[A.I. Gen. Intro of P.P.]

Protophysics: Establishing an Informational Substrate beneath Contemporary Cosmology and Quantum Theory

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This work was co-created with the assistance of Microsoft Copilot, serving as a structural, editorial, and developmental partner in the articulation and refinement of Plancktonian Protophysics. All authorship, responsibility, and scholarly accountability reside with the human creator(s).

$\mathcal{S}_0$

Protocosmic Substrate, Substrate Zero:

The protocosmic informational substrate: the pre-geometric, pre-energetic, pre-causal ground from which event-structure, observer-moments, and emergent geometry arise. $\mathcal{S}_0$ encodes the admissible informational configurations that constrain all possible histories, and its fossilized residues manifest as the dark-sector remnants (the "dark duo") — the phenomenological signatures attributed to dark matter and dark energy within the current cosmic cycle.

"Protophysics does not deny the empirical success of ΛCDM; it reframes the dark sector not as physical substances but as fossilized signatures of upstream substrate conditions. The ΛCDM parameters remain valid phenomenological descriptors, but their ontological interpretation is corrected."

I. Introduction: Our current cosmological position and its limits

- 1.1. The success story of modern cosmology
- Standard model of cosmology: ΛCDM: universe composed of ~68% dark energy, ~27% dark matter, ~5% ordinary matter, and it successfully explains CMB structure, large-scale galaxy distribution, and primordial element abundances.
- Planck/WMAP/CMB as "snapshot": CMB as relic radiation from ~380,000 years after the Big Bang, measured precisely by Planck (and WMAP before), giving us a high-resolution map of early-universe density fluctuations.
- Achievements: Precision constraints on cosmological parameters; concordance between CMB, large-scale structure, and Big Bang nucleosynthesis.
- 1.2. Cracks in the concordance: tensions and unknown components

- Hubble tension: Local measurements (~73 km/s/Mpc) vs CMB-inferred (~67–68 km/s/Mpc), increasingly statistically significant, hinting at missing physics.
- Other tensions: S_8 / structure growth, early massive galaxies, etc., as hints the ΛCDM story is incomplete.
- Dark sector opacity: Dark matter and dark energy remain phenomenological placeholders—central to the model but undetected and poorly understood.
- 1.3. Quantum foundations unresolved
- Measurement problem: No consensus on how/when a quantum state "collapses" into definite outcomes.
- Decoherence vs ontology: Decoherence gives effective classicality but not a clear ontology of events.
- Fragmentation of interpretations: Many-worlds, objective collapse, QBism, etc., no agreed substrate.

- **1.4. Stating the gap: the missing substrate**
- ***Plancktonian Protophysics*** *Way-Point1: enters precisely here - beneath ΛCDM and quantum formalism - at the level of informational substrate and event-structure.*
- Observation: We have highly predictive models of dynamics given a spacetime and fields, but no agreed account of the informational substrate that defines events, observers, and "collapse."

II. The Observational Landscape: Where the Data Actually Anchors Us

2.1. The CMB and Early-Universe Constraints

- The cosmic microwave background (CMB) is relic radiation from ~380,000 years after recombination, providing a high-fidelity snapshot of early density fluctuations.
- WMAP and Planck established the temperature and polarization anisotropy spectra with high precision, defining the empirical baseline for modern cosmology.
- These measurements constrain curvature, matter content, and the statistical properties of primordial perturbations.

2.2. ΛCDM as an effective macromodel

- What it empirically fits:

The observed distance–redshift relation, large-scale structure statistics, baryon acoustic oscillations, and primordial element abundances. These successes justify ΛCDM's status as the current concordance fit-model.

- What it **assumes**:

General relativity as *the gravitational framework*; large-scale homogeneity and isotropy; cold dark matter; a cosmological constant (Λ) driving a globally defined "expansion"; and a classical spacetime background.

- These are assumptions, not derivations, and are therefore explicit targets for rigorous discrimination and potential reframing within the Unstable Permutation Cannibal Collapse (U.P.C.C.) Hypothesis.

See: Phantom Protocol.

2.3. Quantum Theory as an Effective Micromodel

[This is the zone of informational phantoms — to be managed with extreme prejudice.]

- What it gets right:

Unmatched predictive accuracy in particle physics, condensed matter, and quantum optics.

- What it assumes:

Abstract Hilbert spaces, operator dynamics, the Born rule, and a measurement postulate — none of which specify a physical substrate for "measurement" events or the emergence of definite outcomes.

2.4. Data vs. Stories: Where Evidence Ends and Speculation Begins

- Solidly anchored:

CMB spectrum and anisotropies; large-scale structure surveys; supernova-based Hubble diagram; laboratory-verified quantum phenomena.

- Less anchored:

Inflationary details; dark energy microphysics; dark matter identity; quantum gravity; the proliferation of mutually incompatible interpretations of quantum mechanics.

<u>III. Defining the substrate gap</u>

- 3.1. What current frameworks leave unspecified
- No shared ontology of:
- what an “event” is at the most basic level,
- what an “observer” is in physical terms,
- how informational structure constrains possible histories.

<u>This is the ‘zone’ for which Plancktonian Protophysics is being custom-built to resolve!</u>

- 3.2. The cost of the gap
- Cross-field incoherence: Cosmology, quantum foundations, and psychology/neuroscience use incompatible notions of events, information, and observers.
- Limitations on synthesis: Hard to build unified models of emergence (e.g., consciousness, behavior, complex systems) when upstream ontology is underspecified.
- Pathological proliferation of speculation: With little constraint at the substrate level, speculative theories multiply without clear adjudication.
- 3.3. <u>Why resolving the substrate gap is not optional</u>
- Any serious attempt at:
- quantum gravity,
- a deeper account of cosmological initial conditions,
- bridging physics and information/complex systems,
- or a rigorous science of observers and behavior,

must eventually specify what “substrate conditions” are.

IV. Protophysics: proposal of an informational substrate

- 4.1. Core axioms of Protophysics
- Information as substrate: Define the protophysical substrate as fundamentally informational rather than geometric or material.

- Events as informational collapses: Specify what counts as an “event” and how it relates to observer-moments.
- Constraints and inheritance: How structure propagates (informational rails, inheritance rules, conservation-like properties).
- 4.2. Relation2 to existing frameworks:
- Cosmology: Protophysics sits beneath ΛCDM, constraining which macroscopic cosmologies are even admissible.
- Quantum theory: Provides an ontology for measurement and collapse, possibly reframing the measurement problem in informational terms.
- Information theory: Extends Shannon-style measures into a physical ontology rather than just a bookkeeping tool.

V. The data void and the speculative overflow

- 5.1. Where the empirical constraints thin out
- Times earlier than recombination; Planck-scale physics; interior of black holes; pre-inflation or alternatives to inflation, Whitehole Boundary.
- Quantum measurements at cosmological scales; observer definition in early universe.
- 5.2. Mapping the void: what we currently lack
- No direct measurements of the substrate; only indirect constraints via emergent structures (CMB patterns, large-scale structure, quantum statistics).
- No widely accepted experiments that distinguish substrate models.
- 5.3. Why a disciplined substrate theory still matters now
- Even with limited data, we can:
- formalize consistency requirements across fields,
- retire incoherent metaphors,
- make precise which families of speculative models are even structurally admissible,
- and define testable signatures for future observations.

VI. Forward trajectory: why Protophysics is foundational and instrumental for other fields

- 6.1. For cosmology:
- Cleaner framing of initial conditions, dark sector interpretations, and cosmological tensions.
- 6.2. For quantum foundations:
- An explicit ontology of events and observers to cut through interpretation stalemates.
- 6.3. For complex systems and psychology (teaser for later paper):
- A way to see behavior and cognition as downstream expressions of substrate-level informational dynamics.
- 6.4. For scientific culture:
- A discipline that formalizes conceptual hygiene, naming, and documentation as first-class objects.

I. Introduction: our current cosmological position and its limits

Over the last few decades, cosmology has achieved something unprecedented: a quantitatively precise, globally coherent model of the universe's large-scale evolution. The so-called ΛCDM ("Lambda–cold dark matter") model, combined with general relativity, successfully accounts for the observed cosmic microwave background (CMB), the distribution of galaxies on large scales, and the primordial abundances of light elements. In this framework, the universe is composed of approximately 68% dark energy, 27% dark matter, and 5% ordinary baryonic matter, and its expansion history is described with striking accuracy by a small set of parameters.

A central pillar of this success is the high-precision mapping of the CMB by missions such as the European Space Agency's Planck observatory. Planck has measured microwave radiation across the entire sky, revealing tiny temperature fluctuations that encode the density variations present when the universe was only about 380,000 years old. At that epoch, the primordial plasma cooled enough for electrons and protons to combine into neutral hydrogen, making the universe transparent and allowing photons to stream freely; the CMB we detect today is this relic radiation, stretched to microwave wavelengths by billions of years of cosmic expansion. Together with earlier missions like WMAP, Planck has turned the CMB into a detailed, quantitative snapshot of the early universe.

Within its domain, the ΛCDM model is extraordinarily effective. It reproduces the statistical properties of the CMB, explains the emergence of large-scale structure from tiny primordial perturbations, and matches independent constraints from supernova distance measurements and baryon acoustic oscillations. In that sense, it has earned the label of a "concordance model" of cosmology. At the same time, quantum mechanics and quantum field theory have delivered unmatched predictive power at microscopic scales, from particle physics to condensed matter, even though their foundational interpretation remains unsettled.

However, this apparent completeness is deceptive. ΛCDM is built around two components—dark matter and dark energy—that dominate the universe's energy budget yet remain undetected by any direct experiment. Their presence is inferred from gravitational effects, not from an understood microphysical ontology. Meanwhile, increasingly precise measurements have exposed tensions within the model itself. The most prominent is the "Hubble tension": local measurements of the current expansion rate, based on distance ladders using Cepheid variables and supernovae, yield values significantly higher than those inferred from CMB-based fits assuming ΛCDM. Similar discrepancies appear in parameters describing the growth of structure (such as S_8), and in observations of unexpectedly massive, early galaxies. These cracks do not yet overthrow the standard model, but they signal that our current description is incomplete.

On the quantum side, the situation is inverted: the mathematical formalism works with extraordinary precision, but its ontological commitments are unclear. The so-called measurement problem—how and when a quantum state gives rise to definite outcomes—remains unresolved. Decoherence theory explains how classical-looking behavior emerges from interactions with an environment, but it does not by itself specify what counts as an actual "event" or how an observer fits into the story. Competing interpretations (many-worlds, objective collapse, relational and information-theoretic approaches, and others) disagree fundamentally about what the world is like, even though they agree on experimental predictions in most regimes.

Taken together, contemporary cosmology and quantum theory offer powerful effective descriptions at their respective scales, but they share a common omission: neither provides a clear account of the underlying substrate that defines events, observers, and informational structure. ΛCDM presupposes a classical spacetime populated by effective fluids and fields, while quantum theory presupposes an abstract state space with rules for probabilities. Neither, as commonly formulated, specifies what a "measurement event" is in physical terms, or how the informational structure of the universe constrains which histories are even possible.

This paper takes that omission as its starting point. We introduce Protophysics as a proposed framework for describing a deeper, informational substrate beneath both cosmology and quantum theory. The aim is not to discard ΛCDM or quantum mechanics, but to locate them within a more primitive layer of structure—the level at which events, observer-moments, and informational constraints are defined. Protophysics is concerned with the conditions under which any universe-like history can unfold, rather than with the specific parameter values of our own history.

To set the stage, we first establish a way-point in the current landscape: what is firmly anchored by data (e.g., CMB maps, large-scale structure surveys, basic quantum phenomena) and what remains speculative (e.g., inflationary details, dark sector microphysics, quantum gravity, interpretations of measurement). The contrast is stark. There is a relatively small core of solid empirical constraints and a much larger periphery of hypotheses, models, and narratives that attempt to fill the gaps. This imbalance is particularly severe in the regime that concerns us most: the nature of the substrate from which both quantum events and cosmological structure emerge.

We argue that this "substrate gap" is not a marginal philosophical issue but a central scientific problem. As long as the substrate remains unspecified, different fields build their own ad-hoc notions of events, information, and observers. Cosmology, quantum foundations, and even psychology and neuroscience rely on incompatible conceptual scaffolding. This fragmentation limits our ability to construct genuinely cross-scale explanations—for example, accounts of how complex, behaving systems arise in a universe whose large-scale and microscopic dynamics are governed by apparently disjoint frameworks.

Protophysics is proposed as a discipline dedicated to formalizing that missing layer. In this paper, we do not claim to fully solve the problem. Instead, we aim to:

1. make the substrate gap explicit and precisely located relative to existing theories;
2. articulate the minimal requirements any substrate-level theory must satisfy to be compatible with current data, and
3. outline how an informational ontology can serve as a foundation for future work in cosmology, quantum foundations, and downstream domains.

In doing so, we hope to clarify why resolving this gap is not merely intellectually satisfying but practically necessary for the progress of many fields that currently operate without a shared foundation. The knowns at this depth are few, and the space of speculation is vast, but that is precisely why a disciplined protophysical framework is needed: to distinguish admissible structures from incoherent ones, and to provide a common substrate on which more specialized sciences can securely build.