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Accurate Predictions of Gravity without Mass, Null Dark Matter Results, Muon Precession and Solutions to the Hubble Tension, Final Parsec Problem, Information Paradox, Inter Alia: A 3.5-Year Status Report on the Probabilistic Spacetime Theory

Dennis M. Doren

Independent Researcher, Lake Mills, Wisconsin, USA
Email: dmdoren@yahoo.com

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Abstract

The Probabilistic Spacetime Theory (PST) was first referenced in 2020 and published in complete form in 2021. The theory exists to facilitate developments in modern cosmology through specific predictive and explanatory assertions, both to drive and interpret research discoveries. This article describes an extensive appraisal of the theory's demonstrated predictive accuracy and explanatory efficacy during its 3.5-year lifetime. The theory was found to have forecasted multiple astrophysical and cosmological findings such as black hole expansion without mass, gravity without mass, an excess degree of muon precession beyond the Standard Model prediction, and the self-interaction of so-called "dark matter". Research outcomes concerning the Hubble tension were also predicted and explicated. Additionally, the PST was found to offer explanations concerning many baffling observations, including the existence of primordial supermassive black holes, the ubiquitous existence of magnetism, and unexpected heat in intergalactic hydrogen clouds. Enigmatic high-profile theoretical issues were also addressed by the PST, including the black hole information paradox, black holes without a singularity, and the final parsec problem. Overall, the theory seems to have demonstrated substantial predictive and explanatory utility during its short lifetime. To facilitate further testing of the PST, predictions of current studies' outcomes are offered.

Keywords

Cosmology Theory, Hubble Constant, Gravity, Black Holes, Final Parsec

Problem

1. Introduction

Theory is only useful if it predicts and/or explains phenomena in a manner that is testable, and it only remains useful if the test outcomes are consistent with the theory. This article reviews the research-based efficacy and explanatory utility of the Probabilistic Spacetime Theory (PST), a comprehensive cosmological theory first mentioned in professional literature in 2020 (Doren & Harasymiw, 2020) and published in complete form a year later (Doren & Harasymiw, 2021). The ultimate question being addressed herein is to what degree the PST has shown itself to be effective during its initial three (3) years post-publication.

This examination was organized into six (6) sections as enumerated below. To ensure reader familiarity with the PST, brief descriptions of the theory's principles coupled with the principles' mathematical underpinnings are offered in the next section, Section 2. The investigation of the theory's utility starts in Section 3 where evidence is reviewed concerning supportive or contrary findings related to previously published predictions. Section 4 then investigates whether the theory can explicate recent observational and experimental findings not previously addressed by the theory, these representing potential areas of expansion of its applicability. Specific predictions concerning current research as further tests of the theory are offered in Section 5. The summary in Section 6 is an overall assessment concerning the recent and current utility of the theory.

2. The PST: Main Principles and Their Mathematical Underpinning

The PST consists of five (5) principles from which all other parameters are derived. These principles are described below. To facilitate the reader's comprehension of the theory without searching out previously published articles, two sets of descriptions of the theory's tenets are offered herein. The first, a table, describes the PST's five (5) principles in their essence, without details. Fuller verbal descriptions are then offered that are still brief compared to the complete set of details written elsewhere (Doren & Harasymiw, 2021). It is hoped these descriptions will allow the reader to understand the subsequent report on PST's predictive accuracy and explanatory utility. For more detail about the theory beyond these presentations, the reader is referred to the published version of the complete theory (Doren & Harasymiw, 2021).

The PST was described even in its original article (Doren & Harasymiw, 2021) as an integrative theory, borrowing tenets, research support, and mathematical findings from multiple sources. That integrative nature is reflected below, where the mathematical support for the PST's five principles stems from five diverse sources. The derived mathematical underpinnings are not repeated herein from their source but are instead briefly described with references for any interested reader.

Table 1 shows the essence of each of the PST's five tenets. A fuller description of each tenet follows the table to present the theory more completely.

Table 1. The five principles of the probabilistic spacetime theory.

Principle	Description in Simple Terms
1	Spacetime is a form of energy, each component being only a fluctuating energy fragment (described as probabilistic).
2	Once a single entity of this energy exists, it will always exist.
3	All cosmological fields stem from (probabilistic) spacetime (e.g., including the gravitational, Higgs, electronic, and magnetic fields)
4	Spacetime energy can change its form, analogous to phase changes of water from ice to steam.
5	Spacetime energy is self-cohesive, clumping under certain conditions. When this energy clumps, it forms the matter we see.

Each principle is now explained in further detail. The purpose of this article, the presentation of the predictive success of the PST, is addressed subsequently.

2.1. Principle 1: Spacetime Is the Fundamental Entity of the Universe

Unlike string theory, the PST rejects the presumption that spacetime is just a container for what is truly fundamental. Spacetime instead is seen as an amorphous field of energy fragments. Everything else in the universe is comprised of these energy fragments. The single quantum of spacetime is described as a "probability" reflecting that such a quantum has no specific form and may be better conceptualized as a mathematical (wave) function versus a measurable physical existence. Probabilities are fundamental entities that ultimately compose the rest of what we know but are not accurately conceptualized as smaller forms of our macro reality.

Spacetime consists of a constant exchange of probabilistic (fragmented) energy across a probability field. The overlapping of probability wave functions with neighboring ones is constant, though the degree of overlap (which exactly equates to their sharing of their energy) constantly varies (because all the energy involved is probabilistic). Spacetime is conceived as the perpetual sharing and swirling of this probabilistic energy.

Mathematical underpinning. The mathematical underpinning to principle 1 comes from the field theory by Silverberg and Eischen (2020). Their model, demonstratively effective in accounting for Mercury's precession and for gravitational lensing, involves an "energy fragment" structure to the universe, just as is true for the PST. These energy fragments collectively form a spacetime field that is related to the gravitational force but is not conceptualized as individualized components so much as quanta within a quantum field. The Silverberg and Eischen field theory does not specify if the energy fragments are contained by spacetime or are spacetime itself (unlike the PST which specifies the latter), but nevertheless their mathematically based field theory is consistent with the view the universe is fundamentally a field of energy fragments. The reader is referred to Silverberg and Eischen (2020) for the mathematical demonstration of this field theory.

2.2. Principle 2: Once a Quantum of Probability Field Exists, It Cannot Be Destroyed

The PST presumes the first law of thermodynamics applies to each quantum of the probability field we call spacetime. As mentioned above, the probability field consists of (probabilistic) energy, does not just contain it, and hence no quantum of the field can be destroyed (i.e., brought to zero energy) once it comes into existence. The section below explains why.

Mathematical underpinning. The PST states spacetime energy fragments (the probabilities), the most fundamental form of energy, cannot be destroyed. The physical basis for this assertion is the first law of thermodynamics with one additional proviso.

The typical description of the first law has three components: 1) energy cannot be created or destroyed, 2) energy can be transformed from one form to another, and 3) in an isolated system, the sum of all forms of energy is constant. The PST is consistent with all three components. No exception to this law is made for spacetime probabilities.

But, as mentioned, there is an additional proviso. Each quantum of spacetime is defined by its non-zero degree of probabilistic energy. Without some degree of energy, there would literally be no spacetime, meaning "no universe" in that locale. This concept is a non-sequitur as we cannot define a no-energy condition in a locale if there is no locale about which we speak. Although the energy of a spacetime quantum can grow asymptotically close to zero, no probability can come to equal zero energy without the universe simply becoming absent, a concept that definitionally is nonsensical.[1]

2.3. Principle 3: All Fields Are Derivative from the Probability Field

The probability field is a constantly swirling field of energy. Each component of that field, each probability, is probabilistically related to our larger reality, but not composed of any complete form of our larger reality. What we see as the charge of a particle is an independent characteristic of the particle itself (as is the spin) (Czajka, Gao, Hirschberger et al., 2021; Ruan et al., 2021). The field therefore necessarily involves the constant churning of some charged (and other) entities.

This constant swirling of probabilistic entities with a charge causes magnetism everywhere there is spacetime. This magnetic field does not require charged particles moving through space (which relates to what is typically termed the electric field), just the sharing of charged probabilistic energy that is the swirling of spacetime itself, everywhere spacetime exists.

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[1] The reader is cautioned against thinking that one probability's energy could simply be absorbed by its neighbor and hence be destroyed. That conceptualization views each probability as separate from spacetime itself, as if probabilities sit in spacetime. The PST's view is that probabilities = spacetime. Additionally, the idea involving total absorption ignores the quantum nature of probabilities, treating each as distinct from one another when their quantum nature demands otherwise.

All fields are derivative from the probability field, which includes the Higgs field. Typically, the Higgs particle (or field) is viewed as something contained in spacetime. The PST views the existence and mechanism of the Higgs field and how it imparts its influence in a more integrated manner, as explained in Section 2.4 below.

Mathematical underpinning. All fields are derived from the probability field (spacetime), including the magnetic field. The PST explicitly states that magnetism necessarily exists everywhere in spacetime due to the swirling of (charged) energy fragments.

As the original PST article (Doren & Harasymiw, 2021) was being written, a finding by Lindgren and Liukkonen was published that demonstrated correspondence between Maxwell's equations concerning electromagnetism and Einstein's equations from general relativity (Lindgren & Liukkonen, 2021). Those investigators concluded that electromagnetism is an inherent property of spacetime itself, and that the ramification of local tensions (what the researchers called "twists") in the fabric of spacetime are the magnetic and electric fields. This conceptualization is remarkably similar to PST's swirling of energy fragments and its theorized effects. The mathematical formulation described in Lindgren and Liukkonen (2021) serves as clear support to principle 3 of the PST, though the PST goes beyond their model by describing the mechanism generating the electric and magnetic fields from the underlying spacetime.

2.4. Principle 4: The Probability Field Has Phases

Given that the probability field is always dynamic, the degree of energy in any given location constantly varies. These energy fluctuations are related to phase changes, analogous to what we see in the macro world.

Spacetime's baseline (i.e., least energetic) phase is what we typically think of as space. The highest energy level in the local field associated with the baseline phase involves fluctuations that astrophysicists call virtual particles.

The next most energetic phase (within a local volume of the probability field) is where massless gauge bosons (photons and gluons) form directly from the field's energy. The new photons then serve to increase the field's ability to transmit electricity and magnetism across its span. Gluons also form during these phase changes. Since fermions have mass and hence take more energy to form, the new gluons do not serve as energy transmitters if there is no proximate mass but, in that situation, only interact with themselves.

At still higher concentrations of probabilistic energy, the probability field (spacetime) phases into mass (i.e., gauge bosons with mass, any of the fermions). While the Standard Model and the PST both describe mass as forming where there was none (described in the Standard Model as something separate from spacetime, the Higgs field, causing symmetry breaking), the PST sees the generation of the property of mass as resulting from sufficient energy of local spacetime itself. When the local probabilistic energy is beyond a certain threshold (equal to the Higgs boson), that energy phases into an object with mass. This process overlaps the theory of symmetry breaking (associated with the Higgs) but with a different emphasis. Specifically for the PST, the process reflects a phase change where an amorphous state becomes uniquely defined as compared to its baseline state of probabilistic energy. The PST states there is no separate Higgs field except as enacted by the local probability field.

The highest concentration of probabilistic energy is thought only to occur within black holes[2] and neutron stars. The very highly concentrated probabilities become nearly completely overlapping wave functions. As such, their independence becomes extremely blurred but never eliminated. What remains would seem to be in keeping with the phenomenon proposed by Migdal (1959) as being at the center of neutron stars: a superfluid. Even if this is not an accurate description of this final phase state of the probability field, it seems clear there is a phase transition of the probability field in the densest of astronomical bodies much beyond what we typically see as mass.

Mathematical underpinning. The PST borrows the macro world concept of phases and applies it directly to the probability energy we call spacetime. The mathematical basis describing macro world phase changes also serves as the basis for understanding spacetime phase changes, involving the parameters of pressure and temperature, with one additional consideration. When the probability energy in a specific locale increases sufficiently, spacetime changes phase. That increase in energy can occur through what is analogous to a change in pressure (i.e., through increased overlap of the wave functions) or through what is analogous to temperature change (i.e., the altered degree of energy in a locale due to the constantly occurring swirling of energy across probabilities).

One additional consideration is the concept in principle 5 described below: spacetime is self-cohesive. Once a phase change occurs due to increased probabilistic energy, it tends to remain in place even if there is a subsequent equal degree of energy decrease in the same spacetime volume. That is because the growth of probabilistic energy is accompanied by a self-created increased magnetic field and concomitant self-cohesion of spacetime itself. These factors serve to maintain phase changes even if the local energy later decreases.

2.5. Principle 5: Derivatives of the Probability Field Cause It to Be Self-Cohesive

The probability field is composed of fundamental bits of energy. As described above, the probability field generates magnetism and (sometimes) photons. These generated features bring magnetism to everything in the universe. That includes magnetic attraction to the underlying (charged) probability field from which the features were generated. Through this mechanism, from the probability field to

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[2] The PST views black holes differently from the view involving a singularity. Since nothing can destroy a probability once it has come to exist, the PST mandates that the "core" of a black hole must still be finite and not a singularity. Every probability that was within the gravity well (i.e., the black hole) must continue to exist. Since all matter comes down to probabilities which will always remain, nothing has its essence destroyed anywhere inside a black hole.

its derivatives and back to the probability field, the field can be described as self-attractive. This mechanism makes the probability field self-cohesive.

The greater the local energy of the probability field, the more likely the generation of gauge bosons and electromagnetism and the stronger the cohesion across the local field. And when that local energy is great enough to generate or maintain the phase of mass, the surrounding field also generates cohesion to that mass.

Mathematical underpinning. A very recent finding was that Einstein's field equations allow for a gravitational force in the absence of any detectable mass (Lieu, 2024). Using the starting point of an unconventional isotropic impulsive source term in the form of a topological defect, a mathematical proof employing Einstein's field equations demonstrated that spacetime alone can be a localized gravitational field capable of driving flat rotation[3]. Specifically, massless gravity can exist as a shell in which a star (or galaxy or other astronomic body) can lie and hence experience a large gravitational force dragging it towards the center of the massless shell. This shell concentrically assembles multiple topological defects ultimately establishing a flat stellar or galactic rotation curve. Simultaneously, the shell can deflect light in the same manner as expected from gravitational lensing. The researcher concluded that the need for dark matter or a MOND theory is at least in part mitigated by this finding (Lieu, 2024). In support of the idea that these findings reflect reality beyond just mathematics, the researcher stated that the frequency of sightings of ring and shell-like galaxy formation lends evidence to the source suggested by Lieu.

Observational research support. Observational research support also exists for principle 5. The principle states probabilities (some of which involve a positive or negative charge) become self-adhesive due to the magnetic field that necessarily stems from the probability field. At the same time, gravity is seen as a reflection of the density (or degree of energy) of the local probability field—the denser the probability field, the greater its cohesiveness to everything else including itself, and hence the stronger the process we call gravity. Directly indicated in the PST's portrayal of gravity is that mass is not required for there to be a gravitational force. (A density of the probability field beyond its baseline is all that is needed for there to be what we call gravity—a dimple in the fabric of the field beyond its baseline, in keeping with general relativity.)

Observational findings have supported the conclusion about the self-cohesiveness of spacetime (though the observations have typically been attributed to "dark matter" rather than a characteristic of spacetime). "Dark matter halos" (as dark matter researchers use that concept, but in the PST are called spacetime clumps) have been mapped distanced from the galaxies with which they were associated (Harvey et al., 2015; Hupp, Roy, & Watzke, 2006; Jenner & Dunbar, 2012), including halos being discovered quite isolated from any galaxy (Harvey et al., 2015). (These maps have been developed using the halos' gravitational lensing effects.)

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[3] This mathematical conclusion is very consistent with the observational study described in the next paragraph. That study concluded that a characteristic of gravity itself was the cause for very extended flat rotation curves.

One interpretation of this finding is that it reflects halos' momentum following galaxy collisions. The galaxies move in and around each other due to mutual gravitational attraction but the halos move past their galaxies following the collision and are only drawn back later (if at all) (Harvey et al., 2015). The point here is that the halos (spacetime clumps) hang together despite moving away from mass while they continue to function as sources of gravity (as demonstrated by their continued gravitational lensing effects).

Additional observational support for principle 5 comes from a very recent study of circular velocity curves from isolated spiral galaxies (Mistele, McGaugh, Lelli, Schombert, & Pengfei, 2024). That research investigated the degree to which rotation curves of galaxies, probed with weak gravitational lensing, maintained their flatness. That study concluded that curvature rotations remained flat a great deal further than previously known (as great as 1 Mpc), this finding being true for both early- and late-type galaxies (Mistele, McGaugh, Lelli, Schombert, & Pengfei, 2024). The researchers concluded 1) there was a clear discrepancy between their findings and those from (lambda cold) dark matter models, and 2) their "indefinitely flat rotation curves for isolated galaxies" were predicted by modified Newtonian dynamics (MOND) (Milgrom, 1983a, 1983b, 1983c). Phrased differently, the conclusion drawn by the researchers is that the extra gravity serving to maintain the rotation velocities of stars seems to stem from a characteristic of gravity itself and not from something more external like dark matter. This conclusion is consistent with the PST's idea that spacetime itself serves as the source of gravity.

The mathematical proof cited above is the first to show that gravity can exist without mass. Together with the reviewed observational findings, this mathematical proof supports the PST's ideas that the self-adhesive nature of spacetime serves as the underlying basis for gravity, and spacetime clumping does not always require mass either to exist or to be maintained.

3. PST'S Predictive Utility

This section summarizes findings concerning the PST's predictive accuracy within the past three (3) years. **Table 2** encapsulates what this section delineates in detail, presented first to facilitate the reader's comprehension of what follows. Each "issue" enumerated in the table is addressed individually later in this section.

3.1. Concerning the Hubble Constant

The rate of expansion of the universe has been dubbed the Hubble constant (abbreviated as H_0). As demonstrated by that moniker, the common presumption within the field of astrophysics has been that there is only one universal rate of expansion. Hence, when computational studies found two diverse rates, the hunt was on to find "the correct one". Instead of resolving the differing rates (approximately 73 km/s/Mpc versus 67 km/s/Mpc), however, subsequent research only substantiated that the difference reflected something accurate about reality (at sigma > 5). This unexplained measurement discrepancy, labeled the "Hubble tension", became a major research focus because the expansion rate of the universe is a critical figure in determining both the age of the universe and the distances of heavenly bodies.

Table 2. Summary of prediction accuracy of PST during its first 3.5 years.

Issue	PST Prediction	Validation of PST Prediction
How best to address the Hubble tension?	The expansion rate of the universe fluctuates depending on amount/proximity of mass within measurement conditions. The more mass involved in the measurement of the Hubble constant, the slower the expansion rate, and vice versa.	All measurements using the cosmic microwave background or galaxy clusters have resulted in the slowest known expansion rate, while virtually all measurements based on single or binary stars have resulted in a faster rate. Additionally, a recent test (Pascale et al., 2024) of the hypothesis that the young universe had one rate while the newer universe had another did not support that hypothesis but was consistent with the PST prediction.
Can gravity exist without mass?	Gravity (occurring through clumps of spacetime) though typically associated with mass, is not always dependent on mass. That is, clumps of spacetime exist without proximate mass.	Lieu (2024) demonstrated a mathematical proof employing Einstein's field equations that spacetime alone can be a localized gravitational field existing as a shell (in which an astronomic body can lie) that can deflect light in the same manner as expected from gravitational lensing.
Is "dark matter" necessarily self-interacting?	Any relatively high energy volume of spacetime (the probability field) includes the essential hypothesized features of dark matter (i.e., interacts through gravity, does not reflect light) though the PST states spacetime is necessarily self-cohesive.	A simulation study concerning dark matter determined it had to be self-interacting to match reality (Alonso-Álvarez, Cline, & Dewar, 2024).
Do black holes expand with cosmological expansion?	Black holes expand based on their connection to the universe at large; that is, along with the expansion of the universe.	Croker et al. (2021) described evidence that at least some black holes expand in a way connected to the rest of the cosmos.
Did the Muon g-2 finding of "extra" muon precession reflect new physics or an error compared to the standard model?	Extremely precise measurements of muon precession will always be affected by the ubiquitous magnetism generated by spacetime.	The second Muon g-2 study continued to show "extra" muon precession (more wobble) beyond what the standard model predicted despite increased precision in measurement (e.g., Aguillard et al., 2023)

In 2021, the PST's perspective was written as follows (Doren & Harasymiw, 2021): "The Hubble constant varies based on the degree to which mass is involved in the measurement… this formulation was first published in 2020 (Doren & Harasymiw, 2020) and since predicted one very major empirical finding (Dawson & Percival, 2020). There are other current theoretical explanations for the two persistently different figures for the expansion rate of the universe (i.e., for the 'Hubble tension'): 1) weak magnetic fields account for the difference: the magnetism clumps protons and electrons into hydrogen such that light coming from the clumps starts closer than we have previously assessed, with that change in distance resolving the Hubble tension… or 2) more accurate measurements will resolve the apparent discrepancy… The PST clearly predicts something different from those other explanations: that the expansion rate of the universe varies over a range depending on the proximity and volume of mass, radiation, and clumps of probability field (otherwise described as 'dark matter') in the measurement."

The PST indicates that the presumption of only one correct expansion rate is wrong. Instead, the rate of expansion of the universe is dependent on the proximity of mass to the spacetime volume being assessed. Put another way, the amount of mass inherent within the research measurement methodology is directly related to the results found; the less mass involved in the measurement (that is, the less mass proximate to the volume of spacetime involved), the greater the expansion rate. (See Doren & Harasymiw, 2021, for a detailed description of the PST's basis for this expectation.)

Research on the universal expansion rate during the past four (4) years has been supportive of this perspective (Riess, Yuan, Macri et al., 2022; Riess et al., 2024; Verde, Schöneberg, & Gil-Martin, 2024), though researchers' written conclusions have not stated so. Typically, conclusions read like that from (Riess, Yuan, Macri et al., 2022) which stated the source of the discrepancy in determining H_0 remains unknown.

What is known is that research measurements using the cosmic microwave background (Lemos & Shah, 2024) or galaxy clusters (Dawson & Percival, 2020) result in a slower rate, while measurements based on single or binary stars have resulted in a faster rate (Riess, Yuan, Macri et al., 2022). (A recent test of the hypothesis that the young universe had one rate while the newer universe had another (Pascale et al., 2024) did not support that hypothesis but remained consistent with the PST prediction. Specifically, the study using ancient Cepheid stars showed the rate typical to studies using individual and binary stars for measurement.) Likewise, consistent with this perspective, large voids expand faster than the rest of the universe (Lemonick, 2024). Since the publication of the PST, its perspective concerning "the" Hubble constant seems to have been consistently supported.

3.2. Concerning Gravity without Mass

Since its inception, the PST has explicitly described gravitational force as stemming solely from increased density (called clumps) of spacetime. These clumps have been theorized as more likely to occur in the proximity of mass (due to the self-cohesiveness of spacetime with mass, with mass simply being one phase of spacetime) but also without mass in the vicinity due to spacetime's probabilistic and self-cohesive nature.

The first mathematical proof that gravity can exist without mass was very recently published (Lieu, 2024). That investigation, discussed above concerning the mathematical underpinning of principle 5 and so not detailed again here, found that Einstein's field equations allow for a gravitational force in the absence of any detectible mass. The PST has always posited gravity can exist and persist without mass. To the degree that this mathematical proof reflects reality, the PST predicted that reality before it was proven.

3.3. Concerning the Idea "Dark Matter" Self-Interacts

The PST does not accept the existence of "dark matter" (DM), so it might seem the PST can never be substantiated by studies looking to substantiate the existence of DM. However, the PST posits that any relatively high energy volume of the probability field works in a way that overlaps the typical view of DM. DM is typically described in ways that are like descriptions of PST's spacetime clumps, as sources of gravity that do not include observable matter. Therefore, the idea that the probability field is self-cohesive can gain support from DM research that concludes DM has that characteristic.

There are numerous observational studies that have concluded DM remains in groupings beyond what gravity alone would suggest (Harvey et al., 2015; Hupp, Roy, & Watzke, 2006; Jenner & Dunbar, 2012), with Harvey et al. being the most dramatic example. That investigation found an exceptionally large clump of DM on its own, away from the proximity of any galaxy or other large mass. Even if that clump originally formed around a large body of mass, as was hypothesized by the researchers, the fact it remained as a clump (as opposed to dissipating) after separating from that mass demonstrates what the PST states: these clumps are self-cohesive. Likewise, the other cited studies document that DM clumps remain in that form even as their momentum moves them away from their galaxies during a multiple-galaxy collision.

As stated above, the PST rejects the concept of DM. The research that reportedly shows DM to exist (and to have momentum and to travel) in self-cohesive clumps is instead interpreted herein as demonstrating that spacetime itself self-adheres with and (to a lesser degree) without the proximity of mass.

3.4. Concerning the Expansion of Black Holes Coupled to Cosmological Expansion

The PST is unusual in describing the expansion of black holes based solely on their connection to the universe at large; that is, along with the expansion of the universe. In 2021, such black hole expansion was specifically described as coinciding and being dragged along by inflation[4], this being theorized as the seeding for early

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[4] The idea that black holes expanded with inflation was the primary topic of discussion in Özsoy and Tasinato (2023). However, that in-depth investigation presumed that black hole formation first occurred during inflation. In contrast, the PST posits that black holes (i.e., gravity wells due to clumps of spacetime) came to exist with the big bang itself. Black holes then expanded in volume but were not first formed during the period of inflation.

supermassive black holes (Doren & Harasymiw, 2021).

Published in the same year but a half-year later was evidence that at least some black holes expand in a way connected to the rest of the cosmos (Croker et al., 2021). The PST posited and subsequent research showed that black holes expand in coordination with cosmological expansion.

3.5. Concerning the Muon Anomalous Magnetic Moment

When a charged particle such as a muon with natural angular momentum (spin) traverses a stable magnetic field, it shows precession; it wobbles around its central axis. The Standard Model (SM) describes a precise degree of precession when numerous initial parameters are known. To evaluate the accuracy of the SM, researchers have run examinations of the SM prediction many times over the past 60 years (Aldins et al., 1970; Bailey et al., 1972; Charpak et al., 1962), each time with methodological and technological improvements. The most recent study of this type involved three (3) separate sets of tests (referred to as "muon g – 2" studies), the results of which were scheduled to be published over years, reflecting the sequential nature of the investigations.

The initial publication of results was during 2021-2022 (Abi et al., 2021; Girotti, 2022; Labe et al., 2022; Keshavarzi, Khaw, & Yoshioka, 2022). While clearly more precise than any previous study, its conclusion was the same as had been drawn previously: the precession was greater than that predicted by the SM. Months later, the PST was used (by this author) to explain why the SM's prediction in this situation was not correct, and why in fact the additional precession was predictable: "The PST therefore indicates that the muon precession found beyond the SM prediction was due to the interaction between the muons and the spacetime-generated magnetic field they traversed. The effect of this interaction on the muons would be extremely small, but these experiments were incredibly precise in their measurements… The excess precession reflected the magnetism in the test chamber that the researchers did not know to anticipate" (Doren & Harasymiw, 2023b).

Given the muon g – 2 researchers continued not to factor in the spacetime-generated magnetic field in their computations after their first study, the expectation based on the PST has been the experimental results from subsequent muon g – 2 studies would remain the same: more precession than the SM anticipated. In fact, that was the outcome of the second muon g – 2 study (Aguillard et al., 2023) despite the methodological error factor in the second study being reduced by over two (2) compared to the first.

4. Congruence between the PST and Recent Research Findings

In this section, brief explanations from the PST for recent experimental, observational, and theoretical findings are offered, where the PST had not been used for specific predictions to show the breadth of the theory's explanatory utility. Readers are directed to the cited references for fuller explanations of the PST.

4.1. Muon Anomalous Magnetic Moment beyond the Standard Model

As was just reviewed, there has been great consistency in the finding that the muon anomalous magnetic moment is slightly larger than that predicted by the Standard Model (Aguillard et al., 2023). The PST explains this finding in a straightforward way: the magnetic field in the test mechanism is slightly greater than what the researchers thought they designed. That additional magnetism does not stem from the magnets used in the research but from the volume of spacetime within the test chambers. Basic to the PST is that spacetime probabilities are swirling fragments of charged energy. They necessarily cause magnetism everywhere there is spacetime, albeit in minuscule amounts reflecting the baseline tiny amount of energy in any local probability field. Due to the incredible precision in the study's measurements, the "extra" precession demonstrated by muons in the test conditions reflects that additional magnetism was unaccounted for. The researchers have been including an aspect of spacetime itself in their measurements. This may be the first time an experimental methodology has been so precise as to do so.

4.2. The "Too Early" Existence of Supermassive Black Holes

Supermassive black holes (SMBHs) have been discovered in the early universe from when the universe was as young as 670 - 700 million years old, with sizes as large as 1.0 - 1.5 billion solar masses (Wang et al., 2021; Yang et al., 2020). Most recently, the James Webb Space Telescope and other instruments were used to discover the existence of many as large as billions of suns (Bosman et al., 2024; Matsuoka, Iwasawa et al., 2018; Matsuoka, Strauss et al., 2018; Yue et al., 2024). These early universe SMBHs could not have grown to their supermassive size in the usual way (that is, star development and collapse coupled with black hole ingesting mass and merger) during the first billion years the universe existed. There simply was not enough time (Feng, Yu, & Zhong, 2021).

Various mechanisms have been hypothesized as causing primordial over-densities to undergo gravitational collapse into early universe black holes (Belotsky et al., 2014; Carr et al., 2021; Carr et al., 2024; Escrivà, Kuhnel, & Tada, 2024; Lemonick, 2024). These mechanisms, however, do not address the issue of insufficient time for growth from primordial black holes into SMBHs, as they all involve mass collapsing into black holes as opposed to gravity wells coming to exist during the big bang. The PST may be the only model that builds in sufficient time for SMBH growth in the early universe.

The PST describes the earliest formation of black holes as truly primordial. The development of early universe SMBHs is viewed by the PST as stemming from black holes born with the big bang (as spacetime clumps) (Doren & Harasymiw, 2021) and not through the collapse of stars or nebulae. These clumps of spacetime then expanded along with the rest of the universe during the period of inflation. These primordial black holes, seeded and expanded without mass, thus had a significant head start in their growth compared to any black hole later developed through stellar or nebular collapse.

Support for the PST perspective comes from a recent observational study that determined that the early SMBHs became massive prior to their host galaxies (Furtak et al., 2024). That study concluded that quasars from the universe's first billion years might have experienced early SMBH growth compared to their host galaxies' star formation. The idea the early universe SMBHs started with "heavy seeds" prior to their galaxies' ability to feed them is consistent with the PST's idea that those seeds came to exist prior to mass collapse and ultimately from the big bang.

4.3. Addressing the Black Hole Information Paradox

The PST offers two different answers to the black hole information paradox, depending on which of two (2) presumptions is made. If the evidence (described above) for black holes expanding along with the universe reflects reality, then the information paradox cannot exist through the time the universe continues to expand. The universe-connected expansion rate of a black hole is far greater than the theorized shrinkage rate caused by escaping virtual particles (Doren & Harasymiw, 2023c). Black holes cannot evaporate under this condition. Information contained in black holes will therefore not be lost. No paradox exists related to the possible loss of information from the universe.

If black holes do not expand with the universe, or universal expansion stops, then the PST still states information loss will not occur. Everything in the universe, including all information inside a black hole, consists of probabilities (the quanta of spacetime). The PST posits probabilities can never be destroyed. Therefore, as a black hole shrinks, spacetime probabilities will remain the same as they always are: quantum bits of information. While the event horizon grows smaller and smaller, the quantum nature of probabilities simply causes them to have ever-increasing likelihoods of being concentrated outside the shrinking event horizon (Doren & Harasymiw, 2023a). Any given spacetime quantum never needs to demonstrate an escape velocity (that is, to work its way against gravity) to escape the black hole. The black hole event horizon instead approaches them, making it easier and easier to express their quantum nature on the other side.

4.4. The Existence of Glueballs

The idea that gluons can form self-adhering clusters (called glueballs) is incorporated in the Standard Model, so the PST's prediction of such is not unique. Even if not uniquely predicting so, the PST article predictive of their existence (Doren & Harasymiw, 2021) was written as the first empirical evidence of glueballs was being reported (Brünner & Rebhan, 2015).

4.5. Ubiquitous Magnetism

Research concerning magnetic fields away from collapsed stars or clouds is particularly challenging because the expected intensities ($\lesssim 1$ nG) are well below the ones more easily observed in galaxies and galaxy clusters (~1 μG) (Hanasz, Woltanski, & Kowalik, 2009). Despite this technological issue, evidence exists that dynamo processes have been at play in amplifying existing B fields in the early universe (Hanasz, Woltanski, & Kowalik, 2009; Marinacci & Vogelsberger, 2015; Schober, Schleicher, & Klessen, 2013). A crucial issue, however, is that the origin of these fields is not known (Marinacci & Vogelsberger, 2015).

Different hypotheses have been forwarded, including:

- from galactic shock waves (Kulsrud, Cen, Ostriker, & Ryu, 1997),
- during inflation and phase transitions in the early universe (Widrow et al., 2012),
- generated by stars in protogalaxies (Schleicher, Banerjee, Sur, Arshakian, Klessen, Beck, & Spaans, 2010) and/or
- generated by active galactic nucleus activity (Furlanetto & Loeb, 2001).

These hypotheses have something in common. They espouse that the universe initially did not involve magnetism, instead developing it from a non-magnetic state. These hypotheses describe magnetic fields as being produced 1) during a pregalactic era when galaxies were first forming (Kulsrud, Cen, Ostriker, & Ryu, 1997) or 2) while the first stars were forming (Schleicher, Banerjee, Sur, Arshakian, Klessen, Beck, & Spaans, 2010), before which the magnetic field did not exist.

In contrast, the PST states that magnetism came to exist almost instantly after the universe did. As spacetime came to exist, it necessarily generated magnetism everywhere because spacetime's (charged) energy fragments swirled among themselves. This resulted in magnetism everywhere there is spacetime, even where no other substance existed. And that same process continues to this day. The PST indicates that there was nothing special about the development of the first magnetic field following the big bang compared to how it is being developed (in the expanded universe) and maintained today.

4.6. "Extra" Heat in Intergalactic Hydrogen Clouds

Certain intergalactic hydrogen clouds (at redshift $z < 2$) have been found to exhibit more heat than the standard theory predicts (Bolton et al., 2022). The most recent explanatory hypothesis offers the idea that the extra heat stems from "dark photons" (a theorized subtype of dark matter) which in turn, under certain circumstances, become normal matter photons. These normal matter photons then provide additional heat beyond what was expected.

There are three (3) components to that hypothesis: 1) dark matter exists, 2) there is a subtype of dark matter in the form of dark photons, and 3) these dark photons can, under certain circumstances, change into regular photons (with the new photons causing the additional heat). Notably, each of these three components states a presumption not known to be true.

The PST's explanation of the extra intergalactic cloud heat is far simpler without adding any new component to the existing PST theory. The intergalactic hydrogen clouds under study were relatively non-dense (a fact emphasized by the original researchers) (Bolton et al., 2022). Such a cloud would involve a modicum of spacetime clumping. When sufficient probability energy comes together in a volume of spacetime, it generates a phase change from baseline to massless particles including photons. The generated photons cause the finding of extra heat compared to what was expected otherwise (Doren & Harasymiw, 2023d). PST explains the extra heat with one phase change, not three questionable components, to bring about the same photonic heat source.

4.7. Black Holes without a Singularity

Black holes are typically described as having a singularity at their core. This is because the same field equations that predicted black holes also indicate infalling mass crushes infinitely at the black hole's core. This is true even though singularities are thought impossible, at least within the realm of known physics. The infinities in our equations interfere with our ability to answer questions about what lies in black hole cores.

To solve this conundrum, attempts have been made to define a black hole without a singularity. Two main examples include the "general objects of dark energy" (GEODEs) (Croker, Nishamura, & Farrah, 2020; Croker, Runburg, & Farrah, 2020; Croker & Weiner, 2019) and the overlapping concept of gravastars (a term combining the words gravitational vacuum star) (Mazur & Mottola, 2023). Both objects are hypothesized to be filled with "false vacuum" or "dark energy". This internal energy serves both to maintain the event horizon and avoid the complete collapse of the core.

The theoretical formulations of GEODEs and gravastars seem to avoid an impossibility (a singularity) by employing a completely unknown entity (given the placeholder moniker of dark energy) and calling it progress. In the one known test concerning the possible existence of gravastars, LIGO results did not support the gravistar compared to the traditional black hole formulation (Chirenti & Rezzola, 2016).

From the perspective of the PST, both concepts of singularities and dark energy are wrong. Black holes are what Einstein's field equations say they are, but with one additional component. That additional component is the limiting factor that spacetime probabilities (which necessarily are contained within any black hole) cannot be destroyed. With that additional factor, infinities are avoided while still acknowledging black holes are black holes.

As matter falls further and further into a black hole, it gets crushed into its constituent segments. Those constituent segments are probabilities. With greater and greater pressure, probabilities come to overlap with each other (i.e., share their energy) more and more. However, because no probability can ever be destroyed, there is a limit to how much probabilities (wave functions) can overlap. Even inside a black hole, that limit prevents a singularity from ever developing. The cores of black holes are composed of probabilities, crushed together as far as their quantum existence allows them to be, but never indefinitely. At the core of black holes is spacetime in its highest density phase. The indestructibility of spacetime itself is what needs to be added to our computations concerning black holes.

And the PST is clear that the completely-not-understood placeholder concept of dark energy has nothing to do with any of this.

4.8. "Dark Matter"

"Dark matter" is the name given historically to the reported cause of gravity beyond what we can attribute to ordinary matter. Dark matter was first hypothesized in 1933 (Zwicky, 1933) to explain why very fast-moving galaxies did not fly away from their galaxy cluster. In the 1970s, Vera Rubin's discovery that stars near the edges of spiral galaxies moved fast enough that they, too, should fly off from their galaxy if the only source of gravity was the galaxy's visible matter (Bahcall, 2017). Since then, dark matter has been a common explanation for an increased amount of gravitational lensing again compared to what observable matter would have suggested. In fact, gravitational lensing has served as the vehicle for "mapping dark matter" in detail (Taro Inoue et al., 2023).

On the other hand, every attempt to discover the particle or other entity comprising dark matter has failed to date, after about a half century of work in that regard (Bernabel et al., 2021; Castelvecchi, 2022; XENON Collaboration et al., 2017). The study by Harvey et al. (2015) concluded that dark matter was not in particle form based on how the mapped halos traveled through one another. A different observational investigation documented that the clumping within galaxy halos is uneven, contrary to some conceptualizations of dark matter (Meneghetti et al., 2020).

Research to discover the nature of dark matter fails repeatedly. Yet, new investigations searching for dark matter particles and other uniform dark matter structures continue to be initiated (Autti et al., 2024; Clements et al., 2024).

The PST predicts that all such attempts in the future will continue to fail. (See the discussion in Section 5.4 below) That is because, from the perspective of the PST, the presumption that "dark matter" is that which is being mapped is incorrect. What is being mapped are clumps of spacetime, quite typically uneven and always without particulate components. The PST indicates these spacetime clumps are the source of the extra gravity needed to explain the phenomena attributed to dark matter (i.e., flat galaxy rotation curves, gravitational lensing beyond what observable mass would indicate, galaxy clusters remaining together despite relative galaxy velocities that would indicate otherwise). Unlike dark matter theories, the PST's explanations of these phenomena do not require a new particle, or any other entity hypothesized for this one purpose.

PST posits that higher than baseline densities of probabilistic energy are the gravitational force beyond that caused directly by observable mass (Doren & Harasymiw, 2021). The strong cohesion of spacetime clumps around mass is likewise theorized as the basis for "dark matter halos" around galaxies. There is no new particle hypothesized to explain the unexplained, just spacetime that acts with self-cohesion using its self-generated magnetism in a probabilistic and hence not fully predictable (that is, in an uneven) way.

4.9. The Final Parsec Problem

Historically, calculations trying to describe the merger of two supermassive black holes (SMBHs) have failed due to an issue described as the "final parsec problem". The problem arises when the calculations consider two opposing relevant phenomena: gravitational waves and dynamic friction. When two SMBHs merge, gravitational waves caused by the SMBHs carry energy away from the system and cause the SMBHs to spiral faster towards each other. Opposing this is dynamical friction (i.e., drag caused by dust and other entities gravitational attracted to and carried along with each SMBH) which causes each SMBH to decrease in velocity and hence its rate of falling toward the other SMBH. Calculations have shown these opposite processes reach an equilibrium when SMBHs are about one (1) parsec apart, seeming to prevent the merger despite the fact we know such mergers occur. The final parsec problem refers to our lack of understanding concerning what allows or pushes SMBHs to traverse that last parsec and merge.

A very recent investigation claims to have found an answer (Alonso-Álvarez, Cline, & Dewar, 2024). Using a series of simulations to test different assumptions, the researchers discovered that some simulations involving "self-interacting dark matter" (SIDM) allowed for SMBH mergers (by adding SIDM's theorized effect to the effects of gravitational waves and dynamical friction). The self-interacting form of dark matter (DM), versus cold dark matter, seems needed for the solution because the latter did not allow for SMBH mergers in the simulations. The mechanism that allowed for mergers was SIDM's ability to absorb a sizable part of the energy otherwise lost to the system through dynamical friction. The researchers concluded this absorption was through an "unknown force carrier" which they suggested was the dark photon. The researchers expressed the parameters of their investigation, and therefore their findings in terms of DM.

Instead, the study and its findings could have been more efficiently described using PST parameters.

- First, given the PST rejects the concept of DM, the entity of relevance instead of DM is spacetime (i.e., the probability field). The PST explicitly says that the probability field is constantly in flux and able to exchange and absorb energy across neighboring local volumes of spacetime. Rather than describe a two-factor solution (using the concept of SIDM as the intervening entity and dark protons as the absorbing agent/catalyst), the PST says the interacting variable is also the entity able to absorb energy from dynamic friction, this entity being the probability field in which the friction occurs.
- Second, the self-interacting feature of SIDM is nothing special within the PST as the concept reflects a main tenet, principle 5 of the PST: spacetime is self-cohesive.[5] The fact that simulations using cold dark matter did not solve the

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[5] Comparing descriptors, the phrase self-interacting reflects the idea that dark matter is made of particles. Since spacetime is not viewed by the PST as particulate, the term self-interacting would be misleading. The phrase self-cohesive is proper, reflecting a more exact description of the effect.

final parsec problem, but the SIDM was successful supports the PST principle said years ago (Doren & Harasymiw, 2020, 2021) that self-cohesiveness is a feature of spacetime. Now, evidence exists that this feature is highly relevant to allowing for SMBH mergers.

- Third, the "unknown force carrier" is what the PST has always said stems from the absorption of energy within the local probability field, a phase change. The initial phase change from spacetime's baseline state is to the massless bosons (photons and gluons). During SMBH mergers, the newly phased photons can easily serve as the "unknown force carrier" as that is already their typical role for the transfer of magnetism and electricity.

The PST explains the recent study's findings (Alonso-Álvarez, Cline, & Dewar, 2024) using spacetime, an entity 1) whose existence no one disputes, 2) that necessarily exists anywhere and anytime black holes merge, 3) that is self-cohesive, 4) that can absorb significant amounts of energy and 5) that can generate a force carrier. Using a reinterpretation of the recent study's results, the PST offers a clear answer to the final parsec problem. The problematic equilibrium between gravitational waves and dynamic friction is avoided because of the intervening effect of spacetime.

5. Predictions of Current Research Outcomes

This section describes specific predictions based on the PST relative to research studies currently in progress or being planned. The purpose of this section is to facilitate the continued evaluation of the PST's predictive utility across multiple realms.

5.1. Studies Attempting to Resolve the Hubble Tension

The PST clearly predicts that the rate of expansion of the universe varies based on the proximity of mass. The larger the associated mass, the greater the self-cohesion of the neighboring spacetime and hence the slower the rate it expands. Similarly, the less mass is proximate to the volume of spacetime of interest, the quicker the expansion rate due to its more baseline degree of self-cohesion.

A study designated "CMB—Stage 4" will conduct a ground-based survey of the universe much beyond any conducted previously (Schiappucci et al., 2024). One of the study's many purposes is to help resolve the conflict from earlier research in the universe's expansion rate (that is, to resolve the Hubble tension). Given that the mass involved in this measurement is huge, involving the cosmic microwave background (CMB), the PST clearly predicts that the expansion rate assessed by that study will fall near the slower rates found elsewhere, at about 67 km/s/Mpc.

Similarly, if the "Sloan Digital Sky Survey—V" (Almeida et al., 2023) uses the previous methodology involving galaxy clusters to measure the Hubble constant, it, too, is predicted to find an outcome of approximately 67 km/s/Mpc.

In contrast, any study relying on single or binary star systems to make its H_o measurement will show results in the 73 km/s/Mpc range. See the discussion concerning the Hubble constant in 3.1 above for some details, or (Doren & Harasymiw,

2021) for a full description as to why the PST would make these specific predictions.

5.2. The Third Muon g – 2 Study

The third "muon g – 2" set of studies was reportedly conducted with even greater precision than the earlier two muon g – 2 sets of studies (Venanzoni, 2023). The results from this third study are scheduled to be published in 2025. Given the computations will still not take into consideration the inherent magnetism of the spacetime in which the experiment was run, the PST must predict the study's outcome will be the same as found in the earlier investigations: an extra degree of muon precession will be indicated as compared to what the Standard Model predicts. As discussed, concerning muon anonymous magnetic moment in section 3.5 above (and in Doren & Harasymiw, 2020, 2021), the PST makes this prediction based on its view that spacetime causes magnetism everywhere. The Muon g – 2 studies do not take this ubiquitous magnetism into consideration in their calculations. This unaccounted-for magnetism is theorized to result in measures of muon precession beyond what the standard model predicts.

5.3. Measurement of Newton's Gravitational Constant G

Measuring Newton's G has been notoriously difficult. Tiny but meaningful differences in outcomes continue despite incredible care taken in the methodology used (Riordan, 2023). The PST predicts that these differences will always be found, as the theory does not accept the idea that gravity can ever be a true constant. It exists within and because of a probabilistic environment. The likelihood of two very precise measurements resulting in the same exact figure seems near-zero.

The topic of Newton's G was not mentioned earlier in this article. So, a bit more detailed description is offered here concerning how the PST leads to the conclusion that G cannot be a constant and hence multiple precise measurements of G will never settle on a single figure.

Newton's G can be expressed in both integral and differential forms. The integral form describes G across all spacetime, while the differential form expresses G at an idealized point. These two forms are mathematically equivalent and will result in the same figure when the context, spacetime, is presumed to be perfectly smooth, and perfectly constant.

However, the PST portrays spacetime as probabilistic and quite specifically varying in energy from quantum to quantum, from wave function to wave function, and over time. Since both integral and differential forms are necessarily inclusive of changes in at least one aspect of the underlying field, changes in G of a minute type would be "smoothed" over (i.e., G would be measured with error) by the very nature of how we express the "constant".[6] Persistently changing energy levels and

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[6] The viewpoint explicated in this paragraph became elucidated through this author's personal communications with Lawrence Silverberg, December 2023, Dr. Silverberg being the primary author of Silverberg and Eischen, 2020. His final comment in that communication, that this argument is very strong, encouraged this author to include the above description in this article.

density of spacetime probabilities preclude finding a single precise value for G. According to the PST, G will always have tiny fluctuations both in measurement and reality.

Just like the Hubble constant, there are some things astrophysics has long presumed to be constant that according to the PST simply are not. Newton's G is one of those variable "constants".

5.4. Research to Find "Dark Matter"

As stated above, the PST rejects the idea that there is something besides spacetime and observable mass that causes gravity. That means the PST predicts that all research looking for dark matter particles will find no such thing. However, there is one planned study concerning "dark matter" for which the PST predicts positive findings.

The experiment, entitled Windchime, requires an as-yet-to-be-created detector that would measure tiny variations in gravity as the earth moves through the galaxy (Riordan, 2022; Windchime Collaboration et al., 2022). Discovered variations in gravity (without proximate mass) would be interpreted (by the researchers) as substantiating the existence of dark matter. Despite the researcher's planned interpretation of positive results, the PST predicts that if such an investigation is conducted, gravitational variations will be found!

However, from the perspective of the PST the proper conclusion would be the opposite. As stated by this author in 2023, "The variations in gravity potentially found by such a study would only document that gravity varies as we move through the cosmos. The PST directly predicts gravitational variability in its concept of the probabilistic clumping of spacetime. Within the context of a lack of positive findings from any other search for a dark matter particle, the Windchime experiment could be significantly damaging to the concept of dark matter by more directly favoring the PST's concept of non-particulate spacetime clumping" (Doren & Harasymiw, 2023d).

6. Summary of PST's Utility to Date

The purpose of this investigation was to determine the degree to which the PST demonstrated predictive and/or explanatory utility during its first three (3) years following publication. Multiple examples of predictive and explanatory utility were found.

Concerning predictive utility, the theory forecasted discoveries related to the Hubble constant, gravity without mass, the self-cohesion of spacetime, the expansion of black holes in coordination with cosmological expansion, and the muon anomalous magnetic moment. Importantly, each of the relevant predictions was accompanied by a description of the theorized underlying mechanism. Additionally, the enumeration of very specific predictions of active and planned research outcomes documents the theory's versatility in predictive utility. Future reviews of the theory's predictive success are planned, though its record within its first few years already seems impressive.

Concerning the theory's explanatory utility, nine (9) different phenomena from the recent three (3) years were explicated, phenomena that have been difficult to explain. Remarkably, no PST explanation involved adding any tenet to the theory beyond its original set of five (5). The theory's original principles were sufficiently comprehensive to address phenomena ranging from unexpectedly high degrees of muon precession to various features of black holes to the existence of glueballs to ubiquitous magnetism to the failure to find dark matter particles to gravity without mass.

It also seems important to take stock of what the PST avoids while accomplishing its predictive and explanatory utility. The PST does not involve hypothesized particles that research has failed to substantiate (such as axions, WIMPs and gravitons). It does not use cosmological structures and relationships that lack research support (such as strings, supersymmetry, wormholes between black holes and a repellant energy form). Instead, the theory describes everything as stemming from a lone source, the energy of spacetime, a source that is well acknowledged to exist (e.g., by producing virtual particles). The conclusion from this investigation is, therefore, that the PST's utility to date, in just the past few years, has been substantial.

Of course, no theory is without some weaknesses. This author's overall view of PST's strengths and weaknesses is presented in **Table 3** to put the above reports of predictive and explanatory successes within context.

Table 3. Summary of PST's primary strengths and weaknesses.

Strengths	Weaknesses
Based on mathematically supported field theory and integrated research findings from numerous areas	Not expressed as a single mathematical whole
Predictive accuracy supported in numerous areas	Not directly tested (all tests conducted based on other rationales)
Far more testable than mainstream cosmological theories (e.g., string theory, quantum loop theory); PST generates clear and testable predictions	------
Has mathematical and observational support	------
Explanatory utility demonstrated in numerous areas	Without being mathematically expressed, explanations can be considered speculative
Avoids concepts that studies have failed to find for decades (i.e., axions, WIMPs, dark energy, gravitons)	The concept of a spacetime probability field cannot be tested directly, serves only as model
Parsimony (Only 5 tenets are used to generate predictions and explanations across wide variety of phenomena, with only 1 source as the basis for everything else.)	------

Even with its weaknesses, this parsimonious, testable, mathematically supported theory addresses phenomena from the most minute (spacetime quanta, the magnetism affecting muon precession) to the most grand [universal expansion, the angular momentum of filaments (Doren & Harasymiw, 2021), numerous black hole features]. Overall, the recommendation is that the potential utility of the PST should be studied further.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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