with modeling for objects.
    - Use the two element term would-be free to correlate with kinematics modeling such that objects are well-defined and move essentially either at the speed of light (per all observers) or at zero speed (per some observers). An example is an idealization of an electron in a force-free environment.
    - Use the two-element term nearly free to correlate with kinematics modeling such that objects change properties at most somewhat and motion features trajectories that bend at most somewhat. An example is a neutrino in interstellar space.
    - Use the two-element term lightly bound to correlate with kinematics modeling such that objects change properties at most somewhat and motion features a discernible and possibly repeating trajectory. An example is a planet in orbit around a star.
    - Use the two-element term tightly bound to correlate with dynamics modeling such that objects and their motion correlate with inner aspects of more-encompassing objects. An example is a quark in a hadron.
    - Use the two-element term would-be gone to correlate with dynamics modeling that essentially ignores an object. An example is a quark in an atomic nucleus that includes many hadrons.
- Anticipate that aspects paralleling traditional physics theory notions of entanglement pertain for the modeling cases mentioned just above, except the case of would-be free.
- Embrace and explore aspects of kinematics and dynamics.
    - Embrace kinematics by adding, within the framework, traditional physics theory symmetries correlating with conservation of linear momentum and conservation of angular momentum.
    - Explore possibilities for a complementary physics theory QCD (or, quantum chromodynamics). Here, conservation of energy, linear momentum, and angular momentum can pertain to hadrons but do not necessarily pertain to individual quarks or to gluons.
- Propose means to bridge aspects of complementary physics theory and aspects of traditional physics theory. Topics include the following.
    - The elementary particle Standard Model.
    - General relativity.
    - Aspects of the cosmology timeline.
    - Aspects of galaxy evolution.
- Discuss other notions that complementary physics theory suggests. Topics include the following.
    - A suggested relationship between a ratio of two elementary fermion masses and a ratio of two long-range force strengths. This relationship predicts a tauon mass that would be consistent with, and more accurate than, present experimental results.
    - A formula that approximately links the masses of the three charged leptons and the six quarks. This formula suggests a new use of the fine-structure constant.
    - Augmentations to or an alternative to aspects of traditional physics theory nuclear physics.

Tab. 2: A catalog of elementary particles

Entities	Spin	Σ	$\sigma = -1$		$\sigma = +1$	
			$m \doteq 0$	$m > 0$	$m \doteq 0$	$m > 0$
Elementary particles	0	0	0K (1)	0P (1)	0I (1)	0H (1)
”	1/2	1	1R (6)	1Q (6)	1N (3)	1C (3)
”	1	2	2U (8)	2T (2)	-	2W (2)
Long-range forces	≥ 1	≥ 2	-	-	ΣG (NA)	-

3 Results

This unit discusses results regarding elementary particles, relationships between masses of elementary particles, so-called long-range forces, hadron-like particles, the nature of dark matter, explanations regarding ratios of dark matter effects to ordinary matter effects, the evolution of some galaxies, dark energy forces and eras regarding the rate of expansion of the universe, dark energy densities, baryon asymmetry, neutrino oscillations, a complementary physics theory approach to the topic of anomalous magnetic dipole moments, and possibilities for complementary physics theory approaches to modeling aspects of nuclear physics. This unit correlates our results with results of observations.

3.1 Elementary particles, including an analog to the periodic table for elements

This unit shows a table of all known elementary particles and all elementary particles that complementary physics theory predicts.

Table 2 provides a candidate periodic table analog for elementary particles. Here, we separate long-range forces from elementary particles. We de-emphasize using this table to display a detailed catalog of long-range forces. (For a catalog of long-range forces, see table 3.) For elementary particles, each row correlates with one value of spin S. Here, $\Sigma = 2S$. The value of Σ appears as the first element of each two-element symbol $\Sigma\Phi$. The letter value of Φ denotes a so-called family of elementary particles. For $\sigma = -1$, the particles model as if they occur only in so-called confined environments. Examples of confined environments include hadron-like environments and atomic nuclei. Examples of hadron-like environments include hadrons and possible seas made of 2U particles (or, gluons) and at least one of 1Q particles (or, quarks) and 1R particles. For $\sigma = +1$, the particles model as if they can occur in confined environments and can occur outside of confined environments. We use the two-word term free environment to contrast with the two-word term confined environment. The expression $m \doteq 0$ denotes a notion of zerolike mass. Complementary physics theory models correlate the relevant particles with zero mass. Traditional physics theory models do or might correlate the relevant elementary fermions with small positive masses or with zero masses. The expression $m > 0$ correlates with positive mass. A number in parenthesis denotes a number of elementary particles. The symbol NA denotes the two-word term not applicable. Possibly, each cell in which a dash appears does not pertain to nature.

We discuss the elementary particles for which $\sigma = +1$ and $m > 0$. The 0H particle is the Higgs boson. The three 1C particles are the three charged leptons - the electron, the muon, and the tauon. The two 2W particles are the two weak interaction bosons - the Z boson and the W boson.

We discuss the elementary particles for which $\sigma = +1$ and $m \doteq 0$. The 0I, or so-called aye, particle is a suggested zero-mass relative of the Higgs boson. The three 1N particles are the three neutrinos.

We discuss the elementary particles for which $\sigma = -1$ and $m > 0$. Possibly, the 0P, or so-called pie, particle correlates with an attractive component of the residual strong force. The 0P particle provides a possible aspect for alternative modeling regarding interactions between hadrons in atomic nuclei. The six 1Q particles are the six quarks. The two 2T, or so-called tweak, particles are analogs to the weak interaction bosons. The charge of the one non-zero-charge 2T particle is one-third the charge of the W boson. The non-zero-charge tweak particle may have played a role in the creation of baryon asymmetry.

We discuss the elementary particles for which $\sigma = -1$ and $m \doteq 0$. Possibly, the 0K, or so-called cake, particle correlates with a repulsive component of the residual strong force. The 0K particle provides a possible aspect for alternative modeling regarding interactions between hadrons in atomic nuclei. The six 1R, or so-called arc, particles are zero-charge zerolike-mass analogs of the six quarks. Hadron-like particles made from arcs and gluons contain no charged particles and measure as dark matter. The eight 2U particles are the eight gluons.

3.2 Objects and some of their properties

This unit correlates some traditional physics theory internal properties of objects with aspects of complementary physics theory modeling.

For modeling that correlates with free environments, interacting objects correlate with $\sigma = +1$ and the following notions pertain.

- Each object can be, but does not have to be, an elementary particle.
- Oscillator pair SA1-and-SA2 correlates with charge. Oscillator pair TA2-and-TA1 correlates with conservation of charge.
- Oscillator pair SA3-and-SA4 correlates with generation for elementary fermions and with rest mass for objects. Oscillator pair TA4-and-TA3 correlates with somewhat conservation of generation for elementary fermions.
- Oscillator pair SA5-and-SA6 correlates with baryon number. Oscillator pair TA6-and-TA5 correlates with somewhat conservation of baryon number.
- Oscillator pair SA7-and-SA8 correlates with lepton number. Oscillator pair TA8-and-TA7 correlates with somewhat conservation of lepton number.
- Conservation of lepton number minus baryon number pertains.

For modeling that correlates with confined environments and elementary particles for which $\sigma = -1$, the following notions pertain.

- Oscillator pairs TA2-and-TA1 and SA1-and-SA2 correlate with charge and with conservation of charge.
- Oscillator pair SA3-and-SA4 correlates with generation for elementary fermions. Oscillator pair TA4-and-TA3 correlates with somewhat conservation of generation for elementary fermions. Here, somewhat conservation of generation correlates with the traditional physics notion of an approximate symmetry.
- Oscillator pair SA5-and-SA6 correlates with baryon number. Oscillator pair TA6-and-TA5 correlates with somewhat conservation of baryon number for elementary fermions.
- Oscillator pair SA7-and-SA8 correlates with lepton number. Oscillator pair TA8-and-TA7 correlates with somewhat conservation of lepton number for elementary fermions.
- Conservation of lepton number minus baryon number pertains.

3.3 Long-range forces, including an analog to the periodic table for elements

This unit shows a table of all known long-range forces and all long-range forces that complementary physics theory predicts.

Table 3 provides a candidate periodic table analog for long-range forces. Each cluster of rows correlates with one value of spin (or, S). Here, $\Sigma = 2S$. For each G-family solution, the value of Σ appears as the first element of a three-element symbol ΣGΓ. Table 3 shows four-element symbols of the form Σ(s)GΓ. Each Γ is a list of one, two, three, or four unique even integers. The symbol λ denotes such an integer. Values for λ can be two, four, six, and eight. For the SA($\lambda-1$)-and-SAλ oscillator pair, a first conceptual excitation can be either to $n_{SA\text{odd}} = 1$ and $n_{SA\text{even}} = 0$, which correlates with left-circular polarization, or to $n_{SA\text{odd}} = 0$ and $n_{SA\text{even}} = 1$, which correlates with right-circular polarization. (We use the two-word phrase conceptual excitation because we are discussing symmetries and not excitations. Here, $n_{SA\text{odd}}$ denotes $n_{SA(\lambda-1)}$ and $n_{SA\text{even}}$ denotes $n_{SA\lambda}$.) For each ΣGΓ, the number of SA-side oscillator pairs that correlate with conceptual excitation is $-n_{SA0}$. Regarding the Σ in ΣGΓ, Σ denotes both $2S$ and the absolute value of the arithmetic combination across conceptually excitable SA-side oscillators of $+2S_{\text{oscillator}}$ (or, $+2S_{SA(\lambda-1)}$) for each left-circular conceptual excitation and $-2S_{\text{oscillator}}$ (or, $-2S_{SA\lambda}$) for each right-circular conceptual excitation. For example, for ΣG24, Σ can be two, as in $|-2+4|$, or six, as in $|+2+4|$. For purposes of table 3, we ignore solutions for which $\Sigma = 0$. The symbol s correlates with span for cases for which $L6N$ is a positive integer. (See table 5.) In table 3, the symbol SDF denotes the four-word phrase spatial dependence of force. We have yet to introduce notions of motion for objects.

Tab. 3: A catalog of long-range forces

$\Sigma \in \Gamma$	S	Monopole (SDF = r^{-2})	Dipole (SDF = r^{-3})	Quadrupole (SDF = r^{-4})	Octupole (SDF = r^{-5})
Yes	1	2(1)G2	2(1)G24	2(6)G248	
Yes	2	4(6)G4	4(2)G48	4(1)G246	4(1)G2468a
"	"				4(1)G2468b
Yes	3	6(2)G6		6(6)G468	
Yes	4	8(1)G8			8(1)G2468a
"	"				8(1)G2468b
No	1		2(6)G46	2(6)G468	
"	"		2(2)G68		
No	2		4(6)G26	4(6)G268	
No	3		6(1)G24	6(6)G248	
"	"		6(2)G28		
No	4		8(6)G26	8(1)G246	
No	5		10(2)G28	10(6)G248	
"	"		10(6)G46	10(6)G468	
No	6		12(2)G48	12(1)G246	12(1)G2468
"	"			12(6)G268	
No	7		14(2)G68	14(6)G248	
No	8			16(6)G268	16(1)G2468
No	9			18(6)G468	
No	10				20(1)G2468

The use of Newtonian physics notions of variation with distance r between the centers of two adequately small and adequately symmetric objects is appropriate. We assume the non-Newtonian physics notion that, absent refraction, G-family effects propagate at the speed of light. Regarding values of n, as in r^{-n}, equation (8) pertains. (The symbol $\in$ denotes the four-word phrase is a member of. The symbol $n_{\lambda\in\Gamma}$ denotes the number of integers in Γ.) We use the symbol $\Sigma\gamma$ to denote sets of ΣGΓ for which $\Sigma \in \Gamma$. We use the symbol $\gamma\lambda$ to denote sets ΣGΓ for which $\lambda \in \Gamma$ and $\Sigma \notin \Gamma$. (The symbol $\notin$ denotes the five-word phrase is not a member of.) The first four clusters of rows in table 3 show solutions for which $\Sigma \in \Gamma$. The remaining clusters of rows in table 3 show solutions for which $\Sigma \notin \Gamma$.

$$n = n_{\lambda\in\Gamma} + 1 = -n_{SA0} + 1 \tag{8}$$

We discuss an aspect correlating with equation (8). Each λ correlates with a square of potential energy for which the potential energy correlates with r^{-1}. The squares multiply, yielding a square of potential energy that correlates with $r^{-2n_{\lambda\in\Gamma}}$. The corresponding potential energy correlates with $r^{-n_{\lambda\in\Gamma}}$. The corresponding force correlates with $r^{-n_{\lambda\in\Gamma}-1}$ (or, $r^{-(n_{\lambda\in\Gamma}+1)}$).

We discuss the 2γ long-range force. Solution 2(1)G2 correlates with an r^{-2} interaction with charge. Solution 2(1)G24 correlates with an r^{-3} interaction with nominal magnetic dipole moment. A complementary physics theory separation of notions of a traditional physics theory photon into components is not necessarily inappropriate, in part because (at this stage) modeling does not include translational motion (or, kinematics). For example, for a bar magnet or for the earth, nominal magnetic dipole moment does not correlate with a notion of overall charge. Possibly, solution 2(6)G248 correlates with interactions that, in effect, measure a lack of alignment between an axis correlating with spin (of an object) and an axis correlating with nominal magnetic dipole moment (of the object). Possibly, 2(6)G248 correlates with aspects of Larmor precession and/or with some aspects of physics that might correlate with (hypothetical) axions.

We suggest that, assuming a 2(1)G248 interpretation of 2(6)G248, the complementary physics theory notion of 2γ correlates with the traditional physics theory notion of photon.

We discuss the 4G4 solution, which is a component of 4γ. Solution 4G4 correlates with interaction with, for multicomponent objects, rest mass.

Beyond the 2γ and 4G4 solutions, each one of the ΣGΓ solutions that table 3 lists does not necessarily correlate with traditional physics theory.

The following notes pertain regarding ΣGΣ solutions.

- 2G2 interacts with charge.

- 4G4 interacts with generation (for 1f1b→1f1b interactions with elementary fermions), excitation (for 0f2b→0f2b interactions with elementary bosons and long-range forces), and/or rest mass.
- 6G6 interacts with baryon number.
- 8G8 interacts with lepton number.

We anticipate that 4γ solutions other than 4G4 correlate with dark energy forces. We anticipate that $\gamma 2$ solutions correlate with a complementary physics theory approach to the traditional physics theory topic of anomalous magnetic dipole moments. (See discussion related to equation (23).) We anticipate that, for models for much astrophysics that directly pertains to large objects, we can de-emphasize G-family solutions other that $\Sigma\gamma$ solutions. We anticipate that some 2G solutions that are neither 2γ solutions nor $\gamma 2$ solutions correlate with observed effects. For example, we discuss below a model - for depletion of cosmic microwave background radiation (or, CMB) - that features the solution 2(2)G68 and interactions with hydrogen atoms.

The following notes pertain regarding 4γ solutions.

- 4(6)G4 correlates with a property of rest energy.
- 4(2)G48 might correlate with rotation of spherically distributed rest energy.
- 4(1)G246 might correlate with a non-zero quadrupole distribution of rest energy.
- Each of 4(1)G2468a and 4(1)G2468b might correlate with precession correlated with at least one of an axis of minimal moment of rotational inertia and an axis of maximal moment of rotational inertia.

The following notes pertain regarding ΣGΓ solutions. (For further details, see reference [7].)

- Modeling for excitations correlates with modeling for excitation for the ΣGΣ solution. (For example, models for excitation of each 2GΓ parallel models for excitations of 2G2.) This notion correlates with ALG double-entry bookkeeping and with discussion above regarding conceptual excitation.
- In complementary physics theory, excitations can carry more information than do excitations correlating with traditional physics theory. In both types of theory, excitations carry, in effect, information correlating with the interactions that create the excitations. Complementary physics theory G-family excitations can carry information about span. For example, an excitation of 4G correlating with a 4(6)G4 conceptual excitation includes, in effect, knowledge of the span of six, whereas an excitation of 4G correlating with a 4(1)G246 conceptual excitation includes, in effect, knowledge of the span of one. (See discussion related to table 3 and discussion related to table 5.) Traditional physics theory correlates with the notion that span is always one.

Table 4 summarizes information, including so-called TA-side symmetries, regarding conceptual excitations for G-family solutions. The notation $\pi_{0,@_0}$ indicates, for the relevant oscillator pair, that the values of the two $n\_$ are either, respectively, 0 and $@_0$ (for one polarization) or, respectively, $@_0$ and 0 (for the other polarization). The symbol $@_0$ pertains for the one oscillator (out of the two oscillators) for which conceptual excitation does not pertain. The symbol A0+ correlates with an oscillator pair for which, for each of the two oscillators, the symbol $@_0$ pertains. For such a pair, no conceptual excitation pertains.

The following notes pertain.

- For so-called saturated Γ, no TA-side $SU(j)$ symmetry pertains. The notion of saturated Γ correlates with each of the lists 2, 24, 246, 2468, 2468a, and 2468b. We use the one-element term GsatΓ to correlate with these instances of ΣGΓ solutions.
- For other than saturated Γ, we use the one-element term GunsatΓ.
- Complementary physics theory suggests that, for each solution for which the TA-side symmetry is $SU(5)$ or $SU(7)$, the solution correlates with interactions with multicomponent objects and does not correlate with interactions with individual elementary particles. (See discussion related to table 5.)
- The upper limit of eight for items in lists Γ correlates with a notion of channels. (See discussion, regarding equation (11), regarding channels.) Possibly, the upper limit also correlates with the notion that the number of generators of each of $SU(3)$, $SU(5)$, and $SU(7)$ divides evenly the number of generators of $SU(7)$ but the number of generators of each of $SU(5)$ and $SU(7)$ does not divide evenly the number of generators of $SU(9)$. Here, $SU(9)$ would correlate with aspects of 10G$[\![10]\!]$. (Here, we use $[\![10]\!]$ to denote the integer ten and the notion that $\lambda = [\![10]\!]$.)

Tab. 4: Information, including TA-side symmetries, regarding conceptual excitations for long-range forces

ΣΦΓ	σ	TA-side	$\vert\leftarrow$	$\cdots$	TA	$\rightarrow\vert$	$\vert\leftarrow$	$\cdots$	SA	$\cdots$	$\rightarrow\vert$
		$SU(\_)$ symmetry	6,5	4,3	2,1	0	0	1,2	3,4	5,6	7,8
2G2	+1	None				0	−1	$\pi_{0,@_0}$			
4G4	+1	$SU(3)$			0,0	0	−1	A0+	$\pi_{0,@_0}$		
ΣG24	+1	None				0	−2	$\pi_{0,@_0}$	$\pi_{0,@_0}$		
6G6	+1	$SU(5)$		0,0	0,0	0	−1	A0+	A0+	$\pi_{0,@_0}$	
ΣG26	+1	$SU(3)$			0,0	0	−2	$\pi_{0,@_0}$	A0+	$\pi_{0,@_0}$	
ΣG46	+1	$SU(3)$			0,0	0	−2	A0+	$\pi_{0,@_0}$	$\pi_{0,@_0}$	
ΣG246	+1	None				0	−3	$\pi_{0,@_0}$	$\pi_{0,@_0}$	$\pi_{0,@_0}$	
8G8	+1	$SU(7)$	0,0	0,0	0,0	0	−1	A0+	A0+	A0+	$\pi_{0,@_0}$
ΣG28	+1	$SU(5)$		0,0	0,0	0	−2	$\pi_{0,@_0}$	A0+	A0+	$\pi_{0,@_0}$
ΣG48	+1	$SU(5)$		0,0	0,0	0	−2	A0+	$\pi_{0,@_0}$	A0+	$\pi_{0,@_0}$
ΣG68	+1	$SU(5)$		0,0	0,0	0	−2	A0+	A0+	$\pi_{0,@_0}$	$\pi_{0,@_0}$
ΣG248	+1	$SU(3)$			0,0	0	−3	$\pi_{0,@_0}$	$\pi_{0,@_0}$	A0+	$\pi_{0,@_0}$
ΣG268	+1	$SU(3)$			0,0	0	−3	$\pi_{0,@_0}$	A0+	$\pi_{0,@_0}$	$\pi_{0,@_0}$
ΣG468	+1	$SU(3)$			0,0	0	−3	A0+	$\pi_{0,@_0}$	$\pi_{0,@_0}$	$\pi_{0,@_0}$
ΣG2468	+1	None				0	−4	$\pi_{0,@_0}$	$\pi_{0,@_0}$	$\pi_{0,@_0}$	$\pi_{0,@_0}$

3.4 Spans for objects and long-range forces

This unit discusses the notion that nature embraces more than one isomer for each of some elementary particles, some long-range forces, and some hadron-like particles.

For each of each elementary particle, each hadron-like particle, and each long-range force, the one-word term span denotes the number of isomers of the set of, at least, non-zero-charge elementary particles with which an isomer of the particle or force interacts.

Table 5 summarizes information regarding spans (or equivalently, numbers of isomers) for elementary particles and for hadron-like particles and summarizes information regarding types of objects with which elementary bosons and some long-range forces interact. In the table, nnn equals 6^{L6N}. In the symbol PRnnnINe, the two letters PR denote the one-element term physics-relevant and the three letters INe denote the four-word phrase instances of the electron. Here, the word instance is a synonym for the word isomer. The table separates, based on a complementary physics theory view, elementary particle Standard Model aspects from aspects that the elementary particle Standard Model does not embrace. The symbol 1Q⊗2U correlates with known and possible hadrons. The symbol 1R⊗2U correlates with possible hadron-like particles. Regarding the G-family, the table includes just the $\Sigma\gamma$ solutions. Regarding the cases for which nnn is at least 006, the span for 2G68 is two. Table 5 shows the extent to which each of the elementary bosons and some of the long-range forces interacts directly with each of at least some elementary fermions and with each of at least some multicomponent objects. (Regarding the case of elementary fermions, the column label is Elem ferm. Regarding the case of multicomponent objects, the column label is Mc obj.) The symbol Y denotes that interactions occur. The symbol † denotes that somewhat conservation of fermion generation pertains for 1f1b→1f1b interaction vertices. The symbol N denotes that interactions do not occur. Complementary physics theory suggests the possibility that neither the 0H boson nor the 0I boson interacts directly with multicomponent objects. Complementary physics theory suggests that G-family solutions for which the conceptual excitation TA-side symmetry is either $SU(5)$ or $SU(7)$ do not correlate with direct interactions with elementary fermions. (This suggestion correlates with the notions that adding four TA-side oscillators to correlate with conservation of energy would lead to a TA-side symmetry of, respectively, $SU(9)$ or $SU(11)$ and that, for $j > 7$, $SU(j)$ symmetries do not pertain. See table 4 and discussion related to table 9. Note that the number of generators of $SU(5)$ does not evenly divide the number of generators of $SU(9)$ and that the number of generators of $SU(7)$ does not evenly divide the number of generators of $SU(11)$.) Possibly, regarding interactions between the 0K boson and elementary fermions, Y pertains to the extent that modeling correlates the 0K boson with the traditional physics theory notion of a Higgs mechanism and that modeling correlates the Higgs mechanism with the notion that each of some elementary fermions has non-zero mass.

Tab. 5: Particles and/or solutions that correlate with one isomer and particles and/or solutions that might correlate with more than one isomer; plus, the extent to which elementary bosons and some long-range forces interact with elementary fermions and with multicomponent objects

Entities - Particle sets and/or solution sets (hadron-like particles, elementary particles, and long-range forces)		Span (or, s), for PRnnnINe				Direct interactions with	
		nnn				Elem	Mc
Standard Model	Possible	001	006	036	216	ferm	obj
1C ($\sigma = +1$)	-	1	1	1	1	-	-
1N ($\sigma = +1$)	-	1	6	36	36	-	-
1Q ($\sigma = -1$)	-	1	1	1	1	-	-
-	1R ($\sigma = -1$)	1	6	36	36	-	-
2U ($\sigma = -1$)	-	1	6	36	36	$Y^\dagger$	N
2W: Z ($\sigma = +1$)	2T: $2T^0$ ($\sigma = -1$)	1	1	6	6	$Y^\dagger$	N
2W: $W^\pm$ ($\sigma = +1$)	2T: $2T^\pm$ ($\sigma = -1$)	1	1	1	1	$Y^\dagger$	N
1Q$\otimes$2U ($\sigma = +1$)	-	1	1	1	1	-	-
-	1R$\otimes$2U ($\sigma = +1$)	1	6	36	36	-	-
0H ($\sigma = +1$)	-	1	1	6	36	Y	N
-	0P ($\sigma = -1$)	1	1	(6)	(36)	N	Y
-	0I ($\sigma = +1$)	1	6	36	216	Y	N
-	0K ($\sigma = -1$)	1	(6)	(36)	(216)	?	Y
2G2 ($\sigma = +1$)	-	1	1	1	1	Y	Y
2G24 ($\sigma = +1$)	-	1	1	1	1	Y	Y
2G248 ($\sigma = +1$)	-	1	1	6	6	$Y^\dagger$	Y
-	4G4 ($\sigma = +1$)	1	6	6	6	$Y^\dagger$	Y
-	4G48 ($\sigma = +1$)	1	2	2	2	N	Y
-	4G246 ($\sigma = +1$)	1	1	1	1	Y	Y
-	4G2468a ($\sigma = +1$)	1	1	1	1	Y	Y
-	4G2468b ($\sigma = +1$)	1	1	1	1	Y	Y
-	6G6 ($\sigma = +1$)	1	1	1	2	N	Y
-	6G468 ($\sigma = +1$)	1	1	1	6	Y	Y
-	8G8 ($\sigma = +1$)	1	1	1	1	N	Y
-	8G2468a ($\sigma = +1$)	1	1	1	1	Y	Y
-	8G2468b ($\sigma = +1$)	1	1	1	1	Y	Y

(The symbol † denotes that somewhat conservation of fermion generation pertains.)

Tab. 6: Cumulative features of various types of modeling

Modeling	New descriptions and/or explanations	New subtleties
Traditional physics	• (Baseline)	
PR001INe	• New elementary particles	
	• Dark energy forces	
	• Some dark matter	
PR006INe	• More dark matter	• Spans
	• Ratios of dark matter effects to ordinary matter effects	• Dark energy forces
PR036INe	• Dark energy density	• Spans
	• Doubly dark matter	
PR216INe	• (? Triply dark matter)	• (? Spans)
TA-side $SU(5)$	• (? Multiverses)	

3.5 Comparative features of the various PRnnnINe models

This unit compares features of the four PRnnnINe models.

Table 6 discusses cumulative features of various types of modeling. Generally, each row augments the rows above that row. The two-word term traditional physics in the first column of the first row abbreviates the three-word term traditional physics theory. We think that PR006INe provides useful insight about nature. We think that PR036INe provides additional useful insight about nature. We are uncertain as to the extent that the last two rows comport with nature. Possibly, the TA-side $SU(5)$ symmetry that complementary physics theory correlates with conservation of energy points to a multiverse that includes 24 universes similar to the universe that would correlate with PR036INe or similar to the universe that would correlate with PR216INe. The number of generators of $SU(5)$ is 24.

3.6 Some approximate symmetries

This unit discusses somewhat conservation of generation, somewhat conservation of lepton number, and somewhat conservation of baryon number.

We discuss somewhat conservation of generation.

Known 1f1b→1f1b interactions between W bosons and leptons conserve lepton generation. The exiting fermion correlates with the same generation that correlates with the entering fermion. TA-side modeling for elementary fermions points to an $SU(2)$ symmetry that complementary physics theory correlates with a possibility for conservation of fermion generation. TA-side modeling for some elementary bosons, including the W boson, points to an $SU(2)$ symmetry that complementary physics theory correlates with a possibility for somewhat conservation of generation. (This symmetry correlates with the non-TA0 components of $SU(3)$ TA-side symmetries, such as the TA-side symmetries that table 4 shows.) Complementary physics theory posits that conservation of generation pertains to the extent that an overall interaction models as involving only one weak interaction boson. For quarks in hadrons, traditional physics theory correlates with the notion that interactions that involve multiple weak interaction bosons do not necessarily conserve generation and do not necessarily conserve CP (or, charge conjugation and parity). Paralleling traditional physics use of the two-word term approximate symmetry regarding CP, complementary physics theory uses the two-word term somewhat conservation regarding generation.

Complementary physics theory suggests that some elementary boson phenomena correlate with somewhat conservation of generation and that some elementary boson phenomena do not correlate with somewhat conservation of generation. (See table 5.)

We discuss somewhat conservation of baryon number and somewhat conservation of lepton number.

Each of conservation of baryon number and conservation of lepton number pertains, in complementary physics theory, to the extent that one ignores interactions mediated by the $2T^{\pm}$ boson and interactions correlating with 1f1b↔3f0b vertices. (Regarding symbols, a↔b denotes a→b and/or b→a.) For all interactions, complementary physics theory correlates with conservation of lepton number minus baryon number. We use the two-word term somewhat conservation regarding each of lepton number and baryon number.

Tab. 7: Eras and 4G forces, regarding expansion of the universe

Era	A/R	SDF	Components of 4γ	Other components of 4G	Span
early acceleration	net repulsive	r^{-5}	4(1)G2468a, 4(1)G2468b		1
deceleration	net attractive	r^{-4}	4(1)G246	4(1)G268	1
recent acceleration	net repulsive	r^{-3}	4(2)G48	4(2)G26	2 *
(recent, for smaller objects)	attractive	r^{-2}	4(6)G4		6 *

* - Equals 1 for PR001INe models

3.7 The rate of expansion of the universe

This unit discusses dark energy forces and suggests an explanation for three eras regarding the rate of expansion of the universe.

Table 7 summarizes, regarding the rate of expansion of the universe, eras and 4G forces. In this context, the eras pertain to the largest objects that people can directly infer. (Regarding observations and eras, see references [10], [18], [21], and [22]. These observations correlate with the eras that correlate with deceleration and recent acceleration. For each of various redshifts that those references mention and regarding estimating relevant times after the big bang, possibly see reference [14].) Early acceleration pertains (except possibly before and/or during the possible so-called inflationary epoch) for some time after the big bang. Then, deceleration pertains for some billions of years. Acceleration pertains for the most recent few billion years. Regarding smaller objects, dominant forces within objects and between neighboring objects have, at least conceptually, generally transited parallels to the first three eras and now generally exhibit behavior correlating with SDF of r^{-2}. Quasar formation via ejection of stuff from near or inside black holes might constitute an exception. Black hole jets might constitute an exception. Blazars might constitute an exception. For these cases, r^{-3} net repulsion might pertain. The column labeled A/R notes net effects, across forces dominating for each era. The column labeled components of 4γ lists solutions that might correlate with significant forces. Complementary physics theory suggests that, for the components of 4γ that table 7 lists, the two-word term net repulsive correlates with a notion of essentially always repulsive (though sometimes not significantly repulsive). Complementary physics theory suggests that, for the components of 4γ that table 7 lists, the two-word term net attractive correlates with a notion of essentially always attractive (though sometimes not significantly attractive).

Possibly, regarding the early acceleration era, notions that reference [19] discusses correlate with effects of the net repulsion that complementary physics theory correlates with 4(1)G2468a and 4(1)G2468b. Reference [19] notes possibilities for a component of dark energy that had effect during times correlating with $z \geq 3000$. Here, z denotes redshift. Use of reference [14] suggests that this redshift correlates with about 64 thousand years after the big bang.

Complementary physics theory suggests that the traditional physics theory notion of dark energy forces (or, dark energy pressure) correlates with the components, other than 4(6)G4, of 4γ.

We note possible concerns regarding the six-word term rate of expansion of the universe. Concerns feature use of the word universe. Observed rates of expansions correlate with objects that emit 2G (or, light) that people detect. Observed rates do not correlate with objects too distant for people to detect. Observed rates do not necessarily correlate with 1R$\otimes$2U hadron-like particles. Observed rates do not necessarily correlate with objects that correlate with isomers that, while not correlating with PR006INe, might correlate with PRnnnINe for nnn being at least 036. In addition, for example, of the components shown, only 4G4 has a span of six and each other component has a span of one or two.

3.8 Galaxies, galaxy clusters, and ratios of dark matter effects to ordinary matter effects

This unit discusses, for galaxies and galaxy clusters, observed ratios of dark matter effects to ordinary matter effects. This unit suggests aspects of the evolution of some galaxies, such that the evolution correlates with observations and such that complementary physics theory dovetails with the aspects of evolution.

People report, regarding galaxies, inferred ratios of dark matter effects to ordinary matter effects.

- For some galaxies, approximately 10 billion years ago, the following ratio pertains.
  - Zero to one or zero-plus to one, based on velocities of stars within galaxies (or, galaxy rotation curves). (See reference [13].)
- For some galaxies, recently, the following ratios pertain.
  - Somewhat less than four to one, based on observations correlating with gravitational lensing. (See reference [15].)
  - Between zero to one and one to one, based on velocities of stars in each of two galaxies (or, galaxy rotation curves). (See references [27] and [28].)
- For some galaxy-like objects, recently, the following ratio pertains.
  - One to somewhat more than zero, regarding some dark matter galaxies, based on light emitted by a relatively few visible stars. (See reference [26].)

Complementary physics theory suggests the following galaxy evolution scenario for galaxies that would comport early on with zero-plus to one ratios that reference [13] shows and presently with four-minus to one ratios that reference [15] shows. The following thought experiment idealization characterizes the scenario. We assume that PR006INe modeling pertains (or, that six isomers of the set of, at least, non-zero-charge elementary particles pertain). We focus on the forming and evolving of a galaxy that features ordinary matter.

- Stuff that will become the galaxy is always in somewhat proximity with itself. No collisions between would-be galaxies or between galaxies occur.
- Early on, each isomer expands, essentially independently from the other isomers, based on repulsion correlating with 4(1)G2468a and 4(1)G2468b.
- Then, each isomer starts to clump, essentially independently from the other isomers, based on attraction correlating with 4(1)G246.
- With respect to clumps correlating with any one isomer, 4(2)G48 repels one other isomer and repels some stuff correlating with itself. Regarding ordinary matter clumps, the one other isomer is a dark matter isomer.
- An ordinary matter centric galaxy forms, based on 4(6)G4 attraction based on one ordinary matter clump or some ordinary matter clumps. At this stage of formation, results comport with the zero-plus to one ratios that reference [13] shows.
- The galaxy attracts and accrues, via 4(6)G4 attraction, ordinary matter stuff and stuff correlating with the four dark matter isomers for which there is nearby stuff. Results comport with the somewhat less than four to one ratios that reference [15] shows. The following notions might pertain.
  - The ratios are less than four to one because more 4(2)G48 repulsion pertains regarding dark matter isomer stuff repelling dark matter isomer stuff than pertains regarding ordinary matter stuff repelling ordinary matter stuff and dark matter stuff correlating with one isomer.
  - The ratios are not as much less than four to one as they might otherwise be (based on 4(2)G48 repulsion) because of the contribution, which is isomer-independent, of 1R$\otimes$2U to dark matter.

The following notions also pertain.

- Other data might correlate with the notion that at least some ordinary matter intense galaxies (or ordinary matter intense galaxy-like objects) form without original dark matter halos. One might correlate this evolution with the three-word phrase stars before halos. Possibly, reference [3] provides such data. (See, for example, figure 7 in reference [3]. The figure provides two graphs. Key concepts include redshift, stellar mass, peak halo mass, and a stellar - peak halo mass ratio.) Possibly, data correlating with redshifts of at least seven suggests that at least some galaxies accrue, over time, dark matter, with the original fractions of dark matter being small. Use of reference [14] suggests that redshifts of at least seven pertain to times ending about 770 million years after the big bang.

- Dark matter centric galaxies can contain ordinary matter stars. Evolution of some of these galaxies parallels the above scenario for some ordinary matter centric galaxies. Some such dark matter centric galaxies comport with the one to somewhat more than zero ratio that reference [26] shows.
- The scenarios we just discussed are not incompatible with ratios of dark matter density to ordinary matter density that people infer for galaxy clusters. (See references [16], [20], and [23].)
- The scenarios we just discussed are not incompatible with the ratio of between zero to one and one to one that references [27] and [28] shows.

People look for possible local effects, within the Milky Way galaxy, that might correlate with dark matter.

For one example, data regarding the stellar stream GD-1 suggest effects of an object of 10^6 to 10^8 solar masses. (See reference [4].) Researchers tried to identify and did not identify an ordinary matter object that might have caused the effects. Possibly, the object is a clump of dark matter. (See reference [11].)

- Complementary physics theory offers the possibility that the object is an originally dark matter centric clump of stuff (that might include at least one dark matter black hole).

For other examples, people report inhomogeneities regarding Milky Way dark matter. (See references [11] and [17].) Researchers note that simulations suggest that such dark matter may have velocities similar to velocities of nearby ordinary matter stars. Complementary physics theory suggests that these notions are not incompatible with complementary physics theory notions that dark matter stars, that would be similar to ordinary matter stars, exist.

People report, regarding galaxy clusters, inferred ratios of dark matter effects to ordinary matter effects.

- For some galaxy clusters, recently, the following ratios pertain.
  - Five-plus to one, based on observations correlating with gravitational lensing. (See references [16] and [20].)
  - Eight-minus to one, based on observations correlating with X-ray emissions. (See reference [23].)

We suggest that complementary physics theory is not necessarily incompatible with these galaxy cluster centric ratios.

3.9 CMB depletion and a possible ratio of dark matter effects to ordinary matter effects

This unit suggests that complementary physics theory explains an observed result, regarding depletion of cosmic microwave background radiation, that traditional physics theory does not seem to explain.

People report the following possible inferred ratio of dark matter effects to ordinary matter effects.

- For absorption of CMB (or, cosmic microwave background radiation) via hyperfine interactions with hydrogen-like atoms.
  - One to one. (See reference [5]. Perhaps note a possible interpretation in reference [2].)

Here, people measured twice as much depletion of CMB as people predicted via traditional physics theory modeling that was centered on depletion via transitions in ordinary matter hydrogen atoms.

Complementary physics theory suggests the following explanation.

- Solution 2(2)G68 has a span of two.
- Solution 2(2)G68 correlates with that hyperfine transition (and, presumably, with other similar transitions - in multicomponent objects - that are not significant for this discussion).
- Half of the observed effect correlates with hydrogen-atom isomers that correlate with one not ordinary matter isomer of the set of, at least, non-zero-charge elementary particles.
  - To the extent PR006INe modeling pertains to nature and PRnnnINe modeling for nnn of at least 036 does not pertain, the relevant not ordinary matter isomer is a dark matter isomer.

- To the extent PRnnnINe modeling for which nnn of at least 036 is required to explain aspects of nature, the relevant not ordinary matter isomer is a so-called doubly dark matter isomer. The following statements pertain.
  * The number of doubly dark isomers is 30 (or, 36 minus six).
  * None of these 30 isomers interacts with the isomer of 4(6)G4 that interacts with the ordinary matter isomer and the dark matter isomers. None of these 30 isomers interacts with the ordinary matter isomer via interactions that correlate with the solutions 2(1)G2 and 2(1)G24. Hence, we suggest the three-word term doubly dark matter.
  * Five of these 30 doubly dark matter isomers interact with the ordinary matter isomer via 2(6)GΓ interactions. 2(6)G248 interactions are 2(6)GΓ interactions. 2G248 is a component of 2γ.
  * One of those five doubly dark matter isomers interacts with the ordinary matter isomer via 2(2)GΓ interactions. 2(2)G68 interactions are 2(2)GΓ interactions. 2G68 is not a component of 2γ. 2G68 is not a component of $\gamma 2$.

3.10 Baryon acoustic oscillations and dark matter filaments

This unit discusses the concept that dark matter baryon-like acoustic oscillations contributed to the formation of current dark matter filaments.

Complementary physics theory is not incompatible with the traditional physics theory notion that ordinary matter centric baryon acoustic oscillations contributed to the formation of dark matter filaments.

Regarding models for which $L6N$ is at least one, each of the five dark matter isomers has its own baryon-like particles and its own photon-like physics. Complementary physics theory suggests, for models for which $L6N$ is at least one and based on aspects of traditional physics theory, that dark matter baryon-like acoustic oscillations occurred in the early universe. Complementary physics theory suggests that dark matter baryon-like acoustic oscillations contributed (along with ordinary matter baryon acoustic oscillations) to the formation of current dark matter filaments.

3.11 Dark energy density

This unit discusses the notion that dark energy densities might correlate with dark energy stuff and not necessarily with traditional physics theory notions such as vacuum energy and vacuum fluctuations.

Traditional physics theory correlates inferred dark energy densities of the universe with phenomena correlating with terms such as vacuum energy, vacuum fluctuations, or quintessence. Complementary physics theory does not necessarily embrace notions such as vacuum energy. (Double-entry modeling may obviate needs to consider notions such as vacuum energy.)

Equation (9) shows an inferred ratio of present density of the universe of dark energy to present density of the universe of dark matter plus ordinary matter plus (ordinary matter) photons. (Reference [25] provides the four items of data.) Here, the symbols Ω_Λ, Ω_c, Ω_b, and Ω_γ correlate with density of, respectively, dark energy, dark matter, ordinary matter, and (ordinary matter) photons. From a standpoint of complementary physics theory, Ω_c includes effects correlating with photons centric to dark matter and includes effects correlating with 1R⊗2U hadron-like particles. From a standpoint of each of traditional physics theory and complementary physics theory, equation (9), does not include neutrino density of the universe.

$$\Omega_\Lambda/(\Omega_\mathrm{c} + \Omega_\mathrm{b} + \Omega_\gamma) \approx 2.3 \tag{9}$$

Complementary physics theory suggests that the ratio that equation (9) shows correlates with an actual ratio of five to one regarding the number, 30, of doubly dark matter isomers and the number, six, of ordinary matter isomers and dark matter isomers. We know of no inferences that would not comport with a steady increase, regarding the inferred ratio correlating with equation (9), from approximately zero, with time since somewhat after the big bang. Each of PR036INe modeling and PR216INe modeling suggests an upper bound of five on, in effect, a possible future value for the ratio that correlates with equation (9). The growth correlates with interactions based on phenomena for which table 5 shows a number in the column labeled 036 that is larger than the number in the column labeled 006.

Complementary physics theory suggests the modeling case PR216INe and, with that case, a possibility that the universe includes 180 so-called triply dark matter isomers. Here, 180 equals 216 minus 36. Triply dark matter isomers would not interact, via 2G or 4G interactions with any of the ordinary matter, dark matter, or doubly dark matter isomers. Triply dark matter isomers would interact with ordinary matter, dark matter, and doubly dark matter isomers via the 0I boson. (See table 5.)

3.12 Baryon asymmetry

This unit discusses two possible complementary physics theory explanations for baryon asymmetry.

To the extent that the early universe featured roughly the same number of antimatter quarks as matter quarks, something happened to create so-called baryon asymmetry. The two-word term baryon asymmetry correlates with the present lack, compared to matter quarks, of antimatter quarks.

Complementary physics theory suggests two scenarios that might have led to baryon asymmetry. Neither scenario conserves baryon number. Both scenarios conserve lepton number minus baryon number. The following notions pertain.

- In one scenario, the $2T^{\pm}$ boson converts antimatter quarks to matter quarks. This scenario depends on the physics-relevance of 1R elementary fermions. An example of a 1f1b→1f1b interaction is $1Q^{+1/3}_{+1/3;0,-1/3} \rightarrow 1R^{0}_{+1/3;0,-1/3}$ and $2T^{+1/3}$. (Per remarks above, interactions of the form 1f0b→1f1b correlate with 1f1b→1f1b.) Here, the superscripts correlate with charge, in units of $|q_e|$. The subscripts correlate with lepton number minus baryon number, followed by lepton number, followed by baryon number. An example of a 3f0b→1f1b interaction is $1C^{+1}_{-1;-1,0}$ and $1R^{0}_{+1/3;0,-1/3}$ and $1Q^{-2/3}_{+1/3;0,-1/3} \rightarrow 1Q^{+2/3}_{-1/3;0,+1/3}$ and $2T^{-1/3}$. Here, each of the three elementary particles that correlates with 3f differs from the other two elementary particles.
- In one scenario, 3f0b→1f1b interactions destroy antimatter quarks. This scenario does not depend on the existence of 2T (or, tweak) elementary bosons. This scenario does not depend on the existence of 1R (or, arc) elementary fermions. An example of a 3f0b→1f1b interaction is $3\ 1Q^{-2/3}_{+1/3;0,-1/3} \rightarrow 1\ 1C^{-1}_{+1;+1,0}$ and $1\ 2W^{-1}$. Possibly, aspects of traditional physics theory would suggest that the three quarks differ from each other by generation.

3.13 A prediction for the tauon mass

This unit suggests a relationship, which traditional physics theory seems not to discuss, between the ratio of the tauon mass to the electron mass and a ratio of a strength of electromagnetism and the strength of gravity. This unit discusses the notion that adequately increasing the experimental accuracy of either one of the tauon mass and the gravitational constant leads to a prediction regarding the other quantity.

Equation (12) possibly pertains. Here, m denotes mass, τ denotes tauon, e denotes electron, q denotes charge, ε_0 denotes the vacuum permittivity, and G_N denotes the gravitational constant. Equation (12) predicts a tauon mass with a standard deviation of less than one quarter of the standard deviation correlating with the experimental result. (For relevant data, see reference [25].)

$$\beta' = m_\tau / m_e \tag{10}$$

$$(4/3) \times \beta^{12} = ((q_e)^2/(4\pi\varepsilon_0))/(G_N(m_e)^2) \tag{11}$$

$$\beta' = \beta \tag{12}$$

$$m_{\tau,\ \text{calculated}} \approx (1776.8445 \pm 0.024)\ MeV/c^2 \tag{13}$$

$$m_{\tau,\ \text{experimental}} \approx (1776.86 \pm 0.12)\ MeV/c^2 \tag{14}$$

The factor of 4/3 in equation (11) correlates with notions that 2G2 correlates with four so-called channels and 4G4 correlates with three channels. For a 2G2 interaction between two electrons, the strength for each channel is $((q_e)^2/(4\pi\varepsilon_0))/4$ and four channels pertain. For a 4G4 interaction between two electrons, the strength for each channel is $G_N(m_e)^2/3$ and three channels pertain. By extrapolation, for $\Sigma = 10$ and $\Gamma = \Sigma = [\![10]\!]$, $\Sigma \text{G} \Gamma$ would correlate with zero channels and no interactions.

The following notes pertain.

Tab. 8: Aspects that might correlate with the extent to which neutrinos have non-zero masses

Aspects
• The existence of neutrino oscillations. • Neutrino speeds. • Limits regarding neutrino masses, as inferred from astrophysics data. • Other.

- To the extent that equation (12) correlates with nature, a more accurate experimental determination of G_N or m_τ could predict a more accurate (than experimental results) value for, respectively, m_τ or G_N.
- Equation (12) links the ratio of two elementary particle masses to a ratio of the strengths of two long-range forces.

3.14 Other relationships regarding masses of known elementary particles

This unit discusses ratios of masses of known non-zero mass elementary bosons and ratios of masses of quarks and charged leptons.

We discuss approximate ratios for the squares of masses of the Higgs, Z, and W bosons. The most accurately known of the three masses is the mass of the Z boson. Based on the ratios (of squares of masses) that equation (15) shows, the possibly least accurately suggested mass is that of the W boson. Equation (15) correlates with a number that is within four standard deviations of the nominal mass of the W boson. (For data, see reference [25].) Complementary physics theory correlates the numbers in equation (15) with, respectively, $17 = 17$, $9 = 10 - 1$, and $7 = 10 - 1 - 2$. Each of zero, one, two, five, 10, and 17 correlates with a PDE solution for which $D'' = 2$. (See reference [7]. Other than the number zero, each of the numbers is one greater than the square of a nonnegative integer.) Possibly, the notion that the experimental mass of the W boson may be less than a calculated mass correlates with the notion that the span of the W boson is one, whereas for nnn of at least 036, each of the span of the Higgs boson and the span of the Z boson exceeds one.

$$(m_{H^0})^2 : (m_Z)^2 : (m_W)^2 :: 17 : 9 : 7 \tag{15}$$

Reference [7] discusses a formula that approximately fits the masses of the six quarks and three charged leptons. The formula includes two integer variables and seven parameters. One integer variable correlates somewhat with generation. The other integer variable correlates somewhat with charge. The seven parameters can be m_e, m_μ (or, the mass of a muon), β , α, and three other numbers. Here, α denotes the fine-structure constant. Each of the three other numbers pertains regarding one generation of quarks. Possibly, for each generation, the number correlates with the extent to which the two relevant quark masses do not equal the square root of the multiplicative product of the two quark masses.

3.15 Neutrino oscillations and neutrino masses

This unit discusses the notion that all neutrinos have zero mass, even though people interpret neutrino oscillations and other observed phenomena as suggesting that at least one flavor of neutrino correlates with non-zero mass.

Table 8 lists aspects that might correlate with the extent to which neutrinos have non-zero masses.

We discuss neutrino oscillations.

Traditional physics theory hypothesizes that gravity catalyzes neutrino oscillations. Possibly, this hypothesis correlates with a process of elimination. For traditional physics theory, the elementary bosons possibly relevant to neutrino oscillations correlate with, in complementary physics theory parlance, the Higgs boson, the Z boson, the W boson, gluons, approximately 2G2-and-2G24-and-2G248 (or, photons), and a possible boson correlating with 4G4 (or, gravity). Neutrino interactions with W bosons destroy neutrinos. Neutrinos do not interact with the Higgs boson, gluons, or photons. Possibly, any interactions with Z bosons are not relevant. Gravity (or, 4G4) becomes the only possibility.

Regarding $\Sigma\gamma$ solutions and individual interactions with neutrinos, complementary physics theory suggests the following notions. Some solutions, such as the three 2γ solutions, do not correlate with interactions with neutrinos. Some solutions, such as the 4G48, 6G6, and 8G8 solutions, do not correlate with interactions with any individual elementary particles, including neutrinos. (See table 5.) Some solutions, such as 4G4 and 6G468, correlate with a TA-side $SU(2)$ symmetry that, for modeling correlating with free environments, correlates with conservation of generation. (This $SU(2)$ symmetry parallels a W boson TA-side $SU(2)$ symmetry that correlates with approximate conservation of generation.) Complementary physics theory suggests that neutrino oscillations do not correlate with interactions with 4G4 in free environments.

Complementary physics theory suggests that, regarding modeling correlating with free environments, neutrino interactions with the following phenomena might catalyze changes of neutrino generation.

- 4G246, 4G2468a, and 4G2468b.
- 8G2468a and 8G2468b.
- Some $\Sigma\gamma'$ solutions, such as 6G24.

Possibly, given the rareness, for each neutrino, of interactions, modeling correlating with free environments suffices regarding neutrino oscillations. Possibly, people do not necessarily need to consider modeling correlating with the notion of confined environments.

Complementary physics theory suggests that neutrino oscillations do not significantly correlate with 4G4 and can correlate with traditional physics theory notions of dark energy forces (such as the complementary physics theory 4G246 long-range force).

We discuss neutrino speeds.

Possibly, measurements of neutrino speeds have yet to contradict the possibility that neutrinos have zero masses.

We discuss the possibility that astrophysics data have yet to contradict the possibility that neutrinos have zero masses.

Equation (16) provides a traditional physics theory upper limit for the sum, across three generations, of neutrino masses. (See reference [25] and the item "Neutrino Properties" that correlates with reference [12].) In equation (16) (and in equation (17)), the index j correlates with at least one of neutrino generation and neutrino flavor.

$$\sum_{j=1}^{3} m_j \lesssim 0.68eV/c^2 \tag{16}$$

Reference [25] suggests the lower limit that equation (17) shows.

$$\sum_{j=1}^{3} m_j \gtrsim 0.06eV/c^2 \tag{17}$$

Complementary physics theory suggests interactions (that traditional physics theory does not necessarily embrace), such as with 4G246, 4G2468a, 4G2468b, 8G2468a, and 8G2468b, in which neutrinos participate. Possibly, such interactions produce observed astrophysical effects that people interpret, via traditional physics theory, as implying non-zero mass for at least one generation or flavor of neutrino. Possibly, such interpretations are not necessarily optimal.

Possibly, each neutrino correlates with zero rest mass.

3.16 A series of formulas for lengths, including the Planck length

This unit discusses three related formulas that produce lengths and notes possible significance, or lack thereof, for each of the lengths.

We suggest a series of formulas for lengths. Equation (18) correlates with the Schwarzschild radius for an object with mass m. Equation (19) correlates with the Planck length and does not depend on m. Equation (20) includes a factor of m^{-1}. When applied to the mass of 2W bosons, equation (20) correlates somewhat with the range of the weak interaction. When applied to the mass of a charged pion, equation (20) correlates somewhat with a range for the strong interaction. Equation (21) shows the ratio between successive formulas. Equation (22) shows, for the electron, the ratio correlating with equation (21).

$$R_4(m) = (G_N)^1 m^1 \hbar^0 c^{-2} 2^1 \tag{18}$$

$$R_2(m) = (G_N)^{1/2} m^0 \hbar^{1/2} c^{-3/2} 2^0 \tag{19}$$

$$R_0(m) = (G_N)^0 m^{-1} \hbar^1 c^{-1} 2^{-1} \tag{20}$$

$$(G_N)^{-1/2} m^{-1} \hbar^{1/2} c^{1/2} 2^{-1} \tag{21}$$

$$(G_N)^{-1/2} (m_e)^{-1} \hbar^{1/2} c^{1/2} 2^{-1} \approx 1.1945 \times 10^{22} \tag{22}$$

Possibly, complementary physics theory points to a minimal size regarding elementary particles. We consider a possible historical parallel. Regarding the ideal gas law and T (the absolute temperature), people might interpret the ideal gas law, in the limit $T \to 0^+$, as correlating with zero-size for atoms. After the ideal gas law proved useful, people determined that atoms have non-zero size. Complementary physics theory modeling correlates the limit of $|\eta_{SA}| \to 0$ with elementary particles. Possibly, at the scale of the Schwarzschild radius for a non-zero-mass elementary particle, new physics pertains.

Possibly, complementary physics theory does not yet point to physics-relevance for the Planck length.

Possibly, complementary physics theory points to $R_0(m_{H^0})$ as being a minimal size relevant for some modeling of aspects of objects that contain more than one elementary fermion. (Here, m_{H^0} denotes the mass of the Higgs boson.)

3.17 Anomalous moments

This unit discusses a complementary physics theory approach to explaining anomalous magnetic dipole moments.

Traditional physics theory provides means, correlating with Feynman diagrams, to calculate a so-called anomalous magnetic dipole moment for each of, at least, the electron and the muon.

Complementary physics theory suggests that notions of anomalous electromagnetic moments correlate with $\gamma 2$ solutions. Electromagnetic dipole solutions correlate with $\gamma 2$ solutions for which SDF is r^{-3}. The following remarks pertain for other than 2G24, which correlates with the traditional physics theory nominal magnetic moment result of $g \approx 2$. (2G24 correlates with 2γ and not with $\gamma 2$.) Relevant solutions are 4G26, 6G24, 6G28, and 8G26. Possibly, contributions scale as $\alpha^{(\Sigma-2)/2}$, in which α is the fine-structure constant. Possibly, the 4G26 solution correlates with the traditional physics theory result of $\alpha/(2\pi)$. The following two equations pertain in the context of traditional physics theory. (Reference [25] provides data that equations (23) and (24) show.) In equation (23), the subscript e correlates with the word electron. In equation (24), the subscript μ correlates with the word muon. The symbol a correlates with anomalous magnetic dipole moment. Complementary physics theory suggests that each of 6G24 and 6G28 correlates with contributions of the order α^2. Complementary physics theory is not necessarily incompatible with the difference in signs between the number in equation (23) and the number in equation (24). Possibly, people can extrapolate, based on strengths of 6G24 and 6G28, to predict the order α^2 contribution to the anomalous electromagnetic dipole moment of the tauon. Possibly, the contribution that correlates with 8G26 provides an order α^3 result and does not vary between the electron, muon, and tauon.

$$a_e - (\alpha/(2\pi)) \approx -1.76 \times 10^{-6} \tag{23}$$

$$a_\mu - (\alpha/(2\pi)) \approx +4.51 \times 10^{-6} \tag{24}$$

3.18 Lack of magnetic monopoles and of some electric dipole moments

This unit suggests modeling that would comport with nature not including the following - an elementary particle magnetic monopole, a non-zero electric dipole moment for any elementary particle, and a non-zero neutron electric dipole moment.

Table 3 points to no G-family solutions that would correlate with interactions with a magnetic monopole elementary particle or that would correlate with a non-zero electric dipole moment for a point-like elementary particle. Possibly, the lacks of such G-family solutions correlate with nature not including a magnetic monopole elementary particle and with nature not including elementary particles that have non-zero electric dipole moments.

Possibly, for each hadron for which modeling based on PDE techniques pertains and for which all the quarks occupy one state with respect to spatial characteristics, the electric dipole moment is zero. (See discussion, related to table 1, regarding PDE-based modeling that correlates with some aspects of the strong, electromagnetic, and weak interactions.) Complementary physics theory suggests that the neutron and proton might be such hadrons. Some research suggests that some pentaquarks might not be such hadrons. (See interpretation, in reference [24], of reference [1].)

3.19 Nuclear physics

This unit suggests possibilities for developing complementary physics theory models for atomic nuclei.

Traditional physics theory bases some aspects of modeling, regarding nuclear physics, on notions of a Pauli exclusion force and on notions of a Yukawa potential. Traditional physics theory correlates these effects with notions of a residual strong force. The Pauli exclusion force keeps hadrons apart from each other. The Yukawa potential attracts hadrons to each other. Modeling suggests virtual pions as a source for the Yukawa potential.

Complementary physics theory does not necessarily correlate with a Pauli exclusion force or with notions of virtual pions. Possibly, cake (or, 0K) bosons correlate with repulsion between hadrons. Possibly, from a standpoint of modeling, 0K bosons correlate with interactions with colorless color charge or white color charge. Possibly, from a standpoint of modeling, 0K bosons correlate with the identity operator that the relevant (traditional physics theory and complementary physics theory) gluon-related $SU(3)$ symmetry lacks. Possibly, from a standpoint of modeling, pie (or, 0P) bosons correlate with attraction between hadrons. Possibly, the attraction correlates with a PDE-centric expression proportional to $\exp(-tr/(\eta_{TA}\eta_{SA}))$ and with a Yukawa-like $\exp(-r/\eta_{SA})$ potential. (Here, η_{TA} denotes the TA-side analog of the SA-side η_{SA}. The factor η_{TA} has dimensions of time.) Possibly, from a standpoint of modeling, 0P bosons correlate with the identity operator that the $SU(2)$ component of a relevant weak interaction $SU(2) \times U(1)$ symmetry lacks. Possibly, that weak interaction symmetry correlates with the non-zero-charge tweak elementary particle.

4 Discussion

This unit explores synergies between notions that complementary physics theory proposes and aspects of traditional physics theory. The aspects include kinematics and dynamics models and modeling; general relativity and geodesic motion; the elementary particle Standard Model; the Higgs mechanism, entanglement, and tachyon-like behavior; supersymmetry; and aspects of cosmology. This unit suggests categories of opportunities for further research and opportunities for further use of techniques we discuss in this manuscript.

4.1 Kinematics conservation laws

This unit introduces, into our work, aspects of motion that correlate with traditional physics theory kinematics conservation laws.

Work above de-emphasizes the concept of motion. (Some exceptions pertain. One exception correlates with the evolution of galaxies. One exception correlates with the rotation of objects.) Work above de-emphasizes the notion of choosing one or more models of motion.

We introduce some aspects of motion via symmetries that traditional physics correlates with conservation laws related to motion.

Table 9 summarizes symmetries correlating with kinematics conservation laws. Traditional physics correlates an S1G symmetry with conservation of energy. The one-element term S1G denotes a symmetry correlating with a group for which one generator pertains. Complementary physics theory considers this S1G to be a TA-side symmetry. Traditional physics correlates an $SU(2)$ symmetry with conservation of linear momentum and an $SU(2)$ symmetry with conservation of angular momentum. We consider each of these $SU(2)$ symmetries to be an SA-side symmetry.

The following concepts pertain. (See discussion related to tables 4 and 5.)

- Models for the kinematics of objects for which $\sigma = +1$ need to include the possibility that all three conservation laws pertain. The relevance of all three conservation laws correlates with modeling that correlates with would-be free environments. (Objects for which $\sigma = +1$ can exist as components of,

Tab. 9: Symmetries correlating with kinematics conservation laws

Conservation law	Traditional physics theory	Complementary physics theory
Conservation of energy	S1G	TA-side $SU(5)$
Conservation of linear momentum	$SU(2)$	SA-side $SU(2)$
Conservation of angular momentum	$SU(2)$	SA-side $SU(2)$

let us call them, larger objects for which $\sigma = +1$. For one example, an electron can exist as part of an atom. For another example, a hadron can exist as part of an atomic nucleus that includes more than one hadron. In such contexts, modeling of the dynamics of the electron or hadron does not necessarily need to embrace all three conservation laws.)

- Models regarding the dynamics of objects for which $\sigma = -1$ do not necessarily need to embrace all three conservation laws. (These objects exist in the contexts of $\sigma = +1$ larger objects.)
- For a model to embrace conservation of linear momentum and conservation of angular momentum, one, in effect, adds four SA-side oscillators and expresses two instances of $SU(2)$ symmetry. Double-entry bookkeeping suggests adding four TA-side oscillators and, in effect, combining them with the TA0 oscillator to correlate with an $SU(5)$ symmetry. Complementary physics theory suggests that, for each of the eight added oscillators, $n_{\_} = n_{TA0}$.
- Complementary physics theory correlates the TA-side $SU(5)$ symmetry with conservation of energy.

4.2 Possible complements to traditional physics theory QFT, QED, and QCD

This unit summarizes aspects of possible complementary physics theory complements to traditional physics theory QFT (or, quantum field theory), QED (or, quantum electrodynamics), and QCD (or, quantum chromodynamics).

The following statements summarize aspects of possible complements to traditional physics theory QFT (or, quantum field theory).

- Complementary QFT interaction vertices can correlate with aspects of PDE modeling.
- Complementary QFT interaction vertices do not necessarily correlate only, with respect to spatial space-time coordinates, with points. Vertices can correlate with objects that model as having non-zero spatial extent.
- Complementary QFT does not necessarily need to consider notions of virtual particles.
- PDE modeling correlates with aspects of the four traditional physics theory fundamental forces.
- Complementary QFT correlates with the following notions.
  - Modeling correlating with the notion of objects in would-be free environments needs to embrace, for each of those objects, all three traditional physics theory kinematics conservation laws.
  - Modeling correlating with the notion of objects in confined environments (or other non would-be free environments) does not necessarily need to embrace, for each of those objects, all three traditional physics theory kinematics conservation laws and (for confined environments) does not necessarily need to embrace the notion of interaction vertices.

The following statements summarize aspects of possible complements to traditional physics theory QED (or, quantum electrodynamics).

- Complementary QED can describe anomalous magnetic dipole moments (and other aspects of physics) via sums over finite numbers of terms.
- Complementary QED might point to new approaches to atomic physics. (See reference [7].)

The following statement summarizes aspects of possible complements to traditional physics theory QCD (or, quantum chromodynamics).

- Complementary QCD may describe allowed states for hadron-like particles and for atomic nuclei, based on PDE modeling.

4.3 Kinematics models

This unit describes notions regarding, within a context of complementary physics theory, choosing one or more kinematics models.

Work above de-emphasizes the notion of choosing one or more kinematics models. (The work discusses various dynamics models.)

Kinematics models correlate with the motion of objects for which $\sigma = +1$ and with the notion that free environments pertain.

Kinematics models can correlate with classical physics or with quantum physics. Kinematics models can correlate with Newtonian physics modified to limit the speed of free-environment transmission of effects to the speed of light, with special relativity, or with general relativity. Kinematics models can be linear in energy or quadratic in energy. The Dirac equation is linear in energy. The Klein-Gordon equation is quadratic in energy.

The following points pertain.

- Presumably, complementary physics theory is compatible with all choices of kinematics models.
- Special relativity features boost symmetry. In the context of complementary physics theory, boost symmetry correlates with an additional SA-side $SU(2)$ symmetry. The double-entry bookkeeping aspect of complementary physics theory can accommodate boost symmetry by adding a TA-side pair of oscillators that correlates with any one of no symmetry, $U(1)$ symmetry, or $SU(2)$ symmetry. Possibly, the TA-side addition correlates with modeling and does not correlate with observable phenomena.

4.4 Dynamics models for hadron-like particles

This unit discusses an approach, compatible with complementary physics theory, for modeling the dynamics, in hadrons, of quarks and gluons. This unit also calls attention to possible differences between modeling for the dynamics of hadron-like particles that contain no more than three quarks and modeling for the dynamics of hadron-like particles that contain more than three quarks.

Regarding dynamics in hadrons that contain no more than three quarks, for each of quarks and gluons, traditional physics theory QCD modeling correlates with symmetries that correlate with special relativity. Complementary physics theory suggests possibilities for modeling that correlates one subset of those symmetries with dynamics for quarks and another subset of those symmetries with dynamics for gluons.

Complementary physics theory suggests possibilities for modeling of dynamics within hadron-like particles (that contain no more than three quarks and/or arcs) such that the following notions pertain. (See reference [7].)

- Elementary fermions (or, 1Q and/or 1R particles) correlate with a symmetry that correlates, for the hadron-like particles, with one of conservation of linear momentum and conservation of angular momentum.
- Gluons (or, 2U particles) correlate with a symmetry that correlates, for hadron-like particles, with the other one of conservation of linear momentum and conservation of angular momentum.
- To the extent that modeling for hadron-like particles includes boost symmetry, gluons correlate with a symmetry that correlates with boost symmetry for hadron-like particles.

This complementary physics theory modeling correlates with the notion that neither one of quarks and gluons behaves like an elementary particle for which $\sigma = +1$.

Reference [24] suggests that some of the dynamics within at least some pentaquarks correlates with the dynamics for a system composed of a meson-like particle (that features a matter quark and an antimatter quark) and a baryon-like particle (that features three matter quarks). Possibly, aspects that complementary physics theory correlates with the pie elementary particle and/or with the cake elementary particle play roles in such dynamics. Possibly, modeling can consider that, if they exist, some hexaquarks have parallels to short-lived atomic nuclei.

4.5 General relativity, geodesic motion, and large-scale physics

This unit suggests limits regarding the applicability of modeling based on general relativity. This unit discusses the concept that, for at least some models, geodesic motion correlates with modeling but not with space-time. This unit suggests possible opportunities for research regarding various aspects of large-scale physics.

Complementary physics theory suggests that the Einstein field equations (or, general relativity) and/or the concept of geodesic motion with respect to so-called space-time may not suffice to the extent that one of the following conditions pertains.

- Modeling correlates significantly with at least two isomers of 4G4. For example, ...
  - For PR036INe models and PR216INe models, the general relativity concept of geodesic motion might pertain (at least approximately) within PR006INe subsets but does not necessarily pertain for the entirety of modeling. For example, the sun can deflect, via 4G4, the 2G2 and 2G24 components of a photon emitted by ordinary matter, but the sun would not deflect, via 4G4, the 2G2 and 2G24 components of a photon emitted by doubly dark matter.
- Modeling correlates with one isomer of 4G4 and correlates significantly with two or more isomers of a long-range force $\Sigma G \Gamma$ other than 4G4. For example, ...
  - For PR006INe modeling, during the first era of accelerating rate of expansion of the universe, the six isomers of the set of 4(1)G2468a and 4(1)G2468b forces dominate, with each isomer correlating with a unique one of six isomers of (at least) non-zero-charge elementary particles. Possibly, dominance of 4γ components other than 4G4 calls into question notions that the Einstein field equations pertain and that geodesic motion with respect to space-time pertains. For example, the stress energy correlating with any one of the six isomers of (at least) non-zero-charge elementary particles does not correlate significantly with the motion of objects correlating with any of the other six isomers of (at least) non-zero-charge elementary particles.

For each PRnnnINe, our work offers possible tests of and/or challenges to general relativity.

- For any nnn, the extent to which general relativity correlates with effects of components, other than 4G4, of 4γ might be an open question. For example, to what extent do effects that correlate with 4G48 correlate with the general relativity concept of rotational frame-dragging (or, the Lense-Thirring effect)?
- For any nnn that exceeds one, the span of 4(2)G48 is less than the span of 4(6)G4. This mismatch regarding spans suggests that models based solely on general relativity may not accurately portray aspects regarding the presently accelerating rate of expansion of the universe.
- For any nnn that exceeds one, the spans of 4(1)G2468a, 4(1)G2468b, and 4(1)G246 are less than the span of 4(6)G4. This mismatch regarding spans suggests that models based solely on general relativity may not accurately portray aspects regarding large-scale effects in eras that precede the present era of accelerating rate of expansion of the universe.

Our work suggests nominal long-range forces correlating with $\Sigma \geq 6$ (or, $S \geq 3$). However, possibly, under almost all circumstances, nominal long-range forces for which $\Sigma = 4$ or $\Sigma = 2$ are more significant than nominal long-range forces for which $\Sigma \geq 6$.

Possibly, concepts such as those we just mentioned point to caution regarding notions that general relativity pertains precisely for some physics pertaining to objects larger than black holes. For example, effects of non-4G4 components of 4γ can be significant for aspects of galaxy evolution.

Possibly, concepts such as those we just mentioned point to opportunities for observational and theoretical research regarding each of the following topics and regarding relationships between each of the following topics - the domain of applicability of the Einstein field equations; the notion that (within those equations) the cosmological constant is a constant; the notion and applicability of the concept of a Hubble parameter; notions regarding geodesic motion; and the spans and the strengths of forces correlating with the 4G48, 4G246, 4G2468a, and 4G2468b solutions. For example, reference [19] alludes to possible concerns correlating with the Hubble constant (or, a Hubble parameter).

Possibly, concepts such as those we just mentioned suggest that people might explore concepts that might correlate with a term like the three-word term specialized general relativity. The word specialized refers to a specific object for which people want to develop a model for motion. For the specific object, motion might correlate with a metric tensor in a model based on the Einstein field equations. The stress-energy tensor and cosmological constant might correlate with effects that affect the specific object. The concept of geodesic motion might pertain within the context of such a model.

4.6 The elementary particle Standard Model

This unit discusses aspects regarding possibilities for integrating, into the elementary particle Standard Model, elementary particles and long-range forces that complementary physics theory suggests that nature embraces.

Reference [7] suggests that, to the extent that satisfying symmetries such as $SU(3) \times SU(2) \times U(1)$ boson symmetries suffices, people might be able to add, to the Standard Model, elementary particles and long-range forces that complementary physics theory suggests.

4.7 The Higgs mechanism, entanglement, and tachyon-like behavior

This unit provides possible complementary physics theory perspective regarding the traditional physics theory notions of a Higgs mechanism, entanglement, and tachyon-like behavior.

Possibly, at least to the extent that one models the universe as being a confined environment, the following statements pertain.

- The cake (or, 0K) boson correlates with the Higgs mechanism and/or Higgs field.
- Theory does not completely disentangle any object from a notion of the universe minus that object.
- These notions correlate with a large-scale notion of tachyon-like behavior.

Complementary physics theory QFT suggests interaction vertices that correlate with the nine-element term point-like with respect to temporal aspects of interaction vertices and with the nine-element term volume-like with respect to spatial aspects of interaction vertices. Possibly, people would interpret these vertices and other aspects of complementary physics theory as correlating with tachyon-like behavior.

4.8 Supersymmetry

This unit notes that complementary physics theory seems not to be compatible with supersymmetry.

Possibly, tables 2 and 3 are not compatible with supersymmetry.

4.9 Arrow of time

This unit notes that complementary physics theory may provide perspective regarding the topic of arrow of time.

Reference [7] suggests a $\Psi(t_0, r_0)$ that correlates with the TA0-and-SA0 oscillator pair and has similarities to equation (4). Reference [7] shows that such a $\Psi(t_0, r_0)$ normalizes for exactly one of incoming radial momentum or outgoing radial momentum. Possibly, people would choose, for modeling an elementary particle that enters an interaction vertex, normalization for incoming radial momentum. Possibly, people would choose, for modeling an elementary particle that exits an interaction vertex, normalization for outgoing radial momentum. Possibly, the lack of dual normalization provides insight regarding the topic of arrow of time.

Possibly, the complementary physics theory notion that modeling of conservation of energy correlates with an $SU(5)$ symmetry (and not necessarily with a traditional physics theory notion of S1G symmetry) provides insight regarding the topic of arrow of time. Complementary physics theory tends to correlate $SU(\_)$ symmetries with origins (with respect to coordinates) and with radial coordinates.

4.10 Numbers of dimensions

This unit speculates regarding one aspect of the topic of numbers of dimensions.

Complementary physics theory suggests that, at least in some sense, a number - three - of spatial dimensions correlates with $D^*_{SA} = 3$ and a number - one - of temporal dimensions correlates with $D^*_{TA} = 1$.

For a hypothetical five spatial dimensions and $D^*_{SA} = 5$, for an elementary fermion, the particle might correlate with $\nu_{SA} = -5/2$ and modeling might suggest relevance for two fields. One field could correlate with $\nu_{SA} = -1/2$. One field could correlate with $\nu_{SA} = -3/2$. Possibly, the notion of two fields correlates with a lack of physics relevance.

4.11 The cosmology timeline

This unit lists topics, regarding aspects of the cosmology timeline, for which our work suggests insights.

Work that we discuss above makes suggestions about the following aspects of the traditional physics theory cosmology timeline.

- The production of baryon asymmetry.
- Eras regarding the rate of expansion of the universe.
- A possible inflationary epoch.
- Clumping that forms various objects, such as stars, galaxies, and galaxy clusters.
- Galaxy formation and evolution.

Possibly, our work also suggests the following notions.

- Early in the evolution of the universe, quarks, arcs, and gluons formed hadron-like seas. The seas might have undergone phase changes, with the last changes featuring at least one transition from seas to hadron-like particles.
- To the extent that the universe underwent a so-called inflationary epoch, the epoch might have correlated with such changes regarding sea states, with the formation of baryon asymmetry, and/or with dominance of 4G2468a and 4G2468b repulsion.
- Dark matter baryon-like acoustic oscillations produced effects that led to at least some aspects of dark matter filaments.
- Scenarios regarding clumping suggest that early black holes contained stuff correlating with essentially just one isomer. Later phenomena, perhaps most notably collisions between black holes, might produce black holes that contain significant amounts of stuff correlating with each of more than one isomer.
- Significant aspects of quasars, black hole jets, and blazars might correlate with effects of the 4G48 repulsive long-range force.
- Significant aspects of black hole and/or neutron star collisions might correlate with effects of the 4G48 repulsive long-range force.
- Complementary physics theory is not incompatible with possible large-scale flatness for the universe.

4.12 Concluding remarks

This unit discusses possible opportunities based on our work.

Possibly, our work provides impetus for people to tackle broad agendas that the work suggests. Possibly, our work provides means to fulfill aspects of such agendas. Possibly, our work fulfills aspects of such agendas.

Possibly, opportunities exist to develop more sophisticated theory and modeling than the theory and modeling we present. Hopefully, such a new level of work would provide more insight than we provide.

Possibly, our work suggests - directly or indirectly - opportunities for observational research, experimental research, development of precision measuring techniques and data analysis techniques, numerical simulations, and theoretical research regarding elementary particle physics, nuclear physics, atomic physics, astrophysics, and cosmology.

Possibly, our work suggests applied mathematics techniques that have uses other than uses that we make.

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