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Challenges Beyond the Standard Model: An Examination and Evaluation of Alternatives with Respect to Unsolved Problems in Energetics and Signaling

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Abstract

The standard model of particle physics is regarded as one of the greatest achievements of modern physics. It has successfully predicted the existence of numerous hadrons; e.g. the Higgs Boson, the W and Z Bosons, B mesons, etc. Moreover it accurately models many phenomena such as Beta and Radioactive decay, pair production, hadron mass splitting, and others. In spite of this, the standard model has many shortfalls. For example it fails to account for or explain the presence of dark matter and dark energy. Many alternative models of the substructure of matter etc. have been proposed. Some of these are examined.

In addition the strongly related standard model of cosmology, that is the big bang theory, accounts for all observed celestial phenomena. What it cannot do is satisfactorily justify all astrophysical events. As noted, dark matter and dark energy are not well understood yet they are core elements of the big bang model. Many elements of this standard model of cosmology are challenged regularly, yet somehow the community always fits the problems with the model into another mysterious element. This model and others are examined for consistency and reconciliation.

Evidence of particles that move faster than the speed of light has long been sought, but remains elusive. Some of the known space-like observations of physics are examined. Potential consequences of such particles are likewise investigated. Some conclusions are drawn with respect to the framework of tachyons in a rational but non-rigorous sense.

Finally, some of my ideas are presented, concerning all of the above material. The framework of theories of everything is examined, considering what such a theory requires for validity. Sociological notes on the structure of research in physics are given.

Contents

Chapter 1

Particle Physics

1.1 Introduction

Many advances were made to the field of fundamental physics throughout 20^{th} century. Among them, notably, are Ernest Rutherford's gold foil experiment between 1908 and 1913, the advent of quantum mechanics around 1925, and later the development of particle accelerators in their many forms. These each play major roles in understanding the construction and description of matter and the fundamental forces that govern it, yet some of the most interesting problems are elusive. This is true for many other fields of physics as well, including astrophysics and cosmology, plasma physics, condensed matter physics, etc. While many of these also surged ahead during the middle of the 20^{th} century, such as cosmology with the rise of space telescopes and astrophysical radio interferometers, similarly serious fundamental problems have become evident.

The gold foil experiment led to the discovery of dense nuclei and subsequently Bohr's atomic model [8]. While incomplete, Bohr's model for atomic hydrogen induced advances in quantum mechanics, and a further understanding of the actual structure of atomic nuclei. When Rutherford scattered alpha particles off a thin sheet of gold foil, the scattering angles of the outgoing particles indicated that there were dense nucleic objects at regular spacing within the gold foil. This, in combination with further experimental examination and theoretical development led to the current understanding of atomic structure: a dense positively charged nucleus orbited by much lighter negatively charge particles.

Quantum mechanics deserves its own special place in history; it has changed mankind's understanding of most physical sciences. The primary tenet of quantum mechanics is that everything is in a probabilistic superposition of every state it may be in. Whether or not every particle actually exists in a superposition of states, it may as well; due to Heisenberg's uncertainty principle we can never know everything about a particle at once, and therefore cannot entirely determine its behavior.

Particle accelerators have defined fundamental physics since the 1960s, as any new data about subatomic structure comes from results of particle collisions. The ability to detect and analyze the results of collisions on the atomic and subatomic scale has greatly informed theoretical and phenomenological models of fundamental particles, forces, and physics [14].

In the following, a number of particle and cosmological models, both theoretical and phenomenological, are examined. Each of the models accounts for some observations of physical phenomena. We aim to analyze each with respect to some outstanding problems in physics. A fully realized model should explain each and every observed interaction; as such, each model is examined in terms of its ability to explain both well understood and exotic interactions. Further, each model is compared to the standard model, vis-a-vis consistency, elegance, and accuracy. Most of these models are less than fully developed due to a lack of focus on them in the presence of the successful standard model, so a few implications are drawn. These are noted and justified.

All of the particle models share some similarities with each other and the standard model, as required by the successes of extant fundamental physics. Each has the structure of a proton (or neutron) defined by the presence of constituent charged particles. These particles interact with each other (and similar particles in adjacent nucleons) via the mechanism of a strong force — the nature of such force is the main difference between the models. Another difference is the number of constituent particles present, the degree of charge on them, the mass of said particles, and whether or not they are observable.

In contrast, many of the cosmological models are entirely different from one another. The difference of scale may account for this, but it is as likely that the lack of ready testability for those theories induces completely different models for various effects.

Since each particle model discusses the structure of a nucleon, that will be the primary scale by which they are weighed — how successfully the model will reproduce qualities exhibited by both protons and neutrons during collision and decay. Beyond this, speculation will be made into consequences for the production of other composite particles, as well as the effect of these structures on more fundamental particles, e.g. electrons and neutrinos. Likewise, the cosmological models will primarily be analyzed with respect to their mechanisms for redshift and galactic mechanics.

Each particle model will be deconstructed into individual features such as strong force mechanism, use of gauge bosons, physical nucleon structure, etc. Many of these features have places in more than one model, and a section discusses the ways individual specifications of these models explain various consequences and interactions. A list of features that fit phenomenological truth is compiled and discussed. The cosmological models are not as easily separated, and as such will primarily be considered in their entirety.

Finally, the motivation for this paper is sociological as well as physical. It is clear that current physics is not able to explain many observed interactions, so called 'Physics Beyond the Standard Model' [41, 56]. In spite of this evidence of an incomplete schema, the standard model is adhered to with great fervor.

We aim to address some of this dogmatic adherence to incomplete models, in hopes of opening the floor to further progress and understanding.

1.1.1 The problems in physics

The main motivation in producing this report is to show how some alternate theories of particle physics, cosmology, and others produce solutions to the variously unsolved problems in physics. These solutions are by no means perfect, and no single model solves everything, indicating further need for research and ideation. The features of each model that can solve problems are noted, and some suggestions for combining the features and in some cases a scheme for introducing them to theory at large is explored. The major unsolved problems in physics with respect to each field are presented here, with emphasis on consequences.

Some of the problems in physics arise from the interpretation of general physics as it is experienced by humans every day, and the quantum description of those mundane aspects of physics. One of the best known of these is the unidirectionality of time as it is perceived. What causes time to proceed only forward? This effect is clear to organisms, as all appear to experience time in a linear fashion, but it also appears in the second law of thermodynamics since entropy appears only to increase at a macroscopic level in time. A more fundamental understanding of the procession of time may lead to faster communication and transportation. Another much debated problem is the interpretation of quantum theory: is there such a thing as an absolute interpretation? Do the superposition property and wave function description of elementary particles imply other realities, or are they merely the best approximation for a deterministic universe? The measurement problem plays a role here too — it muddles the question even further by changing the state of anything at a small scale immediately by the act of measuring it. Perhaps the best known problem in physics at large is grand unification. Quantum physics and general relativity, even when used in concert, cannot explain why so many constants arise in any fundamental interaction. Is there a theory that does explain each of these constants? Does it reconcile the forces understood with gauge groups and gravity? These questions in particular are topics of much research in current theoretical physics [16], and while they are addressed minimally in this report they strongly indicate that there is a philosophical discontinuity in the pursuit of physics.

Another field of physics rife with phenomena that lack a complete explanation is the theory of condensed matter. For example, it is not understood why some materials exhibit superconductivity at temperatures above 25 degrees Kelvin. Closing this issue could potentially allow superconductors at room temperature, which would cause a sea change in computer hardware. The states of particles in the fractional quantum hall effect are not all well understood, in particular the $u = \frac{5}{2}$ state. This may describe a quasiparticle with non-Abelian fractional statistics, perhaps indicating as yet unobserved quantum states. Many other problems in condensed matter physics also point to a fundamental incompleteness of the quantum theories used to describe solid state phenomena.

In cosmology and astrophysics, there are many constants whose values are not well understood, including the Hubble constant, the cosmological constant Λ, and others. These constants are hints to other major breaks in understanding, such as the morphology of the universe as a whole, and the horizon problem or disagreement between the observed isotropy of the universe and the predicted anisotropy of the big bang theory. A concept that many believe closed is the origin of redshift; while Doppler shifted light from stars in a universe expanding faster than light could explain it, many other explanations exist as well. Some will be investigated. Other outstanding problems include a direct understanding of the nature of dark matter and dark energy, particularly vis-a-vis celestial mechanics; why there is so much more matter than antimatter in the observed universe; what happened in the very short time after the big bang to cause all of these unexpected asymmetries. Many other problems plague astrophysics as well, including the observation of mysterious absorption spectra, the mechanics of a supernova and other massive astrophysical phenomena such as the growth of supermassive black holes, what caused or causes the cosmic microwave background? Many other issues relating to astrophysical energies, particle accelerations, radio bursts, etc. require further research, those are beyond the scope of this report. There are many questions in need of address, though this report will focus on the origin of redshift, dark matter, and dark energy.

Nuclear and particle physics are very well understood in the framework of quantum field theory, yet many of the problems that plague quantum physics extend to the study of quantum fields. The coupling constants of QCD (quantum chromodynamics) are unexplained, and moreover the theory does not tie to gravity well. Many of the particles predicted by QCD are unobserved, and symmetry violations in the theory are often observed despite their mechanism remaining unknown. Further, why the different fundamental forces have their individual strengths and why in particular gravity is so weak is not well understood, which is known as the hierarchy problem. The existence of particles that carry magnetic monopoles is not observed, yet theory indicates they should exist. This contradiction is rather stark in particle physics. It is not well understood either why there are three generations of quarks and leptons instead of some other number. For that matter the origin of neutrino masses and their oscillation is not completely well defined. Some of these problems and others will be examined. Misunderstood elementary-particle physics is prohibitive - many more macroscopic problems in application may become clear with a more rigorous and complete understanding of particle physics. For example a road to sustainable energy production via nuclear fusion may be revealed, or in a more mundane fashion computing may get faster and more efficient, etc. In this report, the substructure of nucleons will be examined, as well as the forces governing subatomic particle and the formalisms that govern them.

All of these problems alone indicate a need for further study of the subject, but together they imply a great misunderstanding in the nature of physics. It is hoped that some day in the future, physics will be a well defined and closed field, but this can never happen if so many outstanding problems are left unalleviated. Unfortunately, theorists and experimentalists have been cracking at some of these problems for decades to little avail. As such, new approaches to old problems should be embraced with open arms, yet they are often derided as foolish and untenable. So in spite of a pressing need for new physics, many researchers continue to delve into niche topics. While productive, this approach may prevent the rise of new branches of physics. The sociology of research will also be examined in the closing comments in this report.

1.2 Observed Truths: How we got here

The new technologies and theories used to analyze particle physics have led to a huge number of discoveries. A veritable zoo of non-atomic particles have been observed and identified, and the relationships between them studied and cataloged. Particle accelerators have been the primary experimental apparatus; used to observe particle collisions at various energies, the data taken from accelerator experiments has been invaluable. Theory has grown up around the experiments. Quantum theories of fields developed to reconcile quantum mechanics as observed in exclusion principles and discrete energy levels etc. with the observation and production of particles.

Some of the particles clearly observed by experimentalists include pions, kaons, betas, muons, taus, $W^{\pm}$ and Z bosons, various mesons, neutrinos, the Higgs boson, and others. Many of these particles have been predicted by the standard model, and certainly all are allowed within its framework. The truly important piece of these observations is the insights into theory they offer. Pions and kaons are mesons, or (theoretically) a bound quark-antiquark pair. Pions are thought to be a main part of the mechanism that binds nuclei together; the strong interactions between quarks act residually through pions on nucleons at large. Kaons on the other hand give insight into symmetry violations, an important part of theory. Kaons were the first particle in which violation of Charge-Parity (CP) conservation was observed. This led to the current explanation of baryon asymmetry, which has yet to be fully confirmed. Beta particles, or fast electrons, are the result of nuclear decay. Through the weak interaction, a neutron can decay into a proton with a negative beta and an electron antineutrino, or a proton can decay into a neutron with a positive beta and an electron neutrino through the exchange of $W^{\pm}$ and Z bosons. All of these observations led to and subsequently upheld the development of gauge theory with respect to elementary-particle physics, the main mathematical formalism in quantum field theory and the standard model [57].

The most convincing confirmation of the standard model to date is certainly the observation of the Higgs boson. Peter Higgs (and others) theorized that there was a field permeating all space with which particles interacted to gain mass. With the theory of this field it was predicted (circa 1964) that there could be a particle — the Higgs boson — that represented a quantum excitation of the field. Its properties were calculated from gauge and quantum field theories, including its rest mass (in GeV/c^2), then a particle was produced and observed in the Large Hadron Collider at CERN that precisely matched those properties [34, 29]. This is beyond compelling evidence for the existence of at least the Higgs field and Higgs mechanism for producing massive particles via a spontaneous symmetry break. It is clear then at the elementary particle level, quantum field theory is a correct approach. That is the current theoretical formalism agrees well with the reality of experimental particle physics. No others have been as successful, as is discussed below.

The primary observables in experimental particle physics are the scattering cross sections in collisions, or structure functions. These functions describe the electromagnetic and momentum transfer interactions at the subatomic scale: that is to say they show clear evidence of an extended nucleon structure. Interpretation of these functions is unclear. Various authors claim the structure functions indicate nine substructures inside the nucleon [71, 72], or three quarks as is the usual standard model interpretation [75], or three valence quarks and an unknown number of quark-antiquark pairs [26]. Due to this disagreement between experts, it seems to me the internal structure of hadrons in general and nucleons in particular is at best unclear.

My description of the successes and failures of particle physics as it stands right now follows. The standard model and its mathematical formalisms, quantum field theories QED and QCD with gauge theory, and the common way to describe particle interactions, are very good predictors of collision results. The particles produced, real or virtual, are well accounted for. In contrast to this, structures appear not to be well understood. Particle interactions are observable, and the theory can be made to fit experiments as it has, but internal structure remains largely a mystery because the rules of confinement and the hidden mechanics of elementary particles are not well understood. A citation for this truth is not included, as the existence of (at least) five qualitatively different models provides evidence. This shows that the theory of the standard model is very good, but incomplete. This is further evidenced by the lack of a clear quantum model of gravity [16]. A strong model of particle physics therefore requires the ability to produce predictions as accurate and precise as those of the standard model, along with a description of the substructure of nucleons (or hadrons in general), and possibly a reconciliation with gravity. In the following, five models including the standard model are discussed with respect to these issues, as well as some other open problems in physics. These are not all extant alternative models, but they capture the main arguments of the larger groups. Namely, each model addresses (or attempts to address) a feature of the standard model that seems *ad hoc* or unjustified.

1.3 The Standard Model

The standard model of particle physics is phenomenologically elegant. Nucleons and other hadrons are made up of quarks, subatomic particles subject to strong interactions. Depending on whether one accepts the common interpretation or another, e.g. that given by Rindani [66], quarks have respectively charge that is represented by a fraction (in thirds) of the elementary charge on the electron, or unit charge. The strong interactions between them are mediated by gauge bosons called gluons, thought also to carry more than half of the nucleons overall momentum [27]. The "charge" that quarks carry, in analog to electricity, is called "color charge" and comes in three varieties. Each of these has a positive and negative pole, like electricity. Quarks and gluons are confined in part due to color charge such that an equal amount of each color must be present in any given observable particle [2]. This phenomenon helps to explain why quarks and gluons may not be observed independently.

There are six types of quarks in the standard model, further divided into three generations having to do with the mass of the quark. The six quarks, grouped by generation are: up and down, strange and charmed, bottom (or beauty) and top. The latter four are exotic and have other quantum properties strangeness, charm, and bottomness associated with them, defining different properties of various hadrons.

Leptons are posited to be elementary particles, that is not composite particles made of quarks. This category includes particles such as electrons, neutrinos, beta particles (or fast electrons), muons, taus, and others. There are three generations of leptons as well, for example muons, electrons, and taus all have Fermi spin qualities and charge $-1e$, but different mass they may be treated as the same particle but in a different bound state. Leptons are particles in the standard model not subject to the strong interaction.

Proton construction in the standard model is theorized to consist of three valence quarks; two up quarks (charge +2/3) and one down quark (charge -1/3). With these may be a soup of sea quarks or quark-antiquark pairs, and more firmly a sea of gluons mediating the strong interactions. All together these account for the total momentum of the proton, as well as its mass and charge. Following is an explication of the major successes and failures of the standard model, with respect to experimental observations and common sense.

There have been many great successes of the standard model; the use of quantum chromodynamics, the scheme by which the strong force is mathematically modeled within the standard model, has led to many successful predictions. These include the Higgs Boson, the so called crowning achievement of the model. Beta decay is also well understood via the standard model [47]. The weak interaction is well documented, with W and Z Bosons the gauge bosons for this force [34], similar to photons for electromagnetism. In both the electromagnetic force and the weak force, it is observed that the force acts via the exchange of energy in the form of these gauge bosons. The standard model also accounts very well for generalized atomic scale phenomena. The theoretical basis for the standard model and QCD (quantum chromodynamics) is the general formalism of quantum mechanics and quantum electrodynamics, both of which are well understood and provide a very solid grounding. This may explain some of the successes of the standard model at the atomic scale; beneath that there has been very little rigorous derivation of the field theory QCD, it is largely determined to fit experimental results. QCD is successful as a phenomenological formalism, it predicts momenta from inelastic scattering within two standard deviations in general [65], though this is generally at the low energies used to derive the field theory.

1.3.1 Standard Model Deficiencies and Inconsistencies

Simultaneously, the model has a number of very serious failures. The aforementioned confinement of quarks and gluons cannot be directly confirmed [2], by definition. Since the model is based on interpreted results, there is very little in the way of a rigorous derivation from first principles. There are many theoretical pitfalls: asymptotic freedom is a very clean concept, but it appears to be inconsistent with *pp* scattering [30]. For example, at higher momentum transfer (Q^2, energy equivalent) scattering cross sections from both elastic and inelastic scattering attain a minimum then start increasing again [63], which seems to disagree with asymptotic freedom. The density of quarks in nucleons and other hadrons is assumed to be constant, but I have not found a convincing argument in favor of such uniformity. Antiquarks appear to be dominant in the outer portions of nucleons [30], this has not been adequately explained either. These particles also seem from scattering experiments to be larger than expected [30]. Furthermore, antiquarks and their qualities are not well defined within the scope of the Pauli exclusion principle [30]. Mesons generally appear to escape nucleon confinement during scattering interactions, which seems to run counter to the predicted strong interactions. Despite years of general adherence to the concept, there does not seem to be a rigorous way to show that quarks certainly have fractional charge. Many of the exotic particles predicted by the standard model, including baryons such as tetra-, penta-, and hexaquarks have never been inarguably observed, nor is there an extant scheme for finding them. Glueballs, or hadrons made up exclusively of gluons, also lack confirmation.

The above problems are all very specific to high energy particle physics, whether experimental theoretical, but there are more big problems relevant to particle determinism. Some of these are well known to the public, although the formulations of the problems may not be. For example, dark matter and dark energy are a theoretical construct introduced to satisfy the inflationary big bang model of cosmology, yet they cannot be observed and the only measurement possible to date is theoretical. In a similar vein, there is a massive disagreement between the small measured vacuum energy density and the large zero-point energy indicated by quantum field theory. Depending on the measurement, the discrepancy ranges from about 40 orders of magnitude to about 100 orders of magnitude [5]. Another major problem is the baryon asymmetry: why is there more matter than antimatter in the observable universe [10]? What is the mechanism that governs quantum entanglement? What is the nature and cause of cosmic inflation, if it exists? These are just a few of the big problems in the standard models of elementary- particle physics and cosmology.

Some other weak points of the standard model are not quite as potent as those mentioned above, but still are in need of address. Pair production and annihilation are described by many physicists in a way that is not entirely accounted for by the standard model [41]. There does not seem to be a good description of the *laws* of strong and weak interactions; the mechanisms of the standard model describe them, but there does not seem to be a formula outside Feynman diagrams to describe the direct phenomenology [40]. The charge radius of the proton is smaller than the quark-gluon model predicts [54].

1.3.2 Assessment of the Standard Model

Few constructs in the history of science have been as successful as the standard model [73]. It is predictively powerful in terms of: seeing new hadrons, spontaneous symmetry breaking [17], and gauge interactions. The model continues to lead to precise predictions that are verified at various accelerator facilities around the world. It is easy to see why alternatives are not explored. Nonetheless, there are many phenomena not discussed in the standard model [41, 56]. Understandably, it seems the physics community at large thinks "surely with enough phenomenological development, higher energy collider facilities, more theoretical research into quantum chromodynamics, along with further examination of those phenomena that do not fit well with the standard model, it can provide a full and complete model of all interactions." Unfortunately the real shortfalls of the standard model have little to do with the particles it accurately predicts, whether exotic or ordinary. While it is true the standard model predicts many more exotic hadrons than have been observed, it is certainly possible high enough energies have not yet been attained for these to be produced.

The standard model and QCD accurately predict the production of almost all observed hadrons. The (as-yet) crowning achievement of the model is the prediction of Higgs Boson, and subsequent (four decades later) observation of it at the large hadron collider in 2012 [29]. This observation theoretically confirms the scheme of symmetries and spontaneous symmetry breaking in QCD. The quantum theories of fields that govern elementary particle interactions have a number of symmetries and gauge symmetries that describe interactions and phenomenology very well. The $U(1)$ gauge symmetry that governs electromagnetism gives rise to a massless photon in theory, which is of course observed. The $SU(2)$ gauge symmetry that describes the weak interactions successfully predicted the $W^{\pm}$ and Z bosons that mediate those interactions and have now been observed.

The standard model handles the strong interaction via a similar mechanism. A $SU(3)$ gauge group is used to describe strong interactions, with very good accuracy and high precision to date. The symmetry comes from the idea of color charge and color confinement; the strong force is an attractive force like electromagnetism (though stronger) but instead of the single dichotomous quality of electric charge, in the strong interaction there are three. Each color has a positive and negative charge quality, and any composite hadron must have an exactly equal amount of each color charge. This symmetry predicts another gauge boson to mediate strong interactions, the gluon. There is further evidence that gluons exist and are massive given by the fact that momentum structure functions for both protons and neutrons show that quarks cannot carry all the momentum of the nucleon in question [27]. In spite of all this, neither quarks nor gluons may be observed, in theory [2]. Since both are subject to the strong interaction and have individual color charges, they therefore do not have the above equal amount of each color, and can only exist in confinement.

There are many extremely useful concepts in the standard model that produce accurate predictions, but may not be fully verified in the foreseeable future. Quarks, gluons, and color confinement are of this variety. The $SU(3)$ gauge group follows from the confirmation of the groups that are known and used to describe electromagnetism and the weak interaction, but lacks a key scientific quality: verifiability and falsifiability. Given the successes of the model, this is typically overlooked. A discovery that could confirm more of the theory would be the theorized glueballs, or hadronic bosons composed of only gluons. So far, these have not been observed [32]. In addition QCD and the standard theory of particle interactions predict many exotic particles like the aforementioned glueballs that have yet to be confirmed. This casts some doubt on the perfection of the standard model.

One of the great drawbacks of the standard model, in fact that which prevents the standard model of particle physics from being in some sense complete, is that it cannot describe gravitational interactions in a quantum universe. It is postulated that at high enough energies, all four fundamental forces; that is electromagnetism, the weak interaction, the strong interaction, and gravitation unify into the same symmetry group interaction. This would require a consistent quantum mechanical description of each force, and none such has been found for gravity. There are many varying theories of quantum gravity, but none has been shown to be more correct than any other at this juncture.

Another missing piece from the standard model is a strong tie to cosmology. While the early universe shortly after the big bang is well understood in terms of quarks and pair production, the current model of the expanding universe requires there be much more mass and energy in the universe than is observable, or interacts with light. This mass and energy is referred to (respectively) as dark matter and dark energy, but due to their unobservable nature the effects of such are the only way to study the existence of dark matter/energy. There is a strong parallel to quarks and gluons here, another unobservable group whose inclusion in calculations simplifies and orders expectations of reality. Whether these incomplete knowledge sets indicate a necessity for further study of current models of both particle and cosmological physics or an impetus for new models entirely is unknown.

Study of some of the open problems in physics may lead to the proposal of modifications to the above standard models. For example understanding the previously mentioned nature of dark matter and dark energy as they pertain to the morphology of the universe could provide insight towards the reconciliation of gravity and quantum mechanics. By the same token, the lack of an observed graviton in the age of readily measurable gravitational waves may lead to a new type of symmetry group that could work towards that same end.

Other concerns stem largely from the unrealized predictions of the standard model. If a modification could explain why glueballs, tetraquarks, and hexaquarks have yet to be clearly observed it may merit further study. Similarly the problem of baryon asymmetry has no conclusive explanation. In a theoretically symmetric process as the big bang is thought to be, equal amounts of matter and antimatter should have been created. It seems clear that this is not the case, unless the models of particle physics have some unnoticed errors. If a discovery of spontaneous symmetry breaking in some gauge group or other Lagrangian could explain this asymmetry, it could also merit intensive study and possible inclusion in or modification of the standard models of particle physics and cosmology.

1.4 John Preston's U-Charge Model

John Preston posits that ambient space is occupied largely by a massless, elementary, charged particle he dubs a unitary charge (or u-charge). He further hypothesizes that these u-charges are the constituents of dark matter and dark energy. U-charge modelling efforts begin with the photon - known properties of the photon are used to construct a two u-charge model of one, and properties of the individual u-charges are inferred.

Preston's model of the proton consists of five u-charges. These interact in a similar way to classical electromagnetism, with a positive u-charge in a central position, with two negative u-charges orbiting at a fixed radius and two more positive u-charges orbiting at a slightly larger fixed radius. The force interaction between these u-charges is defined as

$$F = ma = \frac{k}{\alpha}\frac{qq}{r^2} \tag{1.4.1}$$

where

- k is coulomb's constant,
- α is the fine structure constant,
- each q is the charge of an interacting particle,
- r is the distance between interacting particles.

Moreover, when a u-charge is oppositely paired with more than one other u-charge, its charge is divided evenly between them, as a surface charge density distribution. It is unclear how theses u-charges behave in other situations, as only the proton, electron, and photon have been modeled.

The strength of the strong interactions in this model is in very good agreement with the measured strength of strong interactions, which at a distance of one femtometer appears to be about 137 times stronger than electromagnetism. Indeed, as the model is largely constructed mathematically, relatively few assumptions and parameters are needed outside a few curve fits. Further, the radius of the proton model above comes out very near the measured proton radius of 0.84 fm. More precisely, in the u-charge model the radius comes out about 2.5% smaller than measured, which is within error. This model is also incomplete, and well malleable to experimental interpretation. All of the above information comes from the project's website; www.thedarkenergychallenge.com, listed as reference [62].

1.4.1 U-Charge Weaknesses

Some of the major theoretical problems with this model come from its derivation. The logic used to build the model from first principles is unclear, although the numbers come out very well. For example the electron magnetic moment may appear well-derived because the Bohr magneton is resubstituted in the formulation of it. Though the proton radius is modeled very well, this model does not account for dynamic geometry. It is well known that although an isolated proton may appear spherical, its shape morphs with respect to external forces acting upon it [39], and the u-charge model does not handle this as well as it might. Though Preston's model can account for negative beta decay well, the converse process, that is the expulsion of a positron by a proton forming a neutron does not have a scheme currently. Further, how young and adaptable the model is limits its predictive power substantially; it appears to be phenomenological. It is important to note that this is my analysis of information that is publically available, and not officially associated with the u-charge model.

With respect to experiments, particularly particle accelerator experiments, the u-charge model does not seem to have the correct number of "partons." Momentum and electromagnetic parton distribution functions seem to indicate that a proton consists of nine subnuclear particles, as opposed to five. Their masses (or rest energies) also seem contrived in the model; there is no direct formalism by which a u-charge gains its static mass. In fact, the model posits that u-charges self accelerate to the speed of light in a free environment, but particles with real mass may not achieve the speed of light, by definition.

1.4.2 Features of the U-Charge Model

The mathematical structure of the u-charge model allows it to be an extremely flexible model with respect to observed interactions. For example, in *ep* scattering, there are around seventy possible particle outcomes, some of which are exotic. Most specifically, the model allows for reasonably low energy exchange of u-charges; inducing mass splitting, decay, or even nuclear transmutation. This addresses some of the weaker points of the standard model, specifically meson confinement. The standard model (as stated above) cannot adequately explain how meson pairs escape confinement due to the strong force — all extant explanations are somewhat beyond the standard model and QCD.

The u-charge model also entirely does away with confinement, though the particles remain unobserved for some as yet unspecified reason. The u-charge model explains nuclear scale phenomena fairly well, citing the strong nuclear force as a space diluted form of the strong interaction between u-charges with a relativistic delay. There is certainly no use for asymptotic freedom in this model, as u-charges are kept separate by the conservation of angular momentum and a speed of light limit to how fast they can orbit. One of the elegant points of this model is its explanation of dark matter and dark energy; they would simply be isolated u-charges in space. Single u-charges do not interact reflectively or refractively with light, as a photon in this model is simple made of two u-charges tightly bound in a sterile, non-reactive way.

The construction of particles from dynamically interacting u-charges is a fairly friendly concept, and the mathematics lend themselves well to simulation and computer experiments. In spite of this, there seems to be no extant particle mechanism for gravitational attraction therein. This is just one of the open problems in physics, but it is not shown to be solved here.

Preston's model is unfortunately lacking in terms of upholding the standard model's strengths. The weak interaction is not discussed, and appears *not* to be the motivation for beta decay of neutrons consisting of u-charges. Spin is also not discussed, although the model seems to imply that each u-charge is a fundamental fermion, therefore particles consisting of even numbers of u-charges display characteristic of bosons, odd numbers similarly displaying fermion attributes. This unfortunately does not agree with observed CP symmetry and its known violations, which is a tenet of the standard model.

Perhaps the most significant missing feature of the u-charge model is the treatment of quantum mechanics. Preston's model takes no consideration of quantum mechanics or quantum field theories. These formalisms have been shown true, if perhaps incomplete, over the last century; any model of particle physics must of course take them into account. The u-charge model has not addressed almost any of the most basic quantum rules, including Pauli's exclusion principle and Heisenberg's uncertainty principle. Charge does not appear fully quantized. Failure to address these issues is a major gap in the model, which limits its success. It has some useful features, listed below, but does not yet pass the rigors of either theoretical or experimental testing.

List of Features: U-Charge Model

- Central strong force analogy to EM/Gravitational interactions
- Conservation of momentum as a mechanism preventing collapse
- particles that do not interact individually with light
- No unobserv(ed)(able) gauge bosons

1.4.3 Assessment of the U-Charge Model

Preston's u-charge model is constructed mathematically from concepts in classical mechanics. This fact allows simple analysis of the model; every piece is clearly defined within the scope of electromagnetism and dynamics. Preston altered the formulation of Coulomb's law to increase its strength by 137 times, the difference between the strength of the strong interaction and electromagnetism.

This leads to straightforward equations of motion, easily analyzed in the context of ordinary differential equations. If this model is correct, u-charges are the most fundamental possible blocks of matter. Two of them in a bound state, orbiting each other at the speed of light, create a photon. Since this requires a photon to have some finite size larger than a u-charge, it would not interact with free floating single u-charges, the model's candidate for dark matter. The major problem with the standard model addressed by the u-charge model is therefore dark matter. John Preston calculates the momentum and radius of various particles analytically with respect to the aforementioned ordinary differential equations, to surprisingly good precision and accuracy. Perhaps a somewhat unexpected aberration is the u-charge electron. The particle is posited to consist of three u-charges with a fairly large orbit. The u-charge electron radius is about two orders of magnitude larger than the classical electron radius. In spite of this, the model reproduces many of the properties of the electron, such as self-energy and magnetic moment quite precisely, although it is these very quantities used to build the model of the u-charge electron.

The u-charge model uses circular logic to define the properties of individual u-charges bound in a photon. These individual u-charges are then used to construct models of other hadrons. Some well known constants are used to derive radii, energies, and momenta from the usual classical relationships, then reused in the equations of motion to reproduce those quantities. Importantly, the model does not address quantum mechanics and all quantum theories of fields, which are well established. For example, no gauge symmetries, symmetry breaks or exclusions are considered; the model is new and incomplete which could explain some of this. There is no consideration of gauge bosons, and in fact the photon which is known to be the gauge boson force carrier for quantum electrodynamics has no forthright quantum properties at all in the model. Quantum effects are not considered, in favor of classical formalism, which is much more comprehensible. Unfortunately, the model is left without the ability to explain observed quantum effect such as the discrete energy levels of an electron orbiting a nucleus. The u-charge model does not have a ready made explanation for baryon asymmetry or pair production. Annihilation is not considered. The u-charge model further has no weak interaction consideration, as such a formalism for radioactive decay is not well defined in the model.

The greatest need of the u-charge model is to find some inclusion of quantum field theories. It may become a very powerful and convincing model, or at least a tool for the analysis of particle dynamics. If each u-charge has a wave function to determine some of the particles properties, much of the assumed classical phenomenology could be recreated. Some of the dynamics would obviously change due to exclusion principles etc. but the model could look much the same. Importantly, there is no reason an appropriate experiment (which has yet to be determined) could not observe a u-charge and confirm the theory, or falsify it. Thus a key tenet of theoretical physics is satisfied, the model may be appropriately subjected to the scientific method.

1.5 Oliver Consa's Helicoidal Model

The helicoidal model is interesting. It asserts that all atomic particles (nucleons, electrons) consist of a unit charges orbiting a dynamically fixed point in space, creating current loops and angular momentum. The radius of all of these particles is given to be the Compton wavelength of said particle. Since the Compton wavelength is inversely proportional to the mass of a particle, this defines heavier particles as smaller. The model posits the magnetic moment of the proton and neutron are both equal to a nuclear magneton, which does not quite agree with experimental observations. No explanation is given for strong or weak interactions. Structure and scattering experiments are left entirely unconsidered. The point of this model seems not to make a serious effort to redefine understanding of subatomic structures, but rather to showcase ways in which the successes of the standard model can be duplicated in an *ad hoc* manner. All relevant information available in [31].

1.5.1 Features of the Helicoidal Model

The Helicoidal model of the proton, pursuant to the Helical model of the electron, raises as many questions as it answers. The model is not shown to solve many, if any, of the outstanding problems. It simply describes a model that could produce many of the features of the proton as measured. Some of those features are not even quite in agreement with data; for example the radius of all particles are modeled as their Compton wavelengths. In the case of the proton, this produces a number (precisely) one quarter of the measured size. It is odd how exact the ratio of the Compton wavelength of the proton is to the measured radius is, and this feature may invite further speculation. The model as a whole does not address any of the big problems such as dark matter or meson production. Although the construction is shockingly simple, it seems simply to contend that the generally accepted structure of nucleons is not the only way to produce some of their features.

List of Features: Helicoidal Model

- Charged particles consist of a charge orbiting a dynamically fixed point in space
- Major dependence on the Compton wavelength
- Straightforward construction of magnetic dipole moment from the magneton

1.5.2 Assessment of the Helicoidal Model

Unfortunately the helicoidal model offers no insight into anything left mysterious by the standard model. It shows some possible relationships between fundamental constants, but analysis of the models consequences is incomplete. The model itself is extremely brief in its presentation, shown in [31], and therefore seems not much more than refutation of the standard model. The helicoidal model can recreate the features of the proton and the electron from the standard model, but its power ends there.

Unlike the other models, the helicoidal model fully accepts quantum mechanics. This is to its credit, but unfortunately not enough to make the model viable. There are so many piece parts missing from the construction of this model, which relies primarily on the Compton wavelength, that it seems unlikely to ever carry real consequence.

1.6 William Stubbs's Muonic/Beta Model

William L. Stubbs's model is structure oriented. The speculative model is published in Stubbs's book *"Nuclear Alternative"* [71], and again, somewhat modified, in *"Proton Structure"* [72]. He suggests that each nucleon is made up of nine muonic particles; that is muons and antimuons. These are further comprised of positive and negative beta particles, in the proton there is one more positive beta than negative, and in the neutron there are an equal amount. The muon mass is equivalent to 207 beta particle masses. Stubbs proposes that the nuclear muons (and antimuons) consist of several fewer betas than this, and share between them in a mechanism analogous to covalent atomic bonding. He proposes that this is the nature of the strong force, beta particles shared between nucleon constituent muons. He also assumes that electrons are respectively a negative beta orbiting an electron antineutrino, and a positive beta orbiting an electron neutrino.

The distinct advantages of this model are simple; every proposed piece of a nucleon is observed in scattering collisions. There is no confinement principle, and nothing to suggest there are particles which can never be observed. The model was devised with total consideration of experimental results as of 2008. As such it describes most phenomena observed until that point extremely well. Perhaps most importantly, there is no obvious baryon asymmetry in this model. It predicts exactly equal quantities of matter and antimatter in a way such that the existence of antimatter is somewhat hidden. All of this may be found in the books *Nuclear Alternative.*

With the discovery of Higgs Boson in 2012 [29], Stubbs altered his model somewhat, and published his modified theory in *Proton Structure.* Unfortunately, the newer model resorts to data smearing frequently.

1.6.1 Failures of Stubbs's Model

Unfortunately the simple nature of this model does come with a few drawbacks. Covalent atomic bonding is vastly weaker than the strong force requires. To equal that strength, many beta particles would need to be shared, dissociating the substructure of the proton. Moreover, the model was devised during a time before Higgs Boson had been observed, and questions field theories and mechanics alike, which are at this stage shown to be true. Another open question in this model is thus; by what mechanism do neutrinos capture a beta particle to form an electron or positron? Neutrinos are electrically sterile, so none of Stubbs's proposed interactions apply here.

In the updated model, data discrepancies with the model are noted. For instance in single proton *ep* scattering, the structure function F_2 appears to peak around $frac17$, unlike the $frac19$ that Stubbs predicts. He glosses this over in his analysis and relies on the data from deuteron inelastic scattering. Another point that is ignored in this model; what holds the beta particles together to form a muon? Muons are observed in (albeit unstable) isolation, so the sharing mechanism cannot hold one together of its own accord.

1.6.2 Features of Stubbs's Model

The muonic model of nucleon structure shows pathways to solving many of the contemporary problems with particle physics. Confinement and the inability to observe it is entirely discarded; beta particles and muons with antimuons are observed in the aftermath of almost every collision involving at least one hadron. Similarly QCD is ignored because there's no color confinement at play. Fractional charge has no place with beta particles or muons either. In principle this model is elegant because it is constructed from an amalgamation of first principles and explicit experimental results.

Though such has not been examined, an extremely simple formalism would arise from Stubbs's model. There are only a finite number of ways muons can interact with each other, and the same with beta particles. The huge numbers of betas and antibetas in Stubbs's nucleon allow for some more complicated interactions, but it is not proposed that all other hadrons are comprised solely of beta particles. The beta particles often interact with neutrinos and other leptons to form some other particles, but some of the exotic results postulated by the standard model cannot be modeled in this way. Just as well, as those exotic particles largely have yet to be confirmed.

Perhaps the most powerful advantage of this model is the exhibited similarity between the proton model and neutron. In the standard model the similarity is explained by the nature of valence quarks in each; they are of the same generation, one is simply swapped out for another. In Stubbs's model, the neutron simply has one more constituent beta particle. Among nearly 2000 others, the effects of this extra beta are lost in the mass of others, with the exception of neutralizing the extra +e charge.

Due to the simplicity of the derivation for Stubbs's model, many of the more complex facets of the standard model are unexplained therein. The model was originally published in 2008 before the observation and verification of Higgs' Boson, so William Stubbs assumes that it does not exist. This allows him to ignore symmetry and field mechanics, which of course have since been unequivocally shown to have significance. A few years later, in 2015, he published another book *Proton Structure.* This book explicates the same model, but without reference to the Higgs boson (which had been found by then). This somewhat revised model is weaker, because once again some of the foundations of quantum mechanics are left out despite the fact that their necessity has been rigorously shown.

By its construction, Stubbs's model should seem to have good ability to model both positive and negative beta decay, and meson production. While beta decay is formulated reasonably, that is one of the anti/muons in the outer shells of the nucleon loses a positive or negative beta particle, meson production is not discussed. This points directly at all the troubles with Stubbs's model; he has created a reasonable model for just the proton, that does not connect well with the rest of particle physics. As mentioned in section 1.4.1, the mechanism for neutrino capture is not well defined, and no other particle production/pair production effects are discussed. Moreover, the weak interaction, which is critical to any discussion involving neutrinos and beta particles, is not discussed. Overall it seems this model is an earnest attempt to demystify nuclear structure which misses the mark somewhat due to the fact nuclear mysteries may not be separated from every other subatomic effect.

List of Features: Stubbs's Model

- Nucleons composed of 9 anti/muons, which are further composed of 203-5 beta particles
- Strong force analogous to covalent atomic bonding with muons sharing betas
- Electron composed of one beta particle orbiting one electron antineutrino

1.6.3 Assessment of Stubbs's Model

Since Stubbs constructed his model entirely from the examination of particles observed in the aftermath of particle collisions and from observed nuclear effects, the constituent muon model conceptually reproduces much of what we know phenomenologically about proton interactions. The model of muons as an analogy to atoms is simple and easy to understand. The model shows beta decay in an extremely elegant fashion. The main standard model inconsistency handled by Stubbs's model is baryon asymmetry. In the model there is a precisely even number of beta and antibeta particles as the fundamental constituents of everything. The simplicity of this proposal is enticing.

Unfortunately Stubbs's constituent beta model does not have strong enough binding to match the strong force. Covalent bonding is a probabilistic sharing of electrons and so the similar subatomic sharing of beta particles would have a similar strength. Covalent bonding is much weaker even than a pure electromagnetic attraction, let alone the strong interaction. The mechanism for the weak interaction is also somewhat circumspect. Consistently with the strong force model, Stubbs's weak interaction seems to be statistical, a beta particle breaking free from one of the muons inside a nucleon. Stubbs seems to have disregarded most of the known quantum phenomena, like many of the other models presented here. As such, the model provides no insight into the violations of the conservation of charge and parity. It makes no effort to explain dark matter, or the other open problems in physics.

The constituent beta model is elegant in its simplicity, but lacking in predictive power and theoretical support. There is no clear mathematical description of the mechanisms of the model. Quantum mechanics is disregarded. Since the constituent muons are a complete shift in approach from the standard model, based solely on nucleon structure, there do not seem to be easily applicable modifications that bring it closer to a viable theory. Stubbs's model offers some insight into due process however; it helps show that neither theory nor experiment is enough to describe reality alone.

1.7 Ofer and Eliyahu Comay's Orbital Model

Eliyahu Comay and his son Ofer Comay have published their model in the book *"What's inside the Proton: The Invisibly Obvious"* [30]. The book describes a number of issues with the usual standard model formalism and structure. Unlike the other models presented here, Comay's is a fairly casual modification of the standard model. Quarks are accepted as the particles that make up hadrons, though they are assumed to be magnetic monopoles. These monopoles interact magnetically making up the strong interaction, mediated by photons in the same way as electricity. In this model, hard centroids in hadrons are proposed. That is, a dense center that carries some non-negligible fraction of the particle's mass is orbited by other partons/quarks coupled to it by strong interactions. Specifically a central baryonic core, that is a dense center with three units of attractive force carrier, orbited by the three valence quarks. This is analogous to systems under the influence of any other central force such as solar systems and galaxies under gravity, or atoms under electromagnetism. Comay predicts that the outer orbital shells are occupied by anti-quarks, screening some of the nuclear structure's magnetic 'charge.' It seems the purpose of this re-imagining is to obviate some of the apparent arbitrariness of the standard model, most of which stems from QCD.

Due to this model's deterministic similarity to the standard model, the strengths of each are alike. Comay's model has the advantage of looking more familiar; central forces are well known in physics on all scales. There are no gluons in this construction, the strong force gauge bosons are still photons which explains the lack of radiated gluons without color confinement. The presence of antiquarks towards the exterior of a proton comes naturally out of this model.

1.7.1 Comay's Model Weaknesses

A Central force based model is certainly appealing, however Comay has exchanged one type of magical or unobserved particle and interaction for another; magnetic monopoles have never been observed in any context. One experiment at the University of Michigan in 1982 claimed to observe them, but was later shown to be false [30]. Comay also seems to rely heavily on the natural assumptions of the standard model, that is spin orientation, parity, and other symmetries. For example the weak interaction is not even considered by this model, though the hard core construction effects it. As the others, Comays model of orbital substructure offers some insight into the problems of the standard model, but is incomplete.

1.7.2 Features of Comay's Orbital Model

Any system governed by a central potential, for example any star or galactic system or any atom, have some traits in common. The major commonality is a dense core; at the astronomical scale that means a star or a black hole, typically, while at the atomic scale it is a positively charged nucleus. These cores are dense in terms of whichever property is governing the attraction, that is either matter (stars, black holes) or charge (nuclei). Comay's model uses this fact and proposes that the strong force is purely magnetic interactions between monopoles, inducing a densely magnetic hard core with the valence quarks as orbiting magnetic monopoles. This is an elegant idea, especially in analogy with the standard strong force model. Both the standard model and Comay's model propose unobservable particles that strongly interact, but the standard model proposes more particles involved, and does not give a clear mechanism for said strong interactions. Moreover, since electric and magnetic interactions are mediated by photons, the gauge boson for the strong force becomes the photon instead of the unobserved gluon.

The fairly mystical nature of Comay's magnetic monopoles unfortunately limit this model; until it is further developed or magnetic monopoles are observed, it cannot be truly verified. It is strong in that it retains essentially all the features of the standard model, but changes the mechanism of the strong force. By the same token, this makes it weak as the magnetic modifications to the standard model do not appear well supported by either theory or experiment. This central force model similarly provides no insight into the nature of dark matter or dark energy, nor does it attempt to explain baryon asymmetry.

List of Features: Comay's Model

- Strong interaction as a central potential
- Quarks as magnetic monopoles
- Photon as strong force gauge boson
- Baryonic hard core

1.7.3 Assessment of Comay's Model

Comay's orbital model has a distinct advantage in terms of solving the problems the standard model accounts well for. The fairly minor structure modifications are not meant to change much of the theory. Comay was well aware that any new model must explain all extant phenomena the standard model handles, and as such he does not try to break the model entirely. He has proposed a new, explicit mechanism for the strong interaction and strong nuclear force which has classical advantages over the standard model including mathematical elegance. Comay's magnetic monopoles would change the way electromagnetism is understood, and perhaps shed some light on the quantum nature of ferromagnets. Moreover, since this model assumes the strong force to be simple magnetic interactions, the unobserved gluon is replaced by the photon as the gauge boson of the strong interaction. In this way some of the mystery of the standard model is obviated.

The orbital model, by its similarity to the standard model, suffers many of the same faults. There is no simple explanation for dark matter or the baryon asymmetry. Comay's model, like the others, is primarily a new approach to the structure of nucleons. The mechanism for the other fundamental forces are unchanged. In this way, Comay has no quantum explanation for gravity. Like the helicoidal model, Comay's orbital model embraces quantum mechanics and quantum field theory, but makes no effort to advance the understanding of it. Further, he assumes the natural existence of magnetic monopoles, which have never been observed in nature, and in keeping with both classical electromagnetism and QED never will be. This model's modifications on the standard model seem to be purely classical, which by necessity leaves the model incomplete.

If the orbital model could introduce a gauge theory for the strong force that would agree with the standard model's SU(3) scheme, it may offer some real insight into the construction of large hadrons. Since all other forces are assumed to operate under the same mechanism, the strong force is the only relevant change in this model, and it is certainly not fully analyzed.

1.8 Comparative Feature Analysis

	Standard Model	U-Charges	Helicoidal Model	Stubbs's Model	Comay's Model
Strong Force	Color charge/force	Central U-charge bonding	None specified	Covalent bonding	Central magnetic forces
Strong Force Gauge Boson	Gluon	None	None	None	Photon
Structural design	Constituent or Sea Quarks	Mutually orbiting u-charges	Charges orbit dynamically fixed points	Muons interact like atoms	Classical central force orbit
Motivation	Phenomenological	Explain dark matter, nuclear phenomena	Unknown	Unspecified	Unspecified
Take away	Quantum physics, predictive power	Simple formalism, first principles	Simple construction	First principles, self similarity	Familiarity
Missing	Gravity explanation, simple formalism	Gravity, weak interaction, most subatomic particles	Predictive power (and any formalism at all)	Well defined force quantities	Observable/quantifiable particles

In review of the above models, it is clear that no complete model exists. This gives strong insight into why various scientists and engineers feel the need to propose new models for both particle physics writ large and the structure of nucleons. Unfortunately none of the models proposed above have achieved the clout of the standard model, in part because they are much younger, but certainly also because they disregard the successes of the standard model. An approach to sharing the discontent of these authors in a more readily legible and acceptable way may be to propose some modifications to, but not the replacement of the standard model.

While some of the models here, namely Consa's helicoidal model and Stubbs's beta/muon model are essentially complete rethinks of nucleon structure, both the u-charge model and Comay's orbital model propose one thing that seems to be lacking from the standard model: a specific force vector. While

Comay's magnetic monopoles seem unrealistic, the model of a central force governed nucleon is attractive. Since both gravity and electroweak forces operate in a central fashion, it seems natural the strong force would as well. John Preston's u-charge model does this as well, though lacking some of the classical elements of a central force. The u-charge bond model of the strong force has the correct strength at the one femtometer scale, and it is a strong contender for a force law, however the model is less than complete; it is rather analogous to Bohrs hydrogen atom a step in the right direction, but probabilistic distributions and the realities of quantum mechanics and structures have not been applied to the model yet. In contrast, Comay's magnetic monopoles read like science fiction, but the classic mechanical construction of orbits around a hard centroid is consistent.

William Stubbs's model of valence sharing cannot be strong enough to account for strong interactions, but his very specific ideas about the number and nature of particles inside a nucleon may have some value. His analysis is based entirely on the point values of structure functions, which lends weight to the ideas. It seems possible that point-like beta particles do exist inside nucleons, though it seems unlikely that they make up the entire mass of them as Stubbs proposes. While there does not appear to be strict evidence to the contrary, if nucleons were entirely made up of beta particles, I would expect to see more of the resultants from accelerator experiments decaying into betas. His book *Proton Structure* often uses logical fallacies such as appeals to ignorance to show its points, which indicates a less than complete knowledge of the standard model and its successes.

Oliver Consa's helicoidal model, in spite of its display of a good understanding of contemporary quantum physics, is to be largely baseless. The relationship between the radius, mass, and Compton wavelength of nucleons that is shown in the paper [31] deserves further inspection, and may give rise to some unknown symmetries. Nevertheless, the model does not handle hadrons at large or decay of any sort, and therefore does not warrant recognition as a complete formalism.

To conclude this feature-wise analysis, an explicit central force analogous to electromagnetism at the atomic scale may be a useful tool for particle analysis. The u—charge model as well as Comay's magnetic monopoles are consistent enough to warrant further study of a central strong force. It is proposed that protons and neutrons be studied as different bound states of quarks (whatever their nature, the word here is used to indicate elementary particles subject to strong interactions) and beta particles under a central force analogous to but perhaps not precisely that proposed by John Preston. A set of finite energy configurations and distribution probabilities may be constructed, and used to analyze nuclear structure. Of course this will need to be constructed considering experimental data, namely structure functions, as well as fit to the successful elements of theory like gauge groups and spontaneous symmetry breaking. A more complete model of particle physics, and even of cosmology, may be very close indeed.

Chapter 2

Cosmology

2.1 Introduction and Historical Notes

Even more hotly contested than the standard model of particle physics today is the standard model of cosmology: big bang cosmology. The term “big bang” was coined in 1949 by Fred Hoyle, who at the time was a proponent of the ’Steady State Universe.’ In the 1950s and 1960s in fact, support for big bang cosmology and steady state cosmology was almost evenly split [9]. Big bang cosmology eventually became prevalent as it explained the abundancy of hydrogen and helium in the observable universe, as well as the prevalence of quasi-stellar (QSOs or quasars) objects at large distances.

Big bang cosmology continued to gain traction through the ’60s, ’70s, and ’80s, in spite of numerous challenges. In 1964 the observation of cosmic microwave background radiation as predicted by big bang cosmology ended most support for the steady state universe theory [9]. Though it has certainly gone through several periods of reform, big bang cosmology is currently regarded as the strongest and simplest model of universal evolution.

One of the major stumbling blocks of big bang cosmology for physicists and astronomers studying the evolution of the universe was the classical singularity: a hot dense infinity containing all the matter and energy in the observable universe within a single zero-dimensional point. In the late 1960s however, it was discovered or noted (which is unclear) that the singularity which seems to be physically paradoxical is nonetheless consistent with Einstein’s general relativity. This spelled the acceptance of big bang cosmology as the standard model for universal evolution.

In spite of its successes, the big bang model of standard cosmology has some deficits and unexplained phenomena. These will be explored in the following sections, along with alternate models and concepts that attempt to explain them. Many other schemes of evolution, and some steady state universe models have been proposed. These theories also suffer from some failings and unexplained mysteries, but they are very different from those of the big bang theory.

There are many and varied models to address the issues with standard cosmology. One of these issues is well defined under the big bang theory, but in a physically (though not mathematically) complex way; that is redshifts. The current standard explanation of Doppler boosted spectra works, though many argue that it doesn't pass Occam's Razor [23]. There are many other attempts to explain the redshift of spectra from distant stars and galaxies, some of which are quantitatively convincing. There is a large scale explication of these other possibilities, fifty two of them in fact, in reference [13]. There are many other kinds of propositions as well. An ocean of theories of everything, from string theories to faster than light particles have been proposed. The latter will be examined in the next chapter, but may provide insights into the evolution of the cosmos, for example many mysteries are potentially resolved in [28].

2.2 Big Bang Cosmology

During the last century, the advancement of physics at experimental scales has led to a pervasive model of universal evolution: the Big Bang Theory. It posits that about 13.8 billion years ago, the universe was a hot dense singularity that underwent a period of inflation and baryogenesis, followed by nucleosynthesis and more mundane expansion. In these early epochs, symmetries of the four fundamental forces; that is gravitation, electromagnetism, and the strong and weak interactions, broke and the forces separated from one fundamental force into those four. The expansion of the universe in the Big Bang model was slowed by the gravitational attraction of all matter to all other matter until at some point the average baryonic matter density was low enough for expansion to begin accelerating again, leading to the current state of a universe that is expanding in an accelerating fashion. The model describes many of the features of the observed universe very accurately, but some of the constraints of the Big Bang theory seem arbitrary or unrealistic.

The inflationary period of the big bang theory started when the universe was about $10^{-37}s$ old [1]. This period of evolution is highly speculative, as the energies involved in this inflation are not reproduceable in today's particle accelerators [1]. When time had progressed to about $10^{-11}s$ the picture of what could happen becomes a bit clearer; by that point the universe had in theory cooled to a level at which the particle and energy interactions can be reproduced in current experiments. While still theoretical, after this period physicists can match expected interactions with current high energy physics (HEP) theory and produce models of the early universe.

The strongest evidence for Big Bang Cosmology was discovered by astronomers Arno Penzias and Robert Wilson in 1964; the observation of the cosmic microwave background (CMB). The CMB is nearly uniform black body radiation that permeates the universe in all directions. This lends credibility to the theoretical recombination epoch, shortly after the inflation period, when electrically neutral atoms began to form and could no longer readily absorb thermal radiation [4]. At this point, the thermal radiation within the cloud of electrically neutral atoms created a dense, nearly isotropic, homogeneous, opaque fog, that slowly cleared as the universe expanded further. The photons radiated from this fog make up what we know today as the Cosmic Microwave Background [4]. While some other models of cosmology can show that this uniform CMB may be produced by other effects, none has adequately explained fluctuations in the CMB with the precision of the big bang theory [4].

Another argument for this theory is its explanation of redshift. Doppler shifted spectra from distant stars and galaxies are readily measured consistently with Hubble's principle of an expanding universe. That is, the further away a star or galaxy is, the more its atomic spectrum is shifted from expected values for stars and QSOs. According to the theory, Universal expansion is accelerating, So it is expected that redshift will increase.

Perhaps of greatest importance to both theorists and experimentalists alike is that Big Bang Cosmology adheres exactly to current theoretical predictions and experimental observations. The theory is built largely from the tenets of Einstein's general relativity, and the early epochs reflect the usual understanding of particle physics from the standard model of elementary-particle physics. In the same vein, these are reasons the model does not face many challenges as of 2017.

2.2.1 Big Bang Faults

In spite of its many and far reaching successes, the pieces of the Big Bang model that are not well explained or understood are critical indeed. For example dark energy, or energy that does not interact electromagnetically (i.e., visibly), is postulated to make up about 70% of the energy in the universe [1]. Of course since dark energy cannot interact with light, it can only be detected indirectly. In fact, the very reason for the existence of dark energy is the observed accelerated expansion of the universe [6]. The dark energy mystery is usually discussed in terms of the cosmological constant, which is (depending on one's source) between 40 and 100 orders of magnitude larger than expected for an energy free vacuum. The observed gravitationally interacting matter content of the universe seems to indicate space-time should have curvature, but the universe has observationally flat geometry. Evidence for dark energy comes from three separate phenomenological and theoretical sources. The first is that redshift measurements and cosmic microwave background measurements indicate that a threshold was surpassed around half the lifetime of the universe ago, at which point the expansion of the universe began accelerating. The second indicator of dark energy is that theory requires another energy source to allow the flat geometry of the observed universe. Thirdly the existence of dark matter may be inferred by measures of large-scale wave patterns of mass density. These examples may be referenced at [6].

Another mystery is the similarly named but very different dark matter. Like dark energy, dark matter cannot interact via electromagnetism [7]. As such it it similarly only inferred, not directly observed. Dark matter plays a strong role in every current model of celestial mechanics. Without it, the observed rotation of galactic structures and also gravitational lensing would (at least in theory) operate very differently than they are observed to. That is, unless there is about five times more mass than is observable in galactic structures [7], gravity is misunderstood at scales larger than the solar system. That is to say general relativity and Kepler's laws are precisely accurate at the scale of the solar system, but without dark matter they flunk at the galactic scale and larger [7]. Despite its very probable (though not guaranteed, like anything else unobserved) existence, the precise nature of dark matter remains elusive. The problem of dark energy and matter and their relationship to the universal geometry is known collectively as the horizon problem [61].

One other intricacy of big bang cosmology is mentioned above; that is the existence and specifics of the inflationary period. Theory predicts that the four fundamental forces were united in a single grand force at that energy level, though no theorist has been able to produce a successful model of grand unification. The energies presumed to be present in this period were so high that no device available to researchers can reproduce them, and so the exact structures and effects during this epoch remain frustratingly mysterious and unknown. It is assumed that during this epoch, physics as currently observed was irrelevant. In the typical models of inflation, particles move far faster than c, and space did not obey general relativity[61]. Furthermore, the very concept of inflation was posited to explain the observed isotropy of the visible universe [24]. Given the more recent findings of anisotropies in the CMB, this becomes more questionable. Perhaps the instruments are more sensitive, but perhaps inflation is not the magic bullet it is imagined and hoped to be.

One more major problem with the big bang model of the creation of the universe is the lack of naturally occurring magnetic monopoles. The high energies of the inflationary period in theory should have produced particles with a permanent induced current and subsequently a magnetic monopole, in fact some say there should be more magnetic monopolar particles in the observed universe than normal baryonic matter [61]. No such particle has been observed.

2.3 Plasma Cosmology

One of the more prevalent cosmological models in opposition to big bang theory is the electric plasma universe. This theory posits that electromagnetic forces played as strong a role in the formation of galactic and supergalactic structures as did gravity. Specifically, Birkeland currents merging and warping the space around them. Birkeland currents are tendrils or filaments of plasma; uniformly charged particles in a line current creating a cylindrical magnetic field, and subsequently more charged particles in a cyclotronic current in the magnetic fields. It was postulated by Anthony Perratt that galaxies are formed by the joining of the Birkeland currents in a z-pinch, or a compression of the plasma by its own magnetic field at the joining of the two currents [15].

Perratt reports simulations that seem to reproduce the jets of quasars and active galactic nuclei without the need for a central supermassive black hole [15]. This of course indicates a fault with the theory; at the time of its conception by Hannes Alfvén and Oskar Klein and later during Anthony Perratt's tenure as an ardent of the theory, gravitational waves indicating the existence of supermassive black holes hiding in radio loud galactic centers had not yet been observed [15]. Since their detection in 2015 and 2016, there are not as many articles arguing for plasma cosmology in circulation.

In spite of the galactic nucleus mishap, Plasma cosmology has many strong points. It argues that baryon asymmetry arises in pockets of space, or 'metagalaxies.' That is the observable universe in plasma cosmology may be just a pocket of a much larger universe, separated from the other pockets by a double layer of plasma [15]. It is posited the Birkeland currents form along these double layers, and stretch over light years to meet and create galaxies and clusters of galaxies. The theory explains the seemingly accelerated expansion of the universe as observed by non-linearly increasing redshift as having an intrinsic component due to the cosmic plasmas [3]. In a plasma universe, there appears to be no need for dark matter as galactic orbits have the correct dynamics under electromagnetism [18]. Proponents of plasma cosmology also argue that the distant galaxies we observe; that is those at very high redshift, cannot have had time to form between the big bang and the time they're observed due to the redshift [18]. It is similarly claimed that the anisotropies in the cosmic microwave background may be accounted for by very old plasma vortices, while the fairly constant black body spectrum may be due to plasma filaments as observed in laboratory experiments, scaled up [18]. Plasma cosmology also tends to refute the expansion of the universe, citing the surface brightness problem [11].

2.4 Redshift Mechanisms

Many authors over the last century have presented many mechanisms by which the shifting of frequency of light from distant stellar objects may be produced. Fifty two of them are presented in Louis Marmet's paper, "On the Interpretation of Redshifts: A Quantitative Comparison of Red-Shift Mechanisms II" [13]. In this section a few of those named in the paper are examined for consistency and agreement with data.

2.4.1 Time Dependent Distances

The standard model of cosmology fits into this class of redshift mechanisms. The theories generally posit that the distance from any arbitrary point A to point B in the universe elongates over time. This effect produces a Doppler shift in light, as it travels relative to the expansion of the universe. For most of these positions to be accurate, expansion of the universe needs to be faster than the speed of light. The more naive of these theories do not account for gravitational effects such as lensing by galaxy clusters, or the independent motion of galaxies. No theories of this type account for electromagnetic effects.

All theories of this type listed in [13] are mainly modifications of or addenda to the general theory of relativity. Many are specifically formulated as not to produce the infinities seen in general relativity, such as black holes. This very fact eliminates many of them, as black holes and supermassive black holes are now known to be commonplace in the universe. The original theory is in fact self consistent. Since big bang cosmology is a product of general relativity and observed data, it is also consistent in spite of its stated problems.

2.4.2 Time Dependent Properties of Light and Interactions of Light with Itself

There are a large number of theories of this type, twenty of them are listed in [13]. Several of the more popular theories are described and analyzed below. These theories at large suffer from a high number of *ad hoc* hypotheses.

Tired Light

Tired light theories, of which there are many that share a common structure, posit generally that redshift is caused by the interaction of light with the interstellar and intergalactic medium rather than an expanding universe. The best known and often cited explication of this is certainly given by Lyndon Ashmore in his book *"Big Bang Blasted"* [23]. The book shows that Hubble's constant may be related to Planck's constant and some properties of the electron, specifically its radius and rest mass by the relationship

$$H = \frac{hr}{m} \tag{2.4.1}$$

where

- H is Hubble's constant,
- h is Planck's constant,
- r is the radius of the electron,
- and m is the rest mass of the electron.

Ashmore uses this relationship to posit that photons traveling from distant stars and galaxies interact with electrons in free space, thereby losing energy and elongating in wavelength. He further shows that the cosmic microwave background may be a result of these free electrons radiating the energy gained from photonic interactions. Ashmore shows great courage in his refutation of every piece of the big bang theory, yet does so somewhat naively. Ashmore does not consider many elements of elementary-particle physics that must play a role in these interactions. The greatest theoretical failing of Ashmore's tired light theory is similar to many other failed theories in the recent past; classical Tired Light assumes the nonexistence of the Higgs field and particle. Ashmore uses this to justify ignoring many of the quantum mechanical and gauge theoretical formulations necessary to produce a strong picture of the physics of the universe. Moreover, Ashmore's book is written in non-scientific language, which ensures that many easily choose not to take it seriously, although it offers some interesting perspective.

A more recent theory of tired light has recently been proposed by Mikko Partanen, Teppo Häyrynen, Jani Oskanen, and Juska Tulkki in their paper "Photon Mass Drag and the Momentum of Light in a Medium" [59]. In this paper they rigorously show that electromagnetic waves propagating through any medium changes the mass density distribution in the medium according to photon momentum [59]. They develop a mass polariton, or bound state of a photon with a massive particle, and show that it can accurately reproduce continuum dynamics of light. The paper seems to resolve the Abraham-Minkowski dilemma with respect to the momentum of light [59]. This theory does not so fervently deny big bang cosmology as does Ashmore, but shows some interesting ways in which it may be altered to do away with phenomena like accelerating expansion.

Yet another 'Tired Light' theory looks much like Ashmore's original proposition, but with the addition of Heisenberg's uncertainty principle. In this theory, presented as section 6.4 in [13], photons lose energy to the vacuum due to quantum mechanical effects. This purports to explain the vacuum temperature of $2.7°K$ and produces an "apparent acceleration" of the expansion of the universe with a value of $7.9 \times 10^{-27} m^{-1}$ redshift factor, derived from an energy derivative. The agreement of this with current cosmological theory is unclear, as it posits a static universe, which requires that the value defines the distances to stellar objects. This theory has weaknesses other than this seeming circularity. The quantum mechanical vacuum effects would seem to create massive anisotropies in the CMB, dependent on proximity to a photon source. The anisotropies are not observed at such a scale.

As a rule, Tired Light theories do not address celestial mechanics. For example none attempts to explain dark matter and the inability to observe it. This is a problem, as the concept of dark matter has nothing to do with the expansion of the universe, but rather the rotation and clustering of galaxies. Ashmore and others do not to propose a mechanism by which this arises in a static universe. Unless further developed therefore, elements of the tired light theories may be considered but the overarching theories do not agree entirely with observations.

Tired Light theories may also have their caskets sealed by one final tidbit - they are specifically inconsistent with the general theory of relativity. The invariance of physical laws between accelerating frames described by Einstein's theory requires an expanding universe. The theory does not *a priori* require expansion to be accelerating, but it precludes a steady state universe.

2.4.3 Varying Speed of Light Theories

Theories that postulate the speed of light is inconstant tend to elicit knee-jerk rejection from many physicists (myself certainly included). On the face of the suggestion, it seems that special relativity and general relativity to a lesser degree must fall apart in a universe with an inconstant speed of light. In fact many theories, including hard Lorentz symmetry breaking and others do indeed dismantle the formalism of special relativity and for this reason are dismissed.

A common aspect to many varying speed of light theories is a preferred reference frame for the universe, which disagrees with relativity writ large. In spite of the seeming impossibility of a varying c, the horizon problem of big bang cosmology indicates that a changing speed of light may be an appropriate model to produce the observed anisotropies in the CMB. Specifically, the comoving horizon or furthest observable distance in the universe has (according to reference [52])

$$r_h = \frac{c}{\dot{a}} \tag{2.4.2}$$

which has a solution that requires

$$\frac{\ddot{a}}{\dot{a}} - \frac{\dot{c}}{c} > 0 \tag{2.4.3}$$

where

- r_h is the radius of the universe's horizon
- a is the volume of the universe,
- and c is the speed of light.

According to this solution, the horizon problem requires that for the universe to be causally connected the expansion of the universe must be accelerating or the speed of light must be decreasing or some combination of those two effects. Considering this with one formulation of the speed of light,

$$c = \frac{1}{4\pi\epsilon_0}\frac{e^2}{\hbar\alpha} \tag{2.4.4}$$

and knowing that the fine structure constant α changes a small amount over time [52] it is perhaps more likely that c change a small amount in time than $\epsilon_0, \hbar$, and the charge on the electron all also change in time to preserve the constancy of the speed of light. This is a possibility that deserves more serious investigation, but all potential issues and schema are not yet clear.

2.5 Cosmological Analysis

More than particle physics, the standard big bang model of cosmology lends itself well to small modifications in areas not well understood. Some elements of plasma cosmology and theories of tired light may be adapted to fit it, providing potential solutions to the questions left unanswered. Varying speed of light theories tend not to contradict much in big bang cosmology. While rigorous mathematical analysis will not be presented here, it is suggested that be undertaken. Some pieces of various theories that may come together nicely are presented in this section.

As mentioned in the section above about tired light, the theory of photons coupling with matter in media [59], including the interstellar medium, is shown rigorously. While this theory does not rule out (or even attempt to) the expansion of space, it could explain the observation of accelerating expansion. In a universe which expands but does not do so at an accelerating rate, the need for dark energy is much reduced if not obviated, which could end one very serious argument within standard cosmology.

Another useful tool may be the consideration of electromagnetics in the dynamics of galaxies. While much of plasma cosmology seems far fetched, particularly in the era of LIGO, electromagnetic forces are not typically cited with respect to the motion of astronomical bodies. If plasma dynamics within galaxies can produce observed motion, as claimed by Perratt [11], the need for dark matter in models of the universe may also be removed.

Unfortunately due to the specific and as yet untestable nature of any inflation theory as opposed to any other 'origin story' there do not seem to be easy ways to resolve this mystery. More analysis of data from the ESA's Planck satellite may shed more light on this in years to come.

Many of the other alternate cosmological models, even some cogent ones, have not been considered here. Some are to come in the next chapter, but many others neglect to include key considerations like consistency with particle physics. For example, Gödel's theory of a rotating universe agrees well with the universe having a preferred handedness, as it appears to [50]. The scope of this report does not include rigorous mathematical analysis, which reduces the number specific theories to be considered as well.

Chapter 3

Faster than Light Physics: Theory and Consequence

Since the development of special relativity, the speed of light, c, has been taken as an absolute physical speed limit. There are some notable exceptions to this limit, being quantum entanglement which happens much faster than the speed of light, propagation phase velocity of electromagnetic waves in a plasma medium [44, 74], and virtual particle interactions [19]. Measurements currently indicate a speed of at least $10^4 c$ for quantum entanglement [79]. It is accepted that no massive particle or other object may travel faster than the speed of light, and similarly that no transfer of energy in the form of a signal may propagate faster than light.

The causal ordering postulate (COP) of general and special relativity is the enforcer of signal speed. In keeping with the entropic arrow of time, the COP simply states that no effect may occur before its cause. While generally accepted as a necessary addendum to relativity, the COP lacks rigorous grounding. It is primarily upheld by the second law of thermodynamics [74] which may be violated probabilistically at small metrics. In fact, though the probability of violation decreases with scale, there seems to be nothing to say that under exactly the right conditions the law of entropic increase may not be violated at any scale at all. Armed with this information, many have staggered forth to find evidence of the oft mentioned and typically dismissed tachyon.

3.1 Quantum Non-Locality

One of the great mysteries of physics writ large and more specifically quantum theory is entanglement. A direct result of both the Schwarzchild spherically symmetric solutions to Einstein's field equations [35] and the wave function formalism of quantum mechanics, quantum entanglement or spooky action at a distance appears to be a faster than light communication of the state at which a particle decoheres.

Some time after the advent of quantum theory and mechanics, it was shown anything quantum in nature is quintessentially non-local [25]. This is no less than confounding. The human experience with a macroscopic space defines interactions as extremely local as described by elementary physics and relativity. Nonetheless, experiments show that events may be connected over a space-like interval [79] though whether the connection is causal or not is debatable. It appears that most physicists in the field of relativity dismiss the reversal of causality somewhat arbitrarily — "an effect may not be observed before its cause" is a very powerful argument. Some physicists, including Moses Fayngold among others [37], posit that causality is a construct, and may be simply reversed within a superluminal framework.

Questions raised by quantum non-locality range from practical and perhaps applicable such as "is faster than light communication or travel possible" to the more theoretical in nature, "in what ways has the geometry of space-time been affected by nonlocal effects [64]?" Answers to these questions, if they exist at all, are few and far between.

3.2 Causality and the Speed of Light

The most immediate stumbling block for any theory of superluminal (i.e., faster than light) anything is the causality of relativity, the aforementioned COP. In special relativity, travel at speeds faster than light is equated with travel backwards along the arrow of time. Since every dilatory (and contractive) effect predicted by special relativity for sublight velocities has been observed and confirmed, it is likely this is true [44, 74, 53]. In fact the relativity of simultaneity tends to ignore causal interactions, as they could not possibly happen simultaneously. Quantum entanglement and virtual particles refute this generally, but it is not understood how. What is meant by refutation here is that quantum entanglement has been measured on space-like intervals [79], and virtual particles in theory have no velocity constraints [19].

Notably, neither quantum entanglement nor virtual particles seem to constitute a signal. The importance of this only relates to the practicable applications of faster than light phenomena; currently no mechanism exists to propel energy or information with quantum entanglement or the use of virtual bosons. It seems likely that a way to communicate or travel faster than light may only be realized if the cause and mechanic details of the extant superluminal phenomena is uncovered.

One theory that violates this causality postulate is that every anti-particle is just its particle partner moving backwards in time to produce the inverse relationship. This theory was held near and dear by some of the great physicists of the 20^{th} century, Including Richard Feynman [38]. Feynman's acceptance of this scheme for time-reversed particles seems almost casual. Unfortunately logic does not allow us to give credence to an argument on the basis of others who accept it.

3.3 Tachyons: How Could They Be?

One possible explanation for quantum connections vis-a-vis entanglement and virtuality is a type of particle that exists only in superluminal space — the tachyon. These particles may have any number of exotic properties depending on which theories one reads, for example [28, 44, 74, 53] among others. These properties range from warping space-time [28] to inducing retrocausality [44, 74]. Though the existence of such a particle is at this time purely hypothetical, different proposed mechanisms and limitations for their behavior purport to explain any number of faster than light phenomena. These will be investigated in this section.

In Ya. P. Terletskii's book, *"Paradoxes In the Theory of Relativity"* published in 1968 [74], he describes a number of the usual paradoxes that come directly out of special relativity, for example the twin paradox (or clock paradox as Terletskii puts it), quantum entanglement, the meaning of a four dimensional velocity and others. The four dimensional velocity (or momentum, usually) is a concept currently used often in high energy physics - the three pieces of spacial momentum or velocity and one piece of energy, as all are necessary to predict the dynamics of a particle collision, etc. Terletskii then proceeds to develop his scheme of particles with negative mass, also particles with imaginary mass. He claims that a particle with imaginary mass is constrained differently than one with real (either positive or negative) and must always be traveling faster than the speed of light, yet be subject to a subluminal quantum wave function. While Terletskii seems utterly unconcerned with practical applications of superluminal physics, he develops a formalism by which to prove their existence. He manages to link negative and imaginary masses such that if negative masses exist, so must imaginary masses. He claims that if a system can be developed and held in thermal equilibrium with nonzero energy, then a particle stealing energy from the system as opposed to the usual happenstance of losing energy, then that particle must have negative mass. This scheme may have merit - it is difficult to show rigorously.

Similar to Terletskii, Nick Herbert does not propose much in the way of applicable tachyon physics [44]. He examines the variously extant superluminal phenomena in his book *"Faster Than Light: Superluminal Loopholes in Physics"* [44]. By no means does the lack of clear application mean the book is not useful - it shows specifically a number of the ways in which Einstein's field equations permit faster than light particles, as well as examining the waveforms and structures that exceed c. It is a valuable read for any who aim to develop superluminal physics further. Nick Herbert explicates many "loopholes" in physics that allow some phenomena to travel faster than light, and one or several of these loopholes may hold the key to understanding superluminal effects.

Jason Cole's paper on tachyons and their relative mechanics is mostly tailored towards cosmological effects [28]. He develops a hyperbolic particle geometry and further a way for said hyperbolic particles to bind together to form faster than light atom-like particles. Like Terletskii, Cole presents tachyons as physical objects with imaginary mass. Unlike any others, he posits that they exist in a 'universe' that is orthogonal to and entangled with the observable one. Cole claims that the effects of this entanglement obviate the need for dark matter and dark energy, and proceeds to show that in his model, accelerating expansion and galactic dynamics follow rigorously from tachyons. One of the more important assertions of Cole's model is that he limits the speed of tachyons at $2c$.

By far the most rigorous explication of tachyons is given by Moses Fayngold in chapter eight of his book *"Special Relativity and Motions Faster the Light"* [37]. He, like Terletskii, demonstrates the consistency of faster than light objects with special relativity. In so doing, he also demonstrates that any relative velocity *between tachyons* must be subluminal, which corroborates Terletskii's notion that faster than light particles have subluminal wave functions, particularly once the fact that all motion must be measured in a relative frame is considered. Fayngold further develops an elegant geometry consistent with relativity and quantum mechanics. In this geometry, tachyons behave in a way analogous to subliminal particles with respect to relativistic dimension dilation: that is the slower the tachyon (i.e., the closer to c) the more dilated it is in its direction of motion. In fact, Fayngold's model is so convincing that one finds oneself believing in superluminality almost by rote. He also develops an experiment to reproduce his tachyonic geometry, but unfortunately (and classically speaking, strictly necessarily) he also shows that this "lab developed tachyon" and in analogy any real tachyon may not carry any signal, totally precluding superluminal communication.

What Terletskii, Herbert, Cole, and Fayngold have done is show that regardless of bias, faster than light particles deserve more attention. While the physics community mainly regards them as nothing more than science fiction, the equations of relativity and the known laws of physics do not entirely preclude their existence. Faster than light particles could have any number of unknown and unpredicted consequences for everything from the evolution of the universe to the strong nuclear force.

3.3.1 Notes and Interpretation

There seem to be too many physical actions which occur at a velocity higher than light for them all to be coincidence. As such, it seems reasonable to investigate the existence of a superluminal particle or different sort of mass as proposed by the above authors. In particular, virtual particles and quantum entanglement seem to be inextricably linked through "instantaneous" phenomena. In fact, quantum entanglement seems to occur often between particles created through pair production, indicating some level of virtuality. While it is true that the longer a virtual particle exists the less virtual it is considered to be, between production and interaction the usual quantum formalism seems to indicate that they remain virtual.

Beyond the various superluminal quantum and classical processes, special relativity quite clearly does not forbid a faster than light particle; theory merely places strange constraints on such. All of the hypothetical constructions of tachyons rely on a similar imaginary mass concept that is a direct product of the Lorentz transformations. Different authors have developed this in varying degrees according to a few different schema, but all remain firmly grounded in relativistic mechanics. So much work independently arriving at similar conclusions is strong reason for further investigation.

The idea of generalized superluminal objects seems far reaching and *ad hoc* to me. There are few phenomena to indicate that any type of independent particle moves faster than c. Phase velocity, as an observed phenomenon, does not violate c as no object or signal is moving faster than light, merely the internal structure. In analogy, this may be thought of as the motion of a quasi-rigid body - the different frequency parts of the overall wave "push" the others out of the way at seemingly superluminal speed, but the aggregate effect of this does not propagate faster than light. Similarly, while virtual particles are not constrained by the lightspeed limit, by definition they are never observed. Since virtual particles are an artifact of computation and unobservable, worrying about the speed of their motion seems almost arrogant. Quantum entanglement is the one true effect that *observably* occurs faster than the speed of light, and it happens instantaneously. This would seem to indicate a principle of simultaneity, rather than a tachyon. Speculation thereupon follows in chapter four.

Chapter 4

Musings and Speculation

In the final chapter of this report, some insight is developed into the outstanding problems in physics. Particularly with respect to the problems mentioned in the introduction, some various thoughts about physics are noted. All thoughts in this chapter are just that - thoughts not meant as an explication of new theories. In that some are mentioned, it is hoped that in following years they may be further developed and conclusively proven or disproven.

Some ideas about the laws and structures that govern fundamental physics are discussed, then applied to some of the problems mentioned. Cosmology is largely not addressed. I do not have a great deal of experience interpreting astronomical data, and therefore the ideas as they pertain to fundamental physics may affect cosmology in ways not yet derived or understood.

Similarly, some of the currently extant "Theories of Everything" are examined and analyzed. Few conclusions are drawn about these "Theories of Everything" because they are necessarily incompletely justified.

4.1 Physical Reality

4.1.1 Thoughts

In reading and analyzing as much material relevant to the above as possible, some recurring themes and ideas have jumped out. In a similar fashion, some connections between those dots laid out in earlier sections of this paper appear natural and if not obvious then derivative. I hope that the ideas presented here merit further study.

The first notion that seems consistent with observed particle physics and cosmology is a simple one; that dimensions may be interpreted as fields or interactions with such, and moreover the converse. That is to say that quantized qualities such as charge, angular momentum, mass (already specified in the Higgs mechanism as a field interaction), color charge, isotopic spin, etc. may be interpreted in a fashion analogous to the three observed dimensions of space and the temporal dimension. Likewise, there may be some value in interpreting qualities such as position, size, age, and temporal position, as products of a field interaction.

Unfortunately this idea introduces some philosophically jarring notions. If time and one's position in it is a product of field interactions, does the universe have a beginning? Why is "the flow of time" experienced? Some argue that the arrow of time is a consequence of the entanglement phenomenon [78], though with the notion of a temporal field it seems they could have the same cause instead of being causally related. That is, perhaps the flow of time is a result of continuous coupling to a field, while observed entanglement phenomena could be a discontinuous coupling - that is to say the entangled objects decouple and simultaneously recouple to the field. This may explain why "toy universes" of quantumly entangled particles appear to have internal time evolution.

Analogously, representing spatial dimensions as fields may be consistent with both relativistic and quantum principles. For example if mass coupling with space affects the space itself, the curvature of space-time central to general relativity may result. Dimensionality as a field may also eliminate the need for dark matter due to variable coupling, though this is even more purely speculative than the rest of this section. Following this train of thought, small variations in coupling to any fields could in theory produce the observed small anisotropy of the universe. Thus a field interpretation of space-time has interesting consequences for cosmology as well.

Non-locality

Quantum entanglement is the only isolated physical phenomenon that has been measured at a speed faster than c. Since the speed of entanglement is measured at 10^4c [79], I will assume the massive but finite speed measurement is an artifact of detectors, and therefore assume that the true speed of the quantum connection is infinite. For this to be true, it must be true in all relative frames of reference. That is the particles become polarized, or their wave functions collapse, or whichever effect is observed simultaneously in every reference frame. In this way, the causal ordering postulate does not interfere with the speed of entanglement.

Armed with the "knowledge" that the quantum connection is instantaneous, I make another (granted, *ad hoc*) assumption and work backwards.

Let us assume that the "quantum connection" is an *object*. With reference to time as a field, above, perhaps the object is an excitation of the temporal field. Given that the connection happens at infinite speed, I posit that this *object* has speed v such that

$$v = \infty \tag{4.1.1}$$

Following this train of thought, the Lorentz factor, which determines the extension and contraction of the properties of an object under a change in velocity, has the form:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{\infty^2}{c^2}}} = \frac{1}{\sqrt{1-\infty}} = \frac{1}{\sqrt{-\infty}} = \frac{1}{\infty i} = -0i \tag{4.1.2}$$

That is, viewed from the quantum entangled particle "sending" the connective *object* said object will be length dilated by a factor of ∞ and appear to stretch all the way to the "receiving" particle. In contrast, viewed from the "receiving" particle, the connective *object* will be Lorentz contracted to a size of exactly 0 in the longitudinal direction, and be *in the identically same place as the receiving particle* at all times.

Now we seem to have a paradox of reference frames. In the first, there seems to be a "signal path." In the second, the signal appears to be immediately and exactly present. The resolution of this is fairly simple: since in truth neither particle is actually "sending" or "receiving" a signal, as shown by [67]. In fact, there does not seem to be a causal relationship - both particles decohere the same way simultaneously. If we then consider the reference frames above, we realize that both particles must "see" both a full length connection between the two separated particles and a 0 length connection.

How could this be? How could both particles see both a long connection and no connection whatsoever? It seems that only way for this to happen is for both particles to *share a rest frame.* In other words, they must be identically the same particle, or perhaps anti-particles. Now we see that the supposition of an object to relay the quantum connection is obviated!

A particle and its anti-particle being identically the same does not cause a problem. Following Feynman's reasoning [38], an antiparticle may simply be the particle moving backwards in time. Certainly when time is not a considered metric (which is reasonable by noting that the time contraction/dilation due to special relativistic effects in this model implies that exactly no time at all passes) any property that depends on time to be realized (e.g. spin, charge, etc) may be safely ignored.

4.1.2 Theories of Everything

The quest for great universal understanding is a long and winding one — many notorious scientists have reached the end of their working life searching for it. A theory of everything should in principle reconcile the elegance of relativity with the uncertainty of quantum mechanics, explain the fundamental constants of nature, and mayhaps explicate some yet undiscovered or unobserved phenomenon. The last consideration is a requirement for a *successful* theory because no amount of mathematical elegance justifies a theory without predictive power.

Currently relevant theories of everything tend to begin with a postulate that produces a quantum theory of gravity. String theory has most certainly been the most widely studied of these; it assumes that instead of point-like elementary particles, the universe consists of loops in space, or strings with different vibrational modes that describe different particles and states [24]. The assumptions that govern string theory, or theories more accurately, are that particles are vibrational modes and not point-like objects to eliminate some infinities evident in quantum theory: that there is a special kind of "super-symmetry" between elementary fermions and bosons; that there are (at least) eleven dimensions of space-time. The last assumption (or condition) is interesting; only three of these spatiotemporal dimensions are observable, so it is posited the others must be small and static, folded into spaces on the order of the Planck length in size. The study of string theories became prevalent in the 1980s in an era when searches for fundamental symmetries and conservation laws governed research physics. The reason the phrase "string *theo**ries***" is specified is that there are are many possible variations of the symmetries, any of which may have given rise to the observed physics of the universe, yet only one set of conditions is necessary. In spite of thirty odd years of study, string theory has not yet produced any reasonably testable predictions, in part because which set of parameters are likely to represent our universe is unknown. As such, string theory does net yet posses the power to develop the fundamental constants of nature. I generally take issue with the scope of string theory - it seems as though any correct theory of everything must uniquely give rise to the exact conditions of the evolving universe. This is perhaps a roundabout way of intimating that the initial conditions of the universe must be included in a theory of everything, or a way to smooth them out that does not have the *ad hoc, a priori* nature of inflation.

Another class of theories of everything begins with the postulate that the observable universe is holographic, or a truly higher dimensional space *projected* on this four dimensional space-time we experience. The concept of holography is familiar; a two dimensional holographic image may contain all the information of a three dimensional structure - by shifting the relative position of the image and that which perceives the image, the full structure may be observed. The universe may be like this, four observable dimensions that describe a larger set. These theories are essentially equivalent to string theories without the presumption of supersymmetry.

There are many obstacles, both of a theoretical and a causal nature, between the present state of physics and a unified theory of everything. The root of many assumptions, real but unobserved infinities produced by the arbitrary combination of general relativity and quantum field theory constitute one such. Another that is given vast philosophical weight though largely ignored by physicists on the warpath is Gödel's incompleteness theorem, which states that no set of axioms that can describe an entire group (for example arithmetic transformations) can be complete, or contain a proof for every statement therein. In physics, this could mean that every set of natural laws that reproduces the entire exact universe must have some *ad hoc* assumptions, such as the measured values of fundamental constants. It may also indicate that consistency between quantum field theory and general relativity is impossible. Importantly, physicists tend to ignore the incompleteness theorem and search for higher truth, which seems noble.

4.2 Closing Comments

In any sort of research, to reach any conclusions requires testing hypotheses. Physics is the same — equations are developed in theory and experiments performed and observations made to confirm that theory or refute it. At the time of this writing, the models used to produce these theories, in any area of physics at all, are shockingly effective and accurate. Predictions are made with astounding accuracy, and experimental results agree. So much so in fact, that it seems many researchers have stopped asking "why." The big bang model of cosmology and the standard model of elementary-particle physics remain largely unquestioned. Some alternatives have been explicated in this report, yet they are vastly outnumbered by those who have a death grip on the accepted formalisms.

An unfortunate consequence of the tenacity with which researchers hold up these standard models is that when a researcher sees a problem with the models, they invent an entirely new one to try and explain all the phenomena. Most if not all active researchers in the fields of fundamental physics or cosmology recognize that there are problems their models do not solve, yet many ignore them in favor of further developing successful portions of the models. Many of these researchers will go so far as to refuse to speculate about physics in a more grandiose sense than the work they do.

This trend towards exclusively niche research is intractable. Progress in physics or at least monumental progress in physics, such as the discovery of general relativity or quantum mechanics, happens when a bright scientist gets creative. Specifically, some anomalous result or phenomenon unaccounted for by known physics is noticed and paid attention to until a person has an idea that explains it. this idea is then tested, modified, and added to until it becomes part of the standard literature. There are many unexpected results and unexplained happenings in physics right now, yet many of the most successful scientists in the world refuse to think about them, too concerned with the familiar.

There are of course exceptions to the rule. Many scientists aim to solve the problems in physics (many of which may be found at [10]) by means of a grand unification theory, or a theory of everything. Perhaps the largest subset of these work in String (or M) Theory, which posits a supersymmetry between fermions and bosons. In spite of around 50 years of development, string theorists have produced no testable results. In fact it is said that it cannot produce testable results. Why this fact has not led the masses of advocates of supersymmetry to abandon its pursuit in favor of a theory that may be proved right or wrong is simple. It is probably the same reason that keeps researchers that adhere to a successful experimental model from branching out. The fear of being wrong, and the world knowing it.

This fear of failure needs conquering. If physics keeps stagnating, unable to produce wildly new theories (correct or not) about something other than the specifics of particle interactions or the history of the universe, then progress seems unlikely to move ahead.

The areas where creativity has a voice right now seem to be the search for a quantum description of gravity and theories of everything. I would posit that these are perhaps too ambitious for the time being. Some of the unanswered questions in physics seem to indicate that a new field of study, perhaps superluminal physics or another as yet unidentified field theory, may be waiting in the wings.

In conclusion, stay curious. Keep asking why the universe works. This is how understanding may be found.

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14. ABSTRACT

The standard model of particle physics is regarded as one of the greatest achievements of modern physics. It has successfully predicted the existence of numerous hadrons; e.g. the Higgs Boson, the W and Z Bosons, B mesons, etc. Moreover it accurately models many phenomena such as Beta and Radioactive decay, pair production, hadron mass splitting, and others. In spite of this, the standard model has many shortfalls. For example it fails to account for or explain the presence of dark matter and dark energy. Many alternative models of the substructure of matter etc. have been proposed. Some of these are examined.

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