

Inverse Problems, Underdetermination, and the Ontological Status of Photons in Modern Physics

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Abstract

Modern physics relies on the detection and analysis of electromagnetic signals. From atomic spectroscopy to observational cosmology, empirical data are obtained as structured responses of detectors to incoming radiation.

However, the theoretical narratives constructed from these signals routinely go far beyond what is logically fixed by the measurements themselves. This paper argues that radiation-based observation defines a fundamentally ill-posed inverse problem: many distinct physical configurations can give rise to the same detected electromagnetic patterns.

As a result, claims about particles, fields, spacetime geometry, and cosmic expansion are systematically underdetermined by the data used to support them. What experiments constrain are not internal structures, but the channels through which unknown structures couple to radiation.

We therefore argue that much of contemporary physics conflates a phenomenology of electromagnetic interaction with an ontology of matter and geometry, and that a structural, constraint-based interpretation is required to separate what is measured from what is assumed.

1 Introduction: What Do We Actually Measure?

All physical measurements in fundamental physics ultimately reduce to the registration of electromagnetic signals by detectors. What is recorded are responses of macroscopic devices as functions of time, frequency, and direction of arrival.

These responses are later described using terms such as “photons”, “intensity”, and “polarization”, but these are interpretive layers imposed on the raw data.

No experiment directly observes electrons, quarks, spacetime curvature, or cosmic expansion. Those entities are inferred from patterns in detected electromagnetic signals.

This paper asks a simple but radical question:

What is logically implied by electromagnetic detection events, and what is merely assumed?

2 The Inverse Problem of Physics

Forward modeling dominates theoretical physics:

structure \rightarrow predicted radiation

A microscopic model is postulated, field equations are written, and the radiation pattern that should follow from that model is computed.

Experiments, however, operate in the opposite direction:

measured radiation \rightarrow inferred structure

Only the radiation is observed; the structure is reconstructed.

This inversion is mathematically ill-posed. Multiple distinct microscopic or macroscopic configurations can generate identical radiation patterns. Thus, the mapping from observation to ontology is fundamentally many-to-one.

Modern physics often appeals to the reversibility of its fundamental equations as a justification for this inversion. If the equations are time-reversible, it is implicitly assumed that the underlying structure can, in principle, be reconstructed from its radiative output.

This assumption is false.

Reversibility of differential equations does not imply reversibility of physical processes. The act of radiation emission, propagation, and detection is not a differential operation — it is an *integral* one.

Radiation detectors do not measure instantaneous microstates. They integrate energy, phase, and momentum fluxes over time, area, and frequency bands. Integration is an irreversible operation: distinct microscopic histories collapse into the same macroscopic result.

A simple macroscopic example illustrates this. Consider a vibrating object emitting sound. A microphone records only the integrated pressure waveform at its membrane. Infinitely many internal motions of the object could have produced the same recorded signal. The internal structure is not recoverable from the sound, even if the wave equation is time-reversible.

The same applies to photons.

Once radiation has been integrated over:

- time,
- detector area,
- frequency resolution,
- environmental interactions,

the detailed microstate of the source has been irreversibly lost.

Even in principle, reconstructing the emitting structure from the detected radiation would require reversing not only Maxwell's equations, but also the entire macroscopic measurement chain: thermal noise, decoherence, absorption, and coarse-graining.

This is physically impossible.

Therefore, the inverse map

$$\text{radiation} \rightarrow \text{source}$$

does not exist as a realizable physical operation, even if it exists as a formal solution of idealized equations.

When physics infers electrons, atoms, or spacetime geometry from photon data, it is not inverting the laws of nature. It is choosing one convenient representative from a large equivalence class of hidden structures that could have produced the same radiation.

The success of such models reflects their internal coherence and predictive power, not their ontological uniqueness.

The same irreversibility appears at the microscopic level.

Quantum theory explicitly replaces microstates by probability distributions. What is predicted and measured are not trajectories or configurations, but expectation values, transition probabilities, and spectral intensities.

A probability distribution is an information-compressing object. Infinitely many distinct underlying configurations can give rise to the same probability law. Once a system is described by a distribution, the detailed microstate has been irreversibly discarded.

Mathematically, this is unavoidable: the mapping

$$\text{microstate} \rightarrow \text{probability distribution}$$

is many-to-one.

No inversion exists.

Even with perfect knowledge of all quantum probabilities, amplitudes, and correlation functions, the underlying physical realization remains underdetermined. Different microscopic mechanisms can generate identical statistical predictions.

Thus, quantum measurement compounds the inverse problem rather than solving it. It replaces unknown structure with probability, and probability cannot be inverted into ontology.

The macroscopic and microscopic cases therefore share the same logical defect: both integrate over hidden degrees of freedom, destroying the information required to reconstruct what actually exists.

Radiation data plus probability theory does not reveal the world. It reveals only the stable statistical interface between hidden structure and observation.

There is an even deeper obstruction.

Not only is the physical world irreversible, but our knowledge of it is radically incomplete. We do not merely lack the ability to perform the inverse map from radiation to source — we do not even know what space of possibilities that inverse map would have to range over.

In order to reconstruct a physical structure from its radiative output, one would need to know:

- all possible kinds of microscopic constituents,
- all possible modes of interaction,
- all possible ways in which structure couples to radiation.

But modern physics knows only a tiny subset of what may be physically realizable. Any inversion procedure can only search within the space of models that has already been imagined.

Thus even if radiation data were infinitely precise, and even if no information were lost in detection, the reconstruction problem would remain underdetermined because the model space itself is unknown.

What is called “reconstructing the electron” or “measuring spacetime curvature” is therefore not an inversion of nature, but a projection of data onto a preselected conceptual vocabulary.

The following sections will show that this is not a philosophical quibble but a structural feature of how photon-based science operates.

3 Underdetermination by Radiation Data

In experimental practice, what is called a “photon” is not a directly observed physical object. It is a name given to a detected excitation of an electromagnetic signal registered by a detector.

What is actually measured is far more primitive:

- an amplitude,
- at a given frequency or frequency band,
- arriving at a detector at a given time and direction.

From these raw data, a counting procedure is applied, and the result is described as a “photon flux.” This linguistic shift creates the illusion that discrete objects have been observed. In reality, what has been recorded is a structured electromagnetic response of a macroscopic device.

Nothing in this measurement reveals:

- what produced the radiation,
- how it was generated,
- what internal structure the source possessed,
- or even whether the radiation originated from a localized emitter at all.

The data consist only of spectral and temporal patterns in the detected field.

From these patterns, modern physics proceeds to infer not merely the existence of a source, but its detailed internal constitution: electrons, orbitals, nuclear states, spacetime curvature, cosmic expansion, and more.

This inference is not forced by the data. It is a projection of a theoretical model onto a limited set of measured amplitudes.

The same spectral distribution can, in principle, be generated by many distinct physical mechanisms, involving different geometries, different internal dynamics, and different forms of locality.

Radiation measurements therefore do not determine ontology. They constrain only the space of possible interaction channels between some hidden structure and the electromagnetic field.

What is observed is not matter, not particles, and not geometry, but the interface through which an unknown structure communicates with radiation.

An additional layer of underdetermination is introduced by the role of the speed of light.

In practice, no experiment measures the one-way speed of a photon. What is operationally accessible is only round-trip signal timing, synchronized by clocks whose synchronization already assumes a value for the propagation speed.

The quantity denoted by c is therefore not an empirically measured velocity of individual photons, but a conventionally fixed parameter that defines how time and distance are coordinated in electromagnetic experiments.

Once this convention is adopted, all subsequent inferences about distance, simultaneity, and geometry are expressed in units that already presuppose c .

As a result, when radiation is detected at a given time and frequency, there is no independent way to determine how fast it actually propagated, how long it traveled, or what spatial path it followed.

All geometric reconstructions — whether of atomic size or cosmic scale — are therefore mediated by a fixed kinematic assumption built into the measurement protocol itself.

This further amplifies the inverse problem: not only is the source unknown, but even the spacetime scaffolding used to locate it is inferred through a parameter that is not directly observed.

A further epistemic limitation follows from the indistinguishability of radiation quanta.

Individual photons, even in principle, cannot be tagged, tracked, or re-identified. There is no operational procedure that allows one to say: “this detected photon is the same entity that was emitted at that source.”

Yet modern physics routinely assigns to detected radiation a precise travel time, distance, and trajectory.

This assignment is not based on identifying a physical object moving through space, but on assuming that whatever excitation produced the detector signal propagated along a predefined spacetime geometry at a predefined speed.

In other words, spacetime coordinates are imposed on events whose carriers are themselves unobservable as individuals.

The result is a geometrical narrative built on entities that cannot be followed, distinguished, or verified as persistent carriers of information.

Finally, modern physics assigns momentum to photons. Once momentum is attributed, radiation must respond to gravity: its trajectory is bent by gravitational fields.

Therefore, even if a photon were emitted from a sharply localized source, its path through the universe is not straight in any absolute sense. It is continuously deflected by every mass distribution it encounters.

As a consequence, the geometrical position of the emitting source is not recoverable from the detected radiation, even in principle. The path taken by the radiation is unknowable, and so is the mapping between emission event and detection event.

What reaches a detector is not a geometrically traceable messenger, but a field excitation whose history is irretrievably scrambled by the structure of spacetime itself.

Thus, radiation does not carry reliable information about where its source is, only that some interaction channel exists.

Radiation as Data, Geometry as Model

Let a detector register an electromagnetic signal

$$A(\omega, t, \hat{n}),$$

where A is the measured amplitude, ω is frequency, t is detection time, and \hat{n} is the incoming direction.

This is the entirety of the raw empirical data.

From this, physics constructs a geometrical narrative by introducing a mapping

$$(\omega, t, \hat{n}) \longrightarrow (x, y, z, \tau),$$

assigning each detected signal to a spacetime event of emission.

This mapping requires:

- a propagation speed c ,
- a spacetime geometry $g_{\mu\nu}$,
- and a dynamical law for radiation trajectories.

Symbolically, the reconstruction takes the form

$$(x, y, z, \tau) = \mathcal{G}(A(\omega, t, \hat{n}); c, g_{\mu\nu}, \text{dynamics}).$$

None of these geometric elements — c , $g_{\mu\nu}$, or the trajectory law — are measured by the detector. They are supplied by the theoretical model.

The same radiation data can therefore be mapped to different spacetime structures by choosing different \mathcal{G} . Geometry is not observed; it is inferred.

In particular, once photons are assigned momentum, their paths depend on the gravitational field:

$$\frac{dp^\mu}{d\lambda} + \Gamma_{\alpha\beta}^\mu p^\alpha p^\beta = 0.$$

Even in principle, the unknown gravitational field along the path makes the inversion from detection to emission non-unique.

Thus, all geometrical reconstruction from radiation is model-dependent, not observationally fixed.

The central conclusion is therefore unavoidable:

Radiation data constrain interaction patterns, but spacetime geometry is a model imposed upon those data, not something directly observed.

What is measured are electromagnetic amplitudes. What is inferred are distances, trajectories, sources, and structures.

These inferences depend on theoretical choices that are not fixed by the data itself.

In the following sections, we examine several representative cases — from atomic spectroscopy to astrophysical redshift — in which this gap between radiation data and geometric interpretation becomes especially transparent.

4 The Hydrogen Fallacy

Hydrogen spectroscopy is routinely presented as direct evidence of discrete electron energy levels. In textbooks and popular accounts, spectral lines are interpreted as electrons “jumping” between quantized orbits or orbitals.

What is actually observed, however, is far more modest.

A spectrometer records an electromagnetic signal as a pattern of intensities across frequency. On a screen or detector this appears as alternating bright and dark lines. These lines correspond to the frequencies at which radiation has been detected or not detected.

They are photon amplitudes, nothing more.

From these amplitudes, a narrative is constructed: electrons are said to emit photons when they move between allowed energy levels inside an atom. Orbitals are drawn, selection rules are written, and detailed internal geometries are assigned to the atom.

None of this is observed.

No electron is tracked. No orbit is seen. No internal motion is measured.

Only radiation frequencies and intensities are detected.

The identification of the radiation source as “an electron in a hydrogen atom” is therefore not a measurement, but a hypothesis. It is a particular choice of internal mechanism among many that could, in principle, generate the same spectral pattern.

Indeed, nothing in the spectral data by itself tells us:

- which internal degree of freedom emitted the radiation,
- whether the source was localized or distributed,
- whether the radiation originated from an electron, a proton, their interaction, or a more global field mode.

Yet for over a century, the interpretation that electrons jump between orbitals has been treated not as a model, but as a fact.

The familiar images of spherical s -states and dumbbell-shaped p -states are not visualizations of anything observed inside the atom. They are mathematical basis functions used to organize a pattern of photon frequencies.

The atom has been replaced by its spectrum, and the spectrum by a story about particles.

That story may be useful and predictive. It is not uniquely implied by the data that motivated it.

A closely related example is scanning tunneling microscopy (STM), often presented as a direct imaging of electronic structure.

STM does not detect photons. It measures an electrical current as a function of applied voltage and tip position. From these current–voltage characteristics, a spatial map is reconstructed and interpreted as the “geometry” of electron orbitals or surface electron density.

Once again, what is directly measured is only a macroscopic signal: a tunneling current between a metallic tip and a conductive surface.

From this signal, a detailed internal picture is inferred:

- shapes of orbitals,
- local densities of states,
- even individual “atoms” and “bonds”.

But the measurement itself provides no such ontology. It provides only a response curve of a coupled electronic system.

The STM image is therefore not a photograph of electrons. It is a model-dependent reconstruction of some hidden structure that influences tunneling probability.

Whether that hidden structure is best described as electron clouds, collective modes, vacuum polarization, or something else entirely is not determined by the measurement.

The same underdetermination appears here as in spectroscopy: a macroscopic signal is converted into a microscopic geometry by theoretical assumption, not by observation.

Both spectroscopy and scanning tunneling microscopy are commonly presented not merely as probes, but as identification tools. From spectral lines or tunneling maps, physicists claim to determine what substance is present: hydrogen, helium, iron, silicon.

This practice rests on a critical but rarely stated assumption:

If two systems produce the same measurement patterns, they are taken to be the same physical thing.

But this is not a law of nature. It is a pattern-recognition rule.

Spectroscopy and STM are optimized to recognize equivalence classes of signals, not to reveal underlying structure. They detect whether a measured response matches a known template.

Nothing in these methods guarantees that only one kind of physical reality can generate a given template.

If a different physical system — involving different internal constituents, different geometry, or different dynamics — were to produce exactly the same spectral lines or tunneling responses as hydrogen, no experiment based on those measurements could distinguish it from hydrogen.

Every expert would conclude that hydrogen was present, because the classification rule is built into the methodology.

This does not mean the identification is pragmatically useless. It means it is ontologically ambiguous.

The instruments recognize patterns. They do not observe what generates them.

In this sense, modern experimental physics operates more like a sophisticated pattern-matching engine than a microscope of reality.

It classifies signals into known equivalence classes, but it cannot distinguish between a genuine structure and a perfect imitation that produces the same radiation and tunneling statistics.

5 The Cosmological Analogy

The same epistemic structure that appears in atomic spectroscopy also dominates modern cosmology.

Astronomical instruments detect electromagnetic radiation:

$$A(\omega, t, \hat{n}),$$

the amplitude of incoming radiation as a function of frequency, arrival time, and direction.

From this data alone, cosmology reconstructs a geometric universe.

In particular, frequency shifts of radiation are observed:

$$z = \frac{\lambda_{\text{obs}} - \lambda_{\text{emit}}}{\lambda_{\text{emit}}}.$$

These redshifts are then interpreted through a spacetime model:

$$1 + z = \frac{a(t_{\text{obs}})}{a(t_{\text{emit}})},$$

where $a(t)$ is the cosmological scale factor.

From this, distances, cosmic expansion, dark energy, and even the age of the universe are inferred.

But nothing in the detected radiation directly measures $a(t)$, spacetime curvature, or expansion.

They are introduced by the reconstruction map

$$\mathcal{G} : A(\omega, t, \hat{n}) \longrightarrow (r, \theta, \phi, t_{\text{emit}}),$$

which assigns a geometrical position and emission time to each detected signal.

As shown earlier, radiation does not travel along known, straight, or traceable paths. Photons carry momentum and are deflected by gravitational fields. They can be scattered, delayed, redshifted, and re-emitted.

A detected photon arriving from a given direction \hat{n} need not have originated from a source located along that same line. Its true path may be highly convoluted, passing through gravitational lenses, plasma, or intervening matter before detection.

Nevertheless, cosmological reconstruction treats radiation as if it propagated along a simple geodesic in a known spacetime.

On this basis, structures such as galactic arms, filaments, voids, and large-scale geometry are drawn.

But these structures are not observed. They are images produced by applying a spacetime model to radiation data.

The same redshift pattern could, in principle, be generated by different physical mechanisms:

- spacetime expansion,
- gravitational redshift,
- cumulative scattering,
- or unknown interactions between radiation and intervening structure.

Radiation alone does not choose between them.

Thus cosmology repeats the same epistemic leap as atomic physics: it replaces a field of detected amplitudes by a detailed geometrical story, and then forgets that the story was imposed.

What telescopes see are photons. What cosmology claims to see is the universe.

6 Locality and Hidden Structure

Radiation does not reveal objects. It reveals interfaces.

What electromagnetic measurements constrain are the allowed channels through which some hidden structure can exchange energy, momentum, and phase with the surrounding field. These channels are what spectroscopy, scattering experiments, and detectors actually probe.

They do not probe what the structure *is*. They probe how it couples.

A detected photon carries information only about a boundary interaction:

$$\text{hidden structure} \longleftrightarrow \text{electromagnetic field}.$$

Everything inside that boundary is invisible to radiation.

Two radically different internal organizations can possess the same external coupling channels and therefore produce identical radiation patterns.

This leads to a fundamental misinterpretation in modern physics.

Stable interaction patterns — such as spectral lines, scattering cross sections, or tunneling responses — are reified into objects: electrons, atoms, quasiparticles, spacetime points.

But what is stable is not an object. What is stable is a *mode of interaction*.

Physics has taken persistent interfaces and mistaken them for fundamental entities.

From this perspective, what we call an “electron” is not a little thing inside space. It is a stable local pattern in how some deeper structure exchanges energy and momentum with the electromagnetic field.

What we call an “atom” is not a collection of particles. It is a structured region of locality with a characteristic set of coupling channels.

Radiation allows us to catalog those channels with extraordinary precision. It does not allow us to see what realizes them.

Modern physics is therefore not a theory of what exists, but a theory of how whatever exists interacts with radiation.

The hidden structure remains hidden.

7 Why the Models Still Work

The empirical success of quantum electrodynamics, atomic spectroscopy, and modern cosmology is not in dispute. Their predictions are extraordinarily accurate.

The reason is not that their ontologies are complete. It is that the same underlying physical structures are present in every experiment.

What we call an “atom” is not just an electron and a proton. It is a coupled system consisting of:

- charged constituents (protons and electrons),
- known interaction laws (electromagnetism, gravity, and others),
- the surrounding vacuum,
- and an unknown remainder, denoted here as U .

The term U represents all physical aspects of the system that are not captured by current theoretical constructs: unknown modes, unknown degrees of freedom, unknown couplings, and unknown background structure.

There is no empirical reason to assume that U is small. It may constitute the dominant part of what the system actually is.

When radiation interacts with such a system, the response depends on the entire composite:

$$\text{atom} = (\text{electron, proton, known forces, vacuum, } U).$$

Quantum electrodynamics and related theories model only the part of this composite that couples cleanly and repeatably to radiation. That part is sufficient to reproduce spectral lines, scattering cross sections, and tunneling currents.

But reproducing the interface does not mean describing the whole.

The success of these models therefore reflects the stability and universality of the coupling channels between matter and radiation. It does not imply that the internal constitution of matter has been exhaustively identified.

Reproducibility guarantees that the same hidden structure U is present in all experiments. It does not guarantee that U has been discovered.

A further reason these models appear so successful is methodological.

Over the past century, fundamental physics has increasingly adopted a practice in which theoretical structures are calibrated directly against observational data. Free parameters, effective couplings, renormalized constants, and fitted functions are adjusted until agreement with experiment is achieved.

This procedure is not a flaw — it is often unavoidable. But it has an important epistemic consequence.

When a model is tuned to reproduce what is observed, its success no longer demonstrates that its internal entities are real. It demonstrates only that the model has enough flexibility to absorb the unknown contribution of U into its parameters.

In effect, the unknown structure of reality is encoded into fitted constants.

The theory then appears to “predict” phenomena that it has, in fact, been trained to reproduce.

This does not make the theory false. It makes its ontology underdetermined.

The more successful the fit, the more invisible the hidden structure U becomes.

An additional, often overlooked, source of underdetermination lies in the structure of measurement itself.

Experimental data are never produced by a single unified observer. They are produced by distributed instruments: detectors, clocks, amplifiers, calibration chains, and data-processing pipelines, each operating within its own local frame of reference.

For measurements to correspond to a single physical quantity, these local frames must be coherently aligned. In practice, this alignment is achieved only approximately and operationally, through synchronization procedures, reference signals, and model-based corrections.

This means that what is called “experimental error” is not merely noise. It reflects a deeper lack of global coherence among observational localities.

From the perspective of Coherent Observational Epistemology (COE), every measurement is an act of partial alignment between independent observational domains. Perfect global alignment is neither achievable nor verifiable.

As a result, even the most precise data sets incorporate hidden, model-dependent assumptions about how different local observations are stitched together into a single picture of reality.

The unknown structure U therefore enters not only through the physics of matter, but through the epistemic architecture of measurement itself.

There is a final, structural reason why modern physical theories can drift away from the reality they claim to describe.

Over time, entire research communities become organized around metrics: citation counts, fit quality, likelihood functions, model consistency, and statistical significance. These metrics are not anchored in operational reality; they are anchored in agreement between models and data.

Once such metrics become institutionalized, a subtle inversion occurs.

Theories no longer compete to describe reality more faithfully. They compete to optimize the metrics by which success is measured.

A theory that better fits, better interpolates, and better absorbs discrepancies through adjustable parameters will outperform a theory that seeks deeper structural contact with reality but lacks immediate metric advantages.

In this regime, models are rewarded not for ontological accuracy, but for their ability to adapt to the metric environment.

From the perspective developed in this paper, this is precisely what one would expect in a system where:

- only radiation data are observable,
- internal structure is hidden,
- and geometric reconstructions are model-imposed.

When observation cannot anchor ontology, institutional metrics inevitably anchor practice instead.

The result is a stable but self-referential scientific ecosystem: highly predictive, internally coherent, and increasingly detached from the question of what actually exists.

This does not make modern physics useless. It makes its ontological claims fragile.

Recognizing this fragility is not a rejection of science, but a necessary step toward restoring coherence between what is measured, what is modeled, and what is believed to be real.

8 Toward a Structural Interpretation

The purpose of the preceding analysis is not to propose a new ontology of particles, fields, or hidden substances. It is to clarify what kind of knowledge radiation-based science can and cannot provide.

What experiments actually deliver are structured datasets:

$$A(\omega, t, \hat{n}),$$

amplitudes as functions of frequency, time, and direction. From these, physics constructs models that are extraordinarily effective for prediction and control.

But prediction is not explanation.

A model that reproduces amplitudes is a bookkeeping device unless it identifies the constraints that make those amplitudes possible.

A structural interpretation therefore shifts the question from:

“What objects exist?”

to:

“What constraints must any hidden structure satisfy in order to produce the observed radiation patterns?”

These constraints include:

- locality — interactions occur through limited, structured channels;
- stability — some patterns persist while others decay;
- selectivity — only certain modes of energy exchange are allowed.

These are not assumptions about what reality is made of. They are necessities imposed by what is observed.

The familiar language of electrons, atoms, and fields is one way of organizing these constraints. It is not the only way, and it is not directly measured.

A structural approach does not replace one set of entities with another. It replaces entity-based storytelling with constraint-based explanation.

9 Relation to Coherent Observational Epistemology

The analysis developed in this paper is an explicit application of the framework of Coherent Observational Epistemology (COE) [1].

COE treats observation not as access to objective reality, but as a process of coherence formation between independent localities through finite information channels.

In modern physics, these channels are electromagnetic.

What is usually called a “measurement” is therefore a triple process:

$$\text{local physical process} \longleftrightarrow \text{radiation channel} \longleftrightarrow \text{detector locality}.$$

The inverse problem described in this paper is exactly the COE claim that:

global structure cannot be reconstructed uniquely from locally coherent signals.

Spectroscopy, cosmology, and scanning probe microscopy all operate by constructing global models from radiation-mediated alignments of independent local observation frames.

COE predicts that such reconstructions will be underdetermined, model-dependent, and sensitive to coherence assumptions — precisely what is found in practice.

The hidden structure U introduced in this paper is not a new physical substance; it is the COE recognition that observationally invisible degrees of freedom necessarily exist whenever coherence is achieved without full informational closure.

10 Conclusion

Modern physics has achieved an extraordinary mastery of radiation. It can predict, manipulate, and classify electromagnetic signals with remarkable precision.

What it has not achieved is a direct access to the structures that generate those signals.

The central result of this paper is not that current theories are wrong, but that their ontological interpretations are underdetermined by the data on which they are based. Photon measurements constrain interaction patterns; they do not reveal the internal constitution of the systems that produce them.

The gap between what is measured and what is claimed to exist is not a technical problem that can be closed by more precise instruments or larger datasets. It is a structural feature of any science that infers geometry and substance from radiation.

Recognizing this limitation does not weaken physics. It clarifies its domain.

Physics excels at describing how hidden structures couple to observable channels. The question of what those structures are remains open — and must be approached with methodological humility rather than narrative certainty.

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