On the Possibility of Cosmology: Spacetime Actualism and the Process-Relational Alternative

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Abstract: Contemporary cosmology often proceeds as if reality were exhausted by actualized structures representable within coordinate frameworks such as the four-dimensional spacetime manifold. Whitehead diagnosed this tendency as the "bifurcation of nature," and Eastman's critique of "spacetime actualism" names its contemporary form: the presupposition that the real is nothing but the actual, and the actual nothing but what can be located within the manifold, entailing a tenselessly given block and a closed future. We reframe these critiques as a question about the conditions of possibility of cosmology itself: what must the universe be like to evolve conscious physicists capable of mathematical and experimental inquiry? Drawing on Whitehead's distinctions between homogeneous and heterogeneous thought and between coordinate and genetic analysis, we argue that possibility is ontic—real *potentiae*—and that spacetime is derivative from more fundamental processes of actualization. Two test cases develop the claim: Eastman's Lakatosian critique of the Big Bang research program, and Kastner's Relativistic Transactional Interpretation of quantum theory, in which the metric emerges from transactional processes. The result is a reorientation of cosmology toward an integrative, process-relational view able to honor the achievements of physical science while doing justice to the real becoming of knowers within nature.

Keywords: temporal ontology; eternalism; spacetime actualism; process philosophy; Whitehead; transactional interpretation; quantum foundations; real potentiae; emergent spacetime; philosophy of cosmology

1. The Bifurcation of Nature and the Limits of Spacetime Actualism

Every working physical cosmologist is informed by a metaphysical imaginative background, explicitly stated or not. The dominant view in contemporary cosmology pictures the universe as a four-dimensional manifold of events, each with determinate spacetime coordinates, the relations between which being fully determined by field equations of extraordinary scope. This picture is among the great scientific achievements of the human mind. But a rarely acknowledged metaphysical presupposition underlies it that should make clear its limits as ontology. This presupposition is that the real is exhausted by the actual, and that the actual is exhausted by what can be located within the manifold. Timothy Eastman has given this presupposition the name *spacetime actualism*.[1] Our first task is to show that, whatever its merits as an instrumental model, it

[1] It is important here to disambiguate our terminology (with appreciation to Ben Snyder, personal communication). In contemporary analytic modal metaphysics, "actualism" names the thesis, opposed to Lewisian modal realism and other forms of "possibilism," that whatever exists is actual. Spacetime actualism, as intended here and in the quantum foundations literature, is a different and more specific doctrine. In our usage, an actual is simply an element of the spacetime manifold, that is, an invariant event (see Kastner (2025a), "The Arrow of Time," 9–10), and spacetime actualism is a bundle of positions including (i) the identification of the real with the fully determinate actual, leaving no ontological standing for *potentiae*; (ii)

cannot be the last word in physics or in metaphysics, not only because of theoretical advances in physics itself, but because it cannot account for the very inquiry that produces it.

Alfred North Whitehead diagnosed a century ago the deeper metaphysical disorder of which spacetime actualism is a symptom. In *The Concept of Nature* (1920) he called it the bifurcation of nature, which consists in the splitting of the world into two systems of reality that are then impossible to coherently rejoin. On one side stands the causal nature of physical theory—the modeled charges, wavelengths, and fields that textbooks and popular science media proclaim are the really real. On the other stands the apprehended nature of lived experience—the green of the leaf, the warmth of the sun, the song of the bird, and the felt importance by which some things matter to us more than others. The first system is granted full ontological standing despite remaining "conjecture," while the second, despite being directly experienced, is demoted to mere appearance, a "dream," a private psychological projection with no purchase on the world as it is in itself.[2] Whitehead's protest was not sentimental but ontological. There is only one nature, that disclosed in perception, and to bifurcate it is to saw off the branch on which the possibility of natural knowledge itself is perched. The green of a leaf and the wavelength of a photon are not two natures but two abstractions from one experiential occasion. To reify either at the expense of the other is to commit what he would later call the fallacy of misplaced concreteness.[3]

Spacetime actualism is this same bifurcation blown up to the scale of the cosmos. The qualitative, valuative, and temporal features of experience—including, conspicuously, the conscious experience of the physicist—are treated as epiphenomenal illusions ultimately reducible to the geometry of spacetime, as if the conjectured model could somehow give rise to its dreaming modeler. We shall argue that this view is not merely scientifically impoverished but metaphysically incoherent. A cosmology built on spacetime actualism cannot account for its own possibility as an act or product of knowing, because knowing has precisely the character—conceptual entertainment of alternatives, evaluation, an aim toward truth—that the coordinate scheme is designed to bracket out. The remedy is not to abandon the coordinate scheme but to recover its status as an abstraction, and to re-situate it within the concrete process from which it emerges.

2. The Conditions of Possibility of Cosmology

Our title is deliberately double. Cosmology can account for its own possibility only if possibility is not merely a name for our ignorance, but a real ingredient in the universe's becoming. If cosmology is to tell a genuine story of emergent novelty and historical development, the universe cannot be a finished block of actual facts already laid out in a manifold. In a universe whose spacetime events are all tenselessly actual, becoming would have no ontological standing. Cosmic history would be reducible to a static geometry narrated after the fact. But cosmology is also possible in a second, reflexive sense: the universe must be the kind of process capable of giving rise to inquirers who can measure, mathematize, conjecture, and care about truth. These two senses are not independent. The same ontic openness that makes the cosmos a creative advance

the tenseless givenness of the spacetime manifold of events (eternalism); and (iii) the consequent closure of the future. In the taxonomy of the modal metaphysics debate, the present proposal would itself count as a form of actualism of the dispositionalist sort (see Vetter, *Potentiality: From Dispositions to Modality*, 2015), since real *potentiae* are always the potentiality of actualities rather than free-floating possibilities. Nothing in our argument requires merely possible objects, that is, fully determinate concrete individuals inhabiting other worlds (Lewis, *On the Plurality of Worlds*, 1986). What our argument requires is rather that the ontology harbor real (not merely logical or epistemic) potentialities, conditioned and intensively graded, and that the future remain genuinely open. No merely possible occasions pre-exist their concrescences, as if awaiting admission into existence. When a transaction actualizes, nothing that was already determinate is promoted; rather, a genuine novelty becomes.

[2] Whitehead, *The Concept of Nature*, 30.

[3] Whitehead, *Science and the Modern World*, 51.

rather than a finished block also makes it a process capable, eventually, of flowering into knowers. Whitehead formulated the underlying methodological issue: "All difficulties as to first principles are only camouflaged metaphysical difficulties. Thus also the epistemological difficulty is only solvable by an appeal to ontology."[4] No amount of further epistemological refinement will allow contemporary actualist cosmology to find room for inquiring cosmologists within its scheme. The reflexive question is the ontological one of what nature must be like such that knowers can occur within it.

In the vocabulary of contemporary temporal ontology, spacetime actualism, as defined here, includes eternalism: the thesis that past, present, and future events are equally real constituents of a tenselessly given spacetime manifold.[5] Our position bears some affinities with the growing block theory rigorously formulated by Correia and Rosenkranz in *Nothing to Come* (2018), and with the evolving block universe proposed within relativistic cosmology by Ellis (2006), together with its crystallizing block refinement in Ellis and Rothman (2010). It differs from these positions, however, by locating the openness of the future neither merely in the nonexistence of future events nor in an advancing boundary of an otherwise constituted spacetime, but in the ontological reality of the *potentiae* from which determinate events precipitate. The actualized spacetime order grows event by event as transactions occur. The manifold is therefore the accumulating coordinate record of becoming rather than its antecedent container. Our reflexive argument should accordingly be distinguished from arguments for temporal becoming that appeal to the phenomenology of passage. Empirical findings that ordinary subjects neither uniformly report a phenomenology of robust passage nor represent time as essentially dynamical (Latham, Miller, and No rton, 2020, 2021) may well blunt the phenomenological case, reinforcing deflationary treatments of passage experience within the block (Skow, 2015; Deng, 2013). However, the present argument is not directly answered by that outcome, since it concerns not how time *seems* but what the activity of scientific hypothesizing (in which alternatives are entertained as not yet decided) presupposes about the ontology of nature (at least if we assume science is in the business of uncovering *truth*). Even a conscious subject whose temporal phenomenology were entirely compatible with the block would still, in theorizing, acknowledge an in-principle contrast between settled actuality and possibility. Our claim is that an adequate cosmology must explain the reality and intentional efficacy of this contrast rather than merely redescribe its physical embodiment, and that spacetime actualism cannot do so while denying irreducible ontological standing to real *potentiae*.[6]

Cosmology's object must include its knower. There is no Archimedean standpoint outside the cosmos from which to survey it. The cosmologist is a late and intricate eddy within the very current being charted. A cosmology that cannot locate the cosmologist within its own ontology is to that extent inadequate to the facts. And a cosmology that positively denies the reality of the knower's constitutive features—the entertainment of possibility, the evaluation of alternatives, the directedness toward an aim—is not merely inadequate but self-refuting, for it saws away the conditions of its own assertion. It is always, in the end, a human being who reads the dial and frames the conjecture. If consciousness has no commerce with the totality of things, then physical science loses its empirical foothold.

The question we are pressing is transcendental, but in the post-Kantian, cosmological sense articulated by James Bradley. Following Bradley, by "transcendental" we do not mean Kant's inquiry into the conditions of possible knowledge sequestered in a human subject standing over

[4] Whitehead, *Process and Reality*, 189.
[5] See Miller, *Life in Four Dimensions: A Defence of the Block Universe Theory* (2026), for a recent systematic defense, directed especially against arguments for temporal dynamism from human experience, concepts, attitudes, and beliefs.
[6] See Kastner (2025a) and section 7 below on the transactional actualization of spacetime events, and section 4 on the reflexive argument from scientific hypothesizing.

against a merely apparent nature. We mean what he referred to as Whitehead's "transcendental cosmology": an inquiry into the generic conditions of self-actualization as such, conditions no longer of the representation of things but of their becoming, of which human knowing is one peculiarly intensified exemplification.[7] Our inquiry should be further distinguished from actualist renderings of the anthropic principle. Anthropic reasoning, in its standard employments, presupposes what we are challenging. It assumes a multiverse laid out in advance and renders the presence of observers as a selection effect to explain why we find ourselves in a hospitable corner of what already actually exists. Our question is not why observers find themselves where conditions happen to permit them, but what the existence of inquiry reveals about the ontology of nature as such—what categories any cosmos must exemplify if it is to harbor experiential occasions that entertain, evaluate, and come to know. Selection among actualities leaves that deeper question unaddressed, for it is precisely the reality of the possible that is at issue.

For Whitehead, the Kantian question—*how is knowledge of nature possible?*—becomes cosmological.[8] He allows us to answer in a realist rather than an idealist way. Kant secured objective knowledge by making phenomenal nature a construction of the knowing subject. But the price of his transcendental idealism is that the thing-in-itself withdraws forever behind the phenomena, thus entrenching bifurcation. Whitehead seeks the conditions of possibility of knowledge *within* nature, by making the knower an outgrowth of the same creative process that yields electrons and galaxies.

> "The process of cognition is merely one type of relationship between things which occurs in the general becoming of reality. ... [Kant] asked, How is cognizance possible? I suggest to you the more general question, How is any particular entity possible having regard for the relationships which it presupposes?"[9]

Whereas Kant described how "the world emerges from the subject," Whitehead seeks to describe how the subject emerges from the world, "a superject" rather than a subject.[10] The wager of a rational cosmology is that the categories adequate to the interaction of two particles must be the same categories adequate to the conversation of two persons, differing in complexity and intensity but not in ontological kind. Where bifurcation makes the emergence of mind from nature an unintelligible miracle, the process view makes it the morphogenetic intensification of a possibility ingredient in cosmogenesis from the beginning.

3. Homogeneous and Heterogeneous Thought: A Bridge from Science to Metaphysics

Whitehead's early philosophy of nature provides our argument with a methodological bridge. In *The Concept of Nature* he distinguishes *homogeneous* thought about nature from *heterogeneous* thought. Natural science, properly understood, restricts itself to homogeneous thought, studying the relations among the contents of perception—the coordinatizable, repeatable, measurable features of the world—without including, within its object, the fact that nature is being perceived and thought about. Science holds nature "closed to mind," deliberately bracketing the percipient and treating nature as a self-contained system of relations among the percepta known.[11] This self-limitation is not a defect. On the contrary, it makes exact science possible, allowing the physicist to

[7] See Bradley, "La Cosmologie Transcendantale de Whitehead: La Transformations Spéculative du Concept de Construction Logique" in *Archives de Philosophie* 56 (1993), 3-28.
[8] The subtitle of Whitehead's *Process and Reality* is "An Essay in Cosmology" where "cosmology" refers to a comprehensive philosophical framework that incorporates human experience and metaphysics along with physical cosmology.
[9] Whitehead, "First Lecture, 1924" in *Whitehead at Harvard*, 46-47.
[10] Whitehead, *Process and Reality*, 88.
[11] Whitehead, *The Concept of Nature*, 3, 67.

pursue the structure of the known without at every step having to adjudicate the metaphysics of knowing. But heterogeneous thought, or metaphysics, can no longer accept the instrumental convenience of bracketing half of reality from the inquiry. It takes as part of the datum to be explained the fact that nature is perceived, thought, valued, and known. Where science abstracts the knower out, so as to study the known with precision, metaphysics must put the knower back in, because the knowing is itself a natural fact requiring explanation by the same scheme that explains everything else. The two modes need not be rivals so long as their different scopes are recognized. The trouble begins only when the special homogeneous abstraction is mistaken for the heterogeneous whole from which it is abstracted.

This is the error of spacetime actualism. The coordinate manifold is an attempted homogeneous representation of nature, and as such, it an *abstraction*. It is a map, rather than the territory. Thus, it becomes an explicit metaphysical falsehood when it is declared to be all that is real.

The elevation of the coordinate manifold to a putative exhaustive ontology also has consequences for natural science's methodological closure of nature to mind. Spacetime actualism forgets that the latter assumption was adopted as a methodological convenience, uncritically reifying it into an ontological verdict that the mind that proposed it does not really exist, or if it does, exists only as an impertinent creature that creates "stubbornly persistent illusion[s]" (when what it experiences undermines metaphysical beliefs based on such abstractions).[12] The role of heterogeneous thought about nature is not to refute physical science but to situate it empirically, showing how its homogeneous abstractions arise within, and remain answerable to, the concrete becoming of nature as we experience it—the nature that includes physicists along with photons. For, in fact, nature *as we perceive it* is precisely what physical science is charged with explaining. In this regard, we must beware of double standards that allow certain experiences (e.g., pointer readings) to count as "empirical facts" but not others, such as our experience that two different pointer readings occurred at two different times.[13] The bridge from science to a radically empirical metaphysics is therefore not a leap beyond nature but a widening of attention from the coordinatizable features of experience to its concrete specificity, as well as critical discernment regarding idealized abstractions that may lose touch with that vital empirical anchor.

Eastman's tripartite distinction among three ways of knowing[14]—the way of numbers, or relations treated as context-independent for the purposes of calculation; the way of signs, or context-emphasizing interpretive relations; and the way of ultimate context, or the horizon within which numbers and signs together become intelligible—helps clarify Whitehead's homogeneous/heterogeneous distinction. Homogeneous thought corresponds to the way of numbers, treating what can be coordinatized and repeated, bracketing the interpretive and contextual conditions of measurement. The reflexivity of heterogeneous thought, by contrast, belongs to the way of signs, asking how coordinatable models relate to a knower whose knowing is itself a semiotic act. The further question of why the cosmos issues in inquirers at all opens onto the way of ultimate context, which cannot be the exclusive province of any one special science. Where actualism's reification of coordinate analysis collapses signs into numbers and denies the

[12] Albert Einstein to the family of Michele Besso, March 1955, quoted in Alice Calaprice, ed., *The Ultimate Quotable Einstein* (Princeton: Princeton University Press, 2010), 75: "For us believing physicists, the distinction between past, present, and future is only a stubbornly persistent illusion." The remark is often invoked in support of a "block universe" reading of relativity, though its interpretation remains contested. In the context of our argument, "mind," in that it implies the reality of possibility alongside physical actuality, also implies real becoming. See also Eastman's discussion of the 1922 Einstein-Bergson debate (*Untying the Gordian Knot*, 52-53), where he argues that Einstein stayed within his presumed block-world, Boolean-only description, whereas Bergson (without contesting Einstein's more limited physics descriptions) argued philosophically for a framework that could allow for *potentiae* and human knowing. See also Kastner (2023) for a physics-based dissent from the "illusion" claim.

[13] See Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 226.

[14] Eastman, *Untying the Gordian Knot* (2020), 4, 237.

ultimate context altogether, process-relational cosmology allows us to integrate without collapsing these three ways of knowing.

4. Coordinate and Genetic Analysis

Another instrument for aiding the widening of contemporary cosmology's attention is Whitehead's distinction, in *Process and Reality*, between two analyses of what he calls an "actual occasion"—the pulse of experience that provides the basic unit of process at every scale and grade of nature. *Genetic* analysis, developed in Part III of *Process and Reality* as his theory of prehensions, traces the formal becoming of an occasion in terms of the growing together or concrescence of many feelings into one determinate satisfaction under the guidance of a subjective aim. It is the analysis of final causation, of the occasion considered as a subject in the act of self-creation. Importantly, this act of becoming is not itself spatiotemporally extended in the way its products can be. Each phase of concrescence presupposes the whole quantum it is achieving, so that physical time is produced by the cumulation of occasions rather than presupposed as a pre-given track along which they run.[15] The determinate satisfaction in which their decisions culminate is, in Whitehead's phrase, "incurably atomic": an indivisible unity that cannot be coordinately subdivided without falsifying the determinate novelty it contributes to the creative advance.[16]

Coordinate analysis, developed in Part IV of *Process and Reality* as the theory of extension, takes the completed occasion, the satisfaction or the superject, and exhibits it as divisible. It studies how occasions stand to one another within the extensive continuum, attending only to the physical pole and bracketing the mental pole (the latter being negligible in the low-grade occasions that physics chiefly studies). It is the analysis of efficient causation and it is the proper domain of measurement and of the entire geometrical apparatus of physical science. The crucial point for our argument is, as Whitehead himself states, that coordinate analysis is *hypothetical*, a mode of "as if."[17] The divisions it makes are not actual divisions of a concretely undivided process but are *potential* divisions entertained for the purposes of analysis. Coordinate division yields powerful approximations adequate to low-grade occasions dominated by their physical pole, but it systematically omits the conceptual feelings of the mental pole, that is, the subjective aim and evaluation of alternatives, that genetic analysis recovers.

Spacetime actualism can now be defined in Whitehead's terms as the *reification of coordinate analysis*. It takes the divisible, hypothetical representation of the metrical relations among events and pronounces it the whole of the real. What it leaves out is not a sentimental residue or stubborn illusion but the genetic process itself—the becoming in which alone novelty, value, and the aim of scientific inquiry itself have their place. Whitehead offers a helpful metaphor: actualist physics, in reifying the coordinate domain, "examines the coat, which is superficial, and neglects the body which is fundamental."[18] Coordinate analysis studies the coat of nature, describing its metrical vesture. Genetic analysis studies the body, the concrescing occasion in the act of self-composition, whose incompatibility-resolving felt aim toward determinate satisfaction is the living activity obscured by the coat. The problem is not that physics precisely models the folds of the coat, but that an often unacknowledged actualist metaphysics declares the body beneath the folds to be a fiction.

Genetic analysis is analysis of prehensions, a category that spacetime actualism cannot countenance. Whitehead coins the term to name the concrete relation by which each actual

[15] Whitehead, *Process and Reality*, 283.

[16] Whitehead, *Process and Reality*, 61, 285.

[17] Whitehead, *Process and Reality*, 235.

[18] Whitehead, *Modes of Thought*, 154.

occasion takes account of past occasions (physical prehension) and alternative possibilities (conceptual prehension). Prehension is the vector feeling by which the potentiality of the settled past and the open possibilities of the future grow together into a determinate actuality in the present. It is applicable as much to the emission and absorption of photons as it is to the mutual immanence of knower and known, allowing both to be thought without either idealist inflation or actualist bifurcation (e.g., the idealist inflation that makes "conscious observation" what collapses the wavefunction, or the actualist bifurcation that leads to the "ontological overflow"[19] of the multiverse and Many-Worlds Interpretation). Prehensions are the very sinews of causal connection throughout nature, as well as the ontological ground of what higher-grade occasions of experience elaborate into perception and cognition. On the prehensive reading, knowing is not a supervenient anomaly precariously perched atop indifferent geometry but the intensification of a relation that is operative at every grade of process. The coordinate scheme, because it brackets prehensive unification in order to isolate the spacetime manifold, cannot from its own resources explain how a knower prehends the coordinate scheme itself.

This has further consequences for our reflexive argument. Scientific hypothesizing is itself a mode of high-grade prehensive activity analyzed by Whitehead in terms of what he calls "propositional feelings."[20] Such feelings entertain propositions, which are "lures for feeling" that relate possible predicates to actual entities. Propositions are felt as not yet decided possibilities to be affirmed, negated, or refined by further experience. What Whitehead calls an "intellectual feeling" arises when a physical feeling—which affirms some past actuality as objectified fact—is held together in contrast with a propositional feeling, in which the same content is entertained as mere possibility rather than affirmed as fact. This contrast between what is affirmed as actual and what is entertained as possible is what gives rise to "consciousness" or cognition/knowing in Whitehead's technical sense. What this means for our argument is that the coordinate scheme of contemporary physics is itself a complex proposition entertained by a high-grade society of occasions—the working physicist's conscious stream of concrescing experiences—in which the actuality of a settled physical past is contrasted with the potentiality of alternative theoretical determinations. The scientist's act of theorizing about coordinate manifolds is thereby self-exemplifying of the actual/potential dipolar ontology that our paper defends. On Whitehead's reading of consciousness as the subjective form of the propositional affirmation-negation contrast, the conscious entertainment of a cosmological theory is already to feel a contrast one of whose relata the actualist has declared unreal.[21] A cosmology built on spacetime actualism, by denying ontic standing to the potential contrast without which propositional feeling is unintelligible, thus undermines the very possibility of the scientific hypothesizing in which its proponents are engaged.

A defender of actualism may object that the entertainment of alternatives requires no ontic *potentiae*, since actual neural or computational configurations which merely represent alternatives would suffice. Whitehead's critique of representationalism in *Process and Reality* anticipates this objection. A representation is a symbol, and a symbol refers beyond itself only for an experient whose connection with the represented world has already been secured. Because the representative theory of perception offers no account of physical feelings—no doctrine of the causal efficacy by which the knower directly inherits the settled world—it can never, from within its own resources, produce the "title deeds" guaranteeing that its ideas represent facts at all, and so it locks the mind within a solipsism of its own symbols.[22] When representationalism is

[19] Eastman, *Untying the Gordian Knot*, 82-84, 95.
[20] Whitehead, *Process and Reality*, 184-186, 259-280. On the treatment of scientific hypothesis as Whiteheadian propositions, see also Segall, "Physics Within the Bounds of Feeling Alone" (2024).
[21] Whitehead, *Process and Reality*, 161, 267.
[22] Whitehead, *Process and Reality*, 54.

combined with actualism, the difficulty is compounded, since the scheme retains no equivalent of conceptual prehension, no way for a merely actual configuration to be about an alternative that, by hypothesis, has no ontological standing whatsoever. To call a brain state a "representation of alternatives" is to help oneself to the very relation—the felt contrast between the actual and the possible—that actualism has disqualified. The rejoinder thus reproduces the bifurcation of nature at the level of semantics, rendering reference and aboutness inexplicable additions to a nature declared complete without them.

An additional reason why the coordinate scheme cannot be ontologically primitive is made evident in Whitehead's account of the extensive continuum from which it is abstracted. The continuum is not a metrical spacetime container in which events occur but the most general scheme of *real potentiality*, the relational matrix expressing "the solidarity of all possible standpoints."[23] In its full generality it is pre-metrical and pre-dimensional, defined by the topological relations of whole to part, overlap, and contact. For Whitehead, whereas actuality is incurably atomic, potentiality constitutes a continuum. Actual occasions atomize the continuum, making actual what was antecedently merely potential. The continuum is thus, in Whitehead's words, "divisible but not divided."[24] The dimensionality of space, the seriality of time, the metric relations measured by physics, and even the straight lines presupposed by all measurement are not themselves features of the generic continuum. They are special achievements of our cosmic epoch, inherited *habits* laid down by the vast society of electromagnetic occasions that dominates our epoch, not eternal laws imposed from beyond it.[25]

Two consequences follow that motivate the remainder of our argument. First, Whitehead develops his theory of extension non-metrically, deriving the characteristic properties of straight lines, planes, and flat regions from purely topological relations of whole and part, without smuggling measurement into the definition of straightness, as Euclid and most of modern physics had done.[26] This makes him a geometric pluralist and an epochal realist about the metric. Different geometrical schemes suit different purposes, and it is a fallacy of misplaced concreteness to identify the geometry of spacetime with the physics of gravitation.[27] Against the tendency, evident in the geometrizing readings of general relativity that treat the four-dimensional manifold not as a description of spacetime but as spacetime's very substance, Whitehead insists that the metric is something nature *achieves*, not something antecedent to becoming. Second, and consequently, Whitehead's metaphysical account of the extensive continuum recovers the dipolarity that spacetime actualism collapses. He affirms a continuous order of real potentiality that is pre-spatiotemporal and that conditions without determining. His conditioned and conditioning atomic actualities generate the metric spacetime that physics then coordinately analyzes; a procedure that, unlike standard cosmology, maintains a distinction between the geometry and the physics, thus avoiding a cosmological measurement problem. It is this dipolarity that the transactional interpretation of quantum theory, as we shall see, renders in quantitative physical detail.

[23] Whitehead, *Process and Reality*, 66.
[24] Whitehead, *Process and Reality*, 62.
[25] Whitehead, *Process and Reality*, 92.
[26] Whitehead, *Process and Reality*, 303.
[27] See Whitehead, *The Principle of Relativity* (1922) and Gary Herstein, *Whitehead and the Measurement Problem of Cosmology* (2006).

5. Real *Potentiae*: Possibility and the Poised Realm

Against spacetime actualism's equation of the real with the determinately actualized, the process-relational view holds that possibility is ontic, not merely epistemic.[28] Whitehead distinguishes two grades of the possible. *Pure* potentiality is the realm of eternal objects—possibilities considered in the bare generality of their natures, not relative to any historical standpoint. *Real* potentiality is that same realm as conditioned by, and rendered relevant to, the settled actual world from a given standpoint, with the extensive continuum its most general expression. Pure potentials thus feature as predicates in propositions determining wholly general truths about what is possible for anything whatsoever; real potentials feature in propositions determining contingent truths about what is possible for a given historical situation. On this view possibility is not a measure of the mind's ignorance but a real ingredient in cosmic becoming. The future is real precisely *as* possible. The reality of the future is bound up with the reality of the continuum, which conditions every actualization without dictating its outcome.

Granting *potentiae* this ontic standing does not violate Whitehead's ontological principle, according to which only actual entities furnish the reasons for things. Real *potentiae* are never free-floating possibilities, as if frozen in a morgue like the pale outlines of lifeless bodies awaiting a blood transfusion.[29] They are rather the conditioned potentiality of the settled world (and, for Whitehead, of the primordial divine envisagement), so that no merely possible occasion can be said to pre-exist its radically novel concrescence. The future, then, is real in the mode of general possibility rather than singular fact.

This is the metaphysical link between Whitehead's cosmological scheme and the interpretation of quantum physics pursued by our co-authors. Heisenberg already proposed that the quantum state describes not our ignorance of secretly determinate values but a real intermediate kind of being, a *potentia* poised between possibility and actuality. Stuart Kauffman's *res potentiae*, affirmed in Eastman's *Logoi* Framework and Kastner's Possibilist Transactional Interpretation of the quantum substratum, carries forward this proposal as the basis for a new physical ontology.[30] On such a reading the quantum formalism is not a catalogue of our nescience but a description of a genuine, sub-empirical ordering of real potentialities actualized in determinate occasions. To grant *potentiae* this ontic standing is to make room, at the very foundations of physics, for a structured indeterminacy conditioning without determining what actually occurs. This is what a cosmology of creative advance—a cosmogenesis—requires, and what the actualist block universe model forbids.

Kauffman has pursued this ontology of the possible further than most. His "Poised Realm" is described as a state of matter hovering reversibly, through decoherence and recoherence, between quantum coherence and classicality. He proposes it to secure ontologically real *res potentia* alongside classical *res extensa*. But he gestures beyond the bare dualism the pairing initially suggested by way of a Triad: Mind (akin to consciousness in his terms) measures

[28] While the current account examines primarily philosophical aspects, Kastner and Eastman have argued that the failure to allow for ontic possibilities has led to unnecessarily vexing problems in varied areas of physics, such as the measurement problem of the conventional quantum theory as well as puzzles in statistical mechanics such as "Maxwell's Demon," which is readily solved once it is recognized that quantum indeterminacies and uncertainties involve ontic possibilities (e.g., Kastner, 2025b, 2026).

[29] For a defense of Whitehead's eternal objects against a Bergsonian virtualist critique, see Segall, "Standing Firm in the Flux: On Whitehead's Eternal Objects" in *Whitehead at Harvard, 1925-1927*, ed. by Joseph Petek and Brian Henning (Edinburgh University Press, 2025), Chapter 12.

[30] Heisenberg, *Physics and Philosophy* (1958); Kastner, Kauffman & Epperson, "Taking Heisenberg's *Potentia* Seriously" (2018); Eastman, *Untying the Gordian Knot* (2020). Note that *potentiae* are not a third order of quasi-entities hovering between being and non-being. They are fully real, "intermediate" in Heisenberg's sense only in that they lack actualized determinateness.

Possibles to bring forth new Actuals, which in turn open new Possibles for Mind to measure again "in a persistent becoming, a *status nascendi*"—a cycle he himself likens to Whitehead's process-relational account.[31]

We share Kauffman's realism about possibility (i.e., it is not merely epistemic) and his processual framing. The Whiteheadian approach applied in this paper interprets the entertaining of possibility that Kauffman locates in a conscious measuring Mind set alongside what it measures as occurring in the genesis of each actualization—not as a mind acting upon the world of classical physics from without, but as nature entertaining its own possibilities from within, at every scale of its becoming. This is suggestively exemplified in the phenomenon that first inspired Kauffman to propose a poised realm. In the light-harvesting complexes of chlorophyll, quantum coherence may persist a thousandfold longer than the warm and crowded body of a leaf would normally be expected to permit, so that the excitation can try many pathways simultaneously before any single path is taken.[32] Thus a constellation of real *potentiae* are held open, in superposed contrast, at the very threshold of the actual. Kauffman reads this poised phase as a new state of matter; on a process-relational reading, it is also a natural sacrament of mind. For what the molecule expresses by sustaining an array of alternatives before one is decided upon, is Whitehead's mental pole: the entertainment of real potentials in their relevance to an as yet unresolved situation.

On Whitehead's account, mentality in the generic sense, as the conceptual valuation of real potentials, pervades nature as the mental pole of every actual occasion, whereas, as we've seen, consciousness proper arises only in the late integrative phases of high-grade occasions as the subjective form of the affirmation–negation contrast. The claim here is therefore not that chlorophyll's dim tending of *potentiae* is conscious, but that it is emblematic of mentality that, massively intensified, ripens into consciousness. Consciousness is then not a substance snuck into the gaps of an otherwise mechanical nature, but the amplification of latencies everywhere at work within it, such that the contrast between what is and what might be is not merely lived, as in the plant, but reflexively *felt as such*. Nature holds possibilities open at every scale, in its conscious human occasions coming to savor the taste of the creative openness it enacts everywhere. It is worth dwelling a moment on the emblematic nature of photosynthesis as the taking of light into life, solar radiance made vegetal. That the quantum poise at the base of the biosphere should pry open the possible at the very threshold where light enters the living world is, for a cosmology of creative advance, impossible to pass over in silence. It potently prefigures the flowering of consciousness, not as a fall of possibility into brute fact, but as its incarnational awakening: the possible and the actual becoming worthy of one another as the light of the world learns, in us, to see.

If the process-relational revisioning of classical ontology is correct, then the fraying frontiers at the speculative edges of physical cosmology should provide excellent test cases for the dipolar ontology of potentiality and actuality. We offer two such test cases. The first, Eastman's critique of the Big Bang research program, shows spacetime actualism failing at the largest scale. The second, Kastner's Relativistic Transactional Interpretation, shows the dipolar ontology instantiated in physical detail at the smallest.

[31] Kauffman, *Humanity in a Creative Universe*, 128.

[32] The prolonged coherences in photosynthetic complexes were first reported by Engel et al. (2007), cited by Kauffman, *Humanity in a Creative Universe*, 138-139. The phrase "simultaneously tries many reactions" is Kauffman's gloss. We invoke chlorophyll here as an emblem rather than a settled mechanism. The functional role of quantum coherence in photosynthesis remains contested. Nothing in the metaphysical point turns on the empirical dispute.

6. First Test Case: The Big Bang Research Program and the Reification of the Manifold

Our first test case is Eastman's analysis of contemporary cosmology, which mobilizes Imre Lakatos's distinction between a research program and the specific, falsifiable models it generates. A research program is organized around a "hard core" of first principles accepted, for the program's purposes, without further debate, and elaborated by a chain of auxiliary hypotheses that yield testable predictions. The program as a whole is not directly falsifiable, but it can be appraised as progressive, when it forecasts novel facts later confirmed, or degenerate, when it survives only by *ad hoc* adjustments that accommodate observations after the fact.[33] The Big Bang research program, with its standard ΛCDM model, remains the dominant framework today. Eastman's contention is that its hard core harbors, alongside its physical principles, a set of unstated metaphysical presuppositions that this paper has been calling into question.[34]

Chief among them is spacetime actualism itself, joined by determinism (the assumption that events form quantitative dyads of cause-and-effect bound by strict entailment), by causal closure, and by a nominalism that grants reality only to the particular elements of a variable metric while denying ontic standing to the possible and the general. Following Milič Čapek, Eastman traces these commitments to classical metaphysics and locates their common root in a "view from nowhere," the tacit pretension to a God's-eye survey of a universe laid out in its entirety. Lodged in the hard core, where Lakatos says first principles are held beyond debate, these presuppositions are usually shielded from scrutiny. "Every scientific man," Whitehead once quipped, "in order to preserve his reputation has to say he dislikes metaphysics. What he means is he dislikes having his metaphysics criticized."[35] The unacknowledged metaphysics do not announce themselves as such and so are uncritically passed off as a simple translation of what physics has found. This is the reification of coordinate analysis diagnosed in section 4, which operates not as an explicit doctrine but as the unexamined imaginative background of a research program.

The marks of strain show at both ends of the model. At its origin stands the initial singularity, where the field equations, extrapolated beyond their domain of adequacy, return infinities that signal a breakdown in the applicability of the known laws. Gamow himself, originator of the hot Big Bang, is reported by Eastman (who as a graduate student attended Gamow's final cosmology course at the University of Colorado in spring 1968) to have regarded this singularity with disquiet, recognizing that a theory uniquely requiring such a feature is most likely signaling its own fundamental limitation, rather than disclosing the nature of our cosmic origin. Read in light of Whitehead's metaphysical scheme, the singularity is not the first actual fact but a tear in the coordinate map. Rendering it the beginning of all things mistakes the failure of a representation for the causal origin of the universe. At the other end, the program has met a succession of observational surprises with a corresponding succession of *ad hoc* auxiliary adjustments: an inflaton field to smooth the horizon, non-baryonic dark matter to resolve gravitational anomalies, dark energy to accommodate the unexpected dimming of distant supernovae and to extend the expansion age—none of which has been directly detected despite decades of sustained observational effort, only having been introduced to save the model after the fact rather than

[33] Lakatos, "Falsification and the Methodology of Scientific Research Programmes," in *Criticism and the Growth of Knowledge*, ed. I. Lakatos and A. Musgrave (Cambridge: Cambridge University Press, 1970), 91–196.

[34] This section draws on Eastman, "Cosmic Plasmas" (forthcoming), together with *Untying the Gordian Knot: Process, Reality, and Context* (2020), "Orders of Possibility and Actuality" (2025), and "Duality without Dualism" (2004).

[35] Whitehead, *The Harvard Lectures of Alfred North Whitehead, 1925–1927: General Metaphysical Problems of Science*, ed. Brian G. Henning, Joseph Petek, and George R. Lucas Jr. (Edinburgh: Edinburgh University Press, 2021), 375.

derived from independent physical grounds.[36] This is a symptom of Lakatosian degeneration. Where free parameters can be tuned to fit an array of results, "precision" is bought at the cost of predictive power. What gets celebrated later as prediction proves, on inspection, very often to be *post-diction*. Eastman notes, for instance, that the received story of Gamow's successful prediction of the cosmic microwave background temperature is a tidied-up narrative: a simple average of six pre-1965 non–Big-Bang estimates of the ambient radiation temperature of space yields about 3.1 K against the measured 2.725 K, while Gamow and his collaborators' estimates ranged from 5 to 50 K.[37] It should be conceded that Alpher and Herman's 1948 estimate of roughly 5 K was derived from a physical mechanism—nucleosynthesis in an expanding universe. But the Lakatosian question concerns a program's predictive record appraised across its whole career, not the retrospective selection of its best guess. The received narrative converts a fluctuating range of estimates into a uniquely successful forecast, while estimates derived from independent physical grounds—Eddington's from the measured energy density of starlight, for instance—came nearer the observed value without invoking any expansion dynamics at all. What is at issue is not who guessed best, but whether the program's celebrated results were forecast or after the fact accommodation.

Beneath these difficulties Eastman identifies an even more fundamental one. By taking general relativity as foundational and building ΛCDM around a geometrized metric that drives the physics—so that, in effect, the metric and the physics are collapsed—the program generates a cosmological measurement problem in addition to the more familiar quantum one. A relativistic physics tied to a variable, non-uniform metric has no uniform standard against which its own measurements can be referred.[38] The ruler deforms with the territory it would measure. The two measurement problems, quantum and cosmological, are thus not unrelated embarrassments but twin symptoms of the same actualist metaphysics, each arising because a coordinate abstraction is mistaken for the concrete whole.

It is here that Eastman's critique and Kastner's interpretation converge. The transactional reading of quantum physics resolves the quantum measurement problem by restoring the order of real potentiality. On the transactional account, as Schlatter and Kastner (2023) have argued, gravity is not a co-fundamental geometric field but an emergent, entropic consequence of electromagnetically induced transactions. If the metric is *derivative* from quantum process rather than co-original with it, then the cosmological measurement problem dissolves together with the quantum one, since spacetime is no longer a pre-given container whose deformation threatens to undermine measurement, but a derived order referred to the quantum-level process beneath it. The century-long search for a unified theory that presumed gravity and quantum physics to be equally fundamental appears, from the transactionalist vantage, to have been premised on a category error bequeathed by spacetime actualism.

Whitehead's process-relational ontology makes possible a cosmology that declines to identify the measurable with the real. Eastman's own candidate alternative is the plasma cosmology research program, which posits a universe of indefinite age with no singular origin, treats electromagnetic and plasma processes as dynamically significant alongside gravity at all scales, and—on his detailed comparative assessment of recent data, including results from the James Webb Space Telescope—has lately yielded genuine predictions where ΛCDM has leaned on post-dictive adjustment. We do not adjudicate that empirical contest here, and the metaphysical thesis of this paper does not depend on its outcome. Even a reader who backs the standard model

[36] For a transactional alternative on which the phenomena attributed to dark energy arise from the spacetime emergence process itself, without invoking a new fundamental field, see Kastner and Kauffman (2018).
[37] Eastman, "Cosmic Agnosticism, Revisited," *Journal of Cosmology* 4 (2010).
[38] Herstein, *Whitehead and the Measurement Problem of Cosmology* (2006).

should grant that spacetime actualism is a contingent metaphysical presupposition rather than a deliverance of experimental or mathematical physics, and that a legitimate scientific cosmology can be built without it.[39]

If the universe is of indefinite age and the singularity is the artifact of an over-extended abstraction, then the question of a cosmic beginning is not one that physics can settle by running the metric back to a first instant. It becomes, properly, a metaphysical question to be taken up by heterogeneous thought rather than imprisoned in homogeneous abstraction. A cosmology that mistakes its coordinate model for the whole of the real cannot even pose the question of its own experiential ground, since there is nowhere for the inquiring mind of the physicist in a spacetime block. A process-relational cosmology, by distinguishing without dividing the actual from the potentiality through which it transacts, helps resolve the confusion by making a home in nature for mind, which could now be understood as the intensification of latent potentials in nature, our experience "the cumulation of the universe and not a stage-play about it."[40]

7. Second Test Case: The Relativistic Transactional Interpretation as Process Cosmology

Ruth Kastner has developed the Transactional Interpretation, first proposed by Cramer in 1986, into the relativistic domain. The resulting Relativistic Transactional Interpretation (RTI) identifies two distinct aspects of reality, in pointed contrast to the conventional picture of a spacetime manifold serving as a container for everything physically real. The two levels are (1) the potential or *res potentiae*, in the sense Heisenberg, Whitehead, Kauffman, and Eastman give the term—and (2) the actual, the determinate spacetime events in which those *potentiae* are realized. The potential level corresponds to Kastner's quantum substratum, understood not as a substance but as a pre-spatial domain that spacetime events precipitate out of; the actual level corresponds to those events themselves. Because the model is fully quantified and yields the Einstein equations of general relativity, the proposal goes well beyond speculation to approach a candidate physical "theory of everything"[41] cashing out a process-relational ontology.[42]

Read through the conceptual lens of Whitehead's *Process and Reality*, the quantum substratum may be understood, not as a spatiotemporal substance or persisting container—the background spacetime picture often presupposed by spacetime actualism—but as an order of physical potentiality performing a function partially analogous to Whitehead's "extensive continuum."[43] Whitehead defines the latter as the relational order of real potentiality that coordinates possible standpoints, and that conditions, without determining, the actual occasions that atomize it.[44] Like the extensive continuum, moreover, the quantum substratum is not a deeper container behind

[39] Nor is the demand that cosmology take becoming seriously confined to process philosophy. Unger and Smolin (2015) argue on independent grounds that the reality of time is a precondition of a genuinely historical cosmology, and Ellis (2014) presses the causal openness of the future against block universe readings of general relativity from within relativistic cosmology itself.
[40] Whitehead, *Process and Reality*, 237.
[41] A "theory of everything" in physics means not a total explanation of all phenomena whatsoever, but a physical theory unifying quantum theory, general relativity, and the known fundamental interactions within a single coherent framework. See Steven Weinberg, *Dreams of a Final Theory: The Scientist's Search for the Ultimate Laws of Nature* (Pantheon, 1992).
[42] The affinity between Whitehead's scheme and quantum theory has a substantial lineage: see Shimony, "Quantum Physics and the Philosophy of Whitehead" (1965); Stapp, *Mind, Matter and Quantum Mechanics* (1993); Malin, *Nature Loves to Hide* (2001); Epperson, *Quantum Mechanics and the Philosophy of Whitehead* (2004); the essays collected in Eastman and Keeton, eds., *Physics and Whitehead: Quantum, Process, and Experience* (2004); and Epperson and Zafiris, *Foundations of Relational Realism* (2013); and essays collected in Eastman, Epperson and Griffin, eds., *Physics and Speculative Philosophy* (2016). What RTI distinctively contributes to this lineage is a fully relativistic, direct-action realization of the potential–actual distinction.
[43] Whitehead, *Process and Reality*, 61ff.
[44] In his essay "Orders of Possibility and Actuality," Eastman (2025) focuses on this distinction of fundamental ontological orders and its implications. In *The Quantum of Explanation*, Auxier and Herstein (2017) provide details on Whitehead's concept of the extensive continuum; e.g., "Since extension and prehension are prior to space and time, they are also prior to the metrical relations of space and time" (88).

spacetime. Rather, it is itself conditioned by the settled world—by prepared states, available absorbers, and the growing record of actualized events—so that conditioning runs in both directions, from settled actuality into real potentiality and from real potentiality into new actualization.[45]

The conservation requirements operative in RTI can accordingly be interpreted, not as features of the extensive continuum's generic mereotopological order, but as constraints arising from the prevalent relational order of our cosmic epoch and thereby qualifying the real potentialities available within it.[46] Together with coupling structures, these requirements constrain whether transactions (i.e., offers and confirmations with subsequent actualizations of one outcome) can arise from quantum processes (i.e., unitary evolution and interactions) and which physical quantities can be transferred in actualization, without selecting any unique actualized transaction.

The correspondence between the quantum substratum represented through Hilbert space and Whitehead's extensive continuum remains functional rather than strictly ontological. Hilbert space is a mathematical vector space in which quantum states represent physical *potentiae* through complex amplitudes. It is not a mereotopological continuum of extensive connection. What the two share is therefore neither the same formal structure nor the same ontological status but a partial functional affinity: each, in a different way, articulates an order of conditioned potentiality that structures actualization without by itself determining which actuality will arise. The extensive continuum answers to the quantum substratum's relational ordering of possible events, while the substratum's dynamically evolving *potentiae* provide something akin to the "more complete rendering" of real potentiality that Whitehead assigns to the physical field.[47] Whitehead's extensive continuum conditions the extensive form under which inherited physical data can be objectified and supplies the scheme of possible regional standpoints presupposed by concrescence, without exhaustively determining the occasion's self-formation.

A quantum system (with non-vanishing rest mass) is not to be identified with the extensive continuum. In a Whiteheadian rendering, it may instead be understood as a recurrent process-pattern whose successive transactional actualizations exhibit the serial inheritance characteristic of a historical route or society, rather than as a self-identical persisting substance. Its internal periodicity supplies a local, system-intrinsic proper-time reference associated with its rest frame and requiring no external background clock.[48] This parametric continuity need not conflict with Whitehead's epochal theory of becoming, since it characterizes the systematic ordering of potential processes rather than the internal becoming of an actual occasion. In the domain of quantum *potentiae*, quantum states evolve continuously according to the ordinary probability preserving Schrödinger equation of quantum theory; the formation of a transaction, by contrast, is a discrete, nonunitary actualization yielding determinate events. In Whitehead's phrase, "there is a becoming of continuity, but no continuity of becoming."[49]

[45] The extensive continuum "is not a fact prior to the world; it is the first determination of order—that is, of real potentiality—arising out of the general character of the world" (Whitehead, *Process and Reality*, 66); it is "not productive of the ordered world, but derivative from it" (72). As an order of historically conditioned potentiality, the quantum substratum shares this non-container-like status.

[46] Considered "in its full generality, apart from the additional conditions proper only to the cosmic epoch of electrons, protons, molecules, and star-systems," the continuum's properties "are very few and do not include the relationships of metrical geometry"; shapes, dimensions, and measurability "are additional determinations of real potentiality arising from our cosmic epoch" (Whitehead, *Process and Reality*, 66). Whitehead's account of metrical relationships as epochal rather than generic converges with RTI's account of an emergent metric.

[47] Whitehead, *Process and Reality*, 80: the extensive continuum is "the fundamental aspect of the limitation laid upon abstract potentiality by the actual world," while "a more complete rendering of this limited, 'real' potentiality is the 'physical field.'"

[48] See Schlatter and Kastner (2023), who attribute to fermionic systems and bound states in the quantum substratum an internal clock defining their proper time, the Schrödinger evolution of such systems defining inertial frames for the emergent spacetime.

[49] Whitehead, *Process and Reality*, 35.

This periodicity invites comparison with Whitehead's account in *Science and the Modern World* of the relation among occurrence, recurrence, and endurance. He distinguishes the *occurrence* of an event, which happens once and perishes; the *recurrence* of a pattern, or eternal object, recognizable because reiterated across many events; and *endurance*, in which that reiteration is inherited by a rhythmic, vibratory route or society of successive occasions, such as an atomic element, a star, or a living cell.[50] Whitehead accordingly proposed that a primordial vibratory organism manifests itself only through its complete period, rather than at an isolated instant or in an arbitrary fraction of that period, offering a speculative account of how continuous internal articulation might issue in discrete physical manifestation.[51] The analogy with RTI nevertheless requires a further distinction. The internal periodicity associated with a massive system's rest mass is not the offer–confirmation transaction itself. The former is a local process in the quantum substratum that supplies the system's proper-time reference; the latter is a reciprocal emitter–absorber process whose nonunitary actualization establishes discrete emission and absorption events together with the photon transfer link between them.[52] Periodicity thus belongs to the internal constitution of massive quantum systems in the substratum, while discreteness belongs to the transactional events and links constituting emergent spacetime. The assumed continuous endurance of physical objects in coordinate spacetime is a derivative representation of ordered relations among such events, not the literal persistence of a substance or the continuity of becoming itself.

The discrete transactions a quantum system sources are mappable to actual occasions and their nexūs. An "event," in Whitehead's technical sense, is a nexus of actual occasions inter-related in one extensive quantum, with the actual occasion itself as "the limiting type of an event with only one member."[53] The actualized transaction is an event in this sense—a minimal nexus whose members are an emission occasion and an absorption occasion, bound by the invariant null interval that constitutes their connection. The dipolar aspect of reality is thus mirrored in two modes of process: the continuous, belonging to quantum systems at the level of real potentiality, akin to the genetic phases of concrescence; and the discrete, metrical spacetime of actualized events, akin to his coordinate domain. Quantum decoherence—effected, in RTI, by the responses of absorbers[54]—can be understood in Whiteheadian terms as the early genetic phases of concrescence in which incompatible data are excluded by negative prehension or integrated under novel contrasts. The genetic phases of concrescence must be understood non-temporally. The passage from phase to phase is not in physical time, since each phase presupposes the entire quantum.[55] The isomorphism is one of logical order rather than timeline, mirroring RTI's account of absorber responses belonging to the pre-spatiotemporal substratum of real potentiality, with measured decoherence times appearing only in the coordinate shadow of genetic ordering. This is the distinction Whitehead draws between the continuum of possibility—unitary and reversible if abstracted from the solicited response of absorbers—and the irreversibility of actualization resulting in an emergent arrow of time.[56]

[50] Whitehead's mature statement occurs in *Process and Reality*: the atom "is only explicable as a society with activities involving rhythms with their definite periods," and the quanta of energy are "in their own nature, somehow vibratory" (78–79); a molecule is "a historic route of actual occasions" (80).

[51] Whitehead, *Science and the Modern World*, 35-36. The discrete atomicity in question is not Newton's, the smallness of a corpuscle, but the singularity of a decision: the non-unitary event in which a determinate outcome is selected from among real alternatives.

[52] Schlatter and Kastner 2023. An actualized transaction generates an emission event, an absorption event, and the invariant null interval constituted by the transferred photon. These events and links, not the massive systems themselves, are the elements of emergent spacetime.

[53] Whitehead, *Process and Reality*, 73. This convergence of vocabulary makes the comparison clear: RTI's emission and absorption events are "events" in Whitehead's technical sense, each terminus an occasion, their transaction the minimal nexus.

[54] Kastner, "Decoherence and the Transactional Interpretation," *International Journal of Quantum Foundations* 6(2) (2020): 24–39.

[55] Whitehead, *Process and Reality*, 283.

[56] For the quantitative development of this claim, on which real non-unitary actualization supplies the ontological indeterminacy required to ground the Second Law of Thermodynamics, see Kastner (2017); on the incompatibility of a real

In RTI, the mutual generation of (electromagnetic) offer and confirmation waves by material sources—an emitter and its responding absorbers—already initiates a non-unitary measurement transition, in which the offer is transformed into a weighted field of incipient transactions. In Whiteheadian terms, the absorber response corresponds to the entry of conceptual valuation into concrescence—the mental pole's registration and grading of alternatives—prior to the final decision. Atomicity or discreteness enters only with the actualization of one such transaction. The internal clock grounds the matter system's proper-time reference, while the completed offer–confirmation circuit conditions the entry of atomic fact without determining which incipient transaction is actualized. This actualization is discontinuous and not fixed by the antecedent dynamics—neither the unitary propagation of the offer nor the weighting of incipient transactions. It is therefore "acausal" only in the precise sense that the achieved fact is not deductively entailed by the prior evolution of possibilities.

This culminating non-unitary step of actualization is the physical analogue of Whitehead's "satisfaction." Without such a step, the cyclic process of offer and confirmation would remain an unrealized circulation of *potentiae*, never culminating in determinate fact. The closed circuit is a necessary condition for actualization, but it is not yet the actual occasion. It is the field of eligible relevance, the rhythmic solicitation of possible outcomes. Whitehead argues that decided conditions never banish freedom but only qualify it: there is always a contingency left open for immediate decision. He is careful, however, about how the occasion's regional standpoint in the continuum is settled. In the mere continuum "there is no principle to determine what regional quanta shall be atomized."[57] That determination arises in the initial phase of the subjective aim, wherein the antecedent world and the primordial valuation of possibility propose to the nascent concrescence a graded field of candidate standpoints, leaving to the occasion's final self-causation not the fabrication of alternatives but the decision among them. RTI exhibits the same two-stage structure. Each eligible absorber marks a candidate standpoint in the extensive continuum. The weighted field of incipient transactions gives physical definition to the graded initial relevance, with the Born weights functioning as the physical registration of that grading, while the non-unitary actualization answers to the final decision that no antecedent grading determines. Each terminus of the actualized transaction is a decision embodying its quantum *in solido*—not assembled part by part or accreted instant by instant, but actualized as one undivided whole, all at once, the transaction actualizing both termini jointly.[58]

In *Process and Reality*, Whitehead distinguishes between two modes of fluency: concrescence and transition.[59] Concrescence is the genetic becoming of an occasion, the internal passage from the data of many real potentialities toward one determinate satisfaction. It is not a little process occurring inside already constituted physical time. On the contrary, physical time is abstracted from the completed extensive quantum once the occasion has achieved satisfaction. In this sense, the closed transactional cycle belongs to the concrescent phase as the ordering and valuation of real potentialities considered in abstraction from actualization. The non-unitary transaction corresponds to the decisive attainment of satisfaction at each terminus, integrating the many possible absorbers, confirmations, and amplitudes into one determinate minimal nexus. In this regard, it may be noted that the absorbers not receiving the photon in the actualized decision nevertheless participate as heralds of "null measurments."[60]

Transition is then what follows from this completion. Once the transaction is actualized, the Whiteheadian interpretation would be that the occasion perishes as subjective immediacy and

arrow of time with the received actualist view, see Kastner (2025a).
[57] Whitehead, *Process and Reality*, 67.
[58] Whitehead, *Process and Reality*, 283.
[59] Whitehead, *Process and Reality*, 210.
[60] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 56.

becomes objectively immortal. It is no longer a becoming subject but a settled superject, a determinate spacetime event available for prehension by subsequent occasions. In RTI's terms, the completed transaction is now an emission–absorption event within the emergent spacetime manifold, capable of conditioning further transactions. Thus the creative advance has two inseparable but distinguishable phases: the concrescent actualization of real potentiality into a definite quantum of fact, and the transitional inheritance of that fact by later occasions. The offer supplies the ordered potency, the confirming response its valuation, and the non-unitary transaction the atomic actuality. The subsequent web of such actualities weaves the historical continuity of nature.

Despite giving the designation of "eternal object" to his potentials, Whitehead does not deny the evolution of their graded relevance to the settled world. These eternal objects are not locatable in spacetime, are uncreated, and do not themselves change, but are not therefore static. Instead, the decisions of each actual occasion cast back upon them what Whitehead calls the "shadow of truth," enriching and reordering their relevance to the future universe.[61] The eternal objects together with the settled actualities of the past therefore do not constitute a finished world but a growing eternal memory, which each newly concrescing occasion prehends—physically in its inheritance of settled actuality, conceptually in its registration of the graded relevance of eternal objects—as bearing on its present situation and future aim.

A further correspondence concerns the character of field interactions in RTI. The relevant physics is the Direct-Action Theory—also known as the Absorber Theory of Radiation developed by Wheeler and Feynman[62]—a well-quantified account subtly distinct from the conventional treatment of field propagation. The conventional approach is unilateral, prioritizing emission and treating absorption as a passive, unquantified sink. In the Direct-Action Theory, by contrast, both emission and absorption are active processes contributing in specific ways to the actualization of a spacetime event. On a process-relational reading, the retarded offer wave is the real potentiality of the objectified past pressing in, prehended by the physical pole of an actualizing occasion; the absorber's advanced confirmation conforms physically to that offer and, across the many eligible absorbers, expresses the contrasted field of alternative real *potentiae* from which a single outcome is selected via the mental pole's evaluation of alternatives.

The "advanced" character of that confirmation has, ever since the original absorber theory and Cramer's first formulation of the transactional interpretation, invited the objection (encouraged by spacetime actualism) that it requires retrocausation—a confirmation propagating backward through time from absorber to emitter, with all the paradoxes that backward-in-time signaling would entail. Kastner's possibilist interpretation dissolves that objection. Offer and confirmation waves are not entities propagating through spacetime at all but "physically efficacious but not necessarily actualized" real possibilities whose emissions and absorptions are primary dynamical processes originating in a sub-empirical, pre-spatiotemporal realm described by Hilbert space.[63] This substratum should not be imagined as though it featured free-floating possibilities. Within RTI, offer and confirmation waves do not subsist on their own but are generated by an emitter and its responding absorbers (e.g., atoms and molecules[64]), so that the *potentiae* of the substratum are always the conditioned potentiality of antecedent

[61] Whitehead, *The Harvard Lectures of Alfred North Whitehead*, 1924–1925, 75.

[62] Wheeler and Feynman (1945, 1949). The quantum relativistic form of the direct-action theory on which RTI builds draws on Davies (1971, 1972).

[63] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 66-67, 203.

[64] Kastner *The Transactional Interpretation of Quantum Mechanics* (2022), 51.

actuality, never merely possible objects awaiting promotion into existence.[65] But as Kastner clarifies:

> "emitters and absorbers are 'only' quantum possibilities themselves—that is, field excitations that couple to other fields or sets of bound field excitations such as atoms and molecules. A macroscopic emitter or absorber (e.g., a detector) comprises a large number of such micro-emitters and micro-absorbers. Its observable aspect is a network of linked actualized transactions."[66]

Determinate spacetime event-networks, with their fixed, future-directed order of emission before absorption, do not contain this quantum process but emerge from it, precipitating out of a pre-spacetime realm of indeterminate possibility.[67] Because the time-symmetric, advanced-and-retarded structure of the direct-action propagator characterizes this level of possibility and not the manifold of actual events, nothing literally travels backward in time. Actualization is itself an extra-spatiotemporal process rather than the spacetime "echoing" of Cramer's original proposal, and the attendant causal-loop paradoxes arise only on the block world picture that the possibilist reading avoids.[68] The appearance of retrocausation arises only from mistaking the logical ordering of the sub-empirical substratum for a process unfolding within metrical spacetime.[69]

This has a metaphysical analogue in Whitehead. The confirmation wave's selective contribution is no more to be imagined as backward-in-time causation than the mental pole's evaluation is, for the mental pole is not in time at all. As Whitehead clarifies:

> "Every actual entity is 'in time' so far as its physical pole is concerned, and is 'out of time' so far as its mental pole is concerned. [An actual occasion] is the union of two worlds, namely, the temporal world, and the world of autonomous valuation."[70]

The confirmation wave thus functions like Whitehead's mental pole in that both belong to what is "out of time"—the order of autonomous valuation among possibilities—rather than to the temporal world of physical transmission proper to the physical pole. Kastner's relocation of the offer/confirmation dynamics to the substratum of real potentiality is the physical counterpart of

[65] In the terms of contemporary analytic modal metaphysics (see note 1), real *potentiae* may be understood as dispositional powers grounded in and conditioned by actuality, preserving the proposal's consistency with Whitehead's ontological principle. The quantum substratum is not a realm in which fully determinate but unactualized things subsist, as in certain reifications of Platonic forms or merely possible individuals. It names instead the objectively real potential or dispositional order of actuality prior to its resolution into any particular actualized transaction.

[66] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 67. It is worth quoting Kastner at length here to clarify the point: "A macroscopic object termed an 'emitter' is just a type of object with a high probability of generating fields that can couple to other fields (i.e., microscopic emitters and absorbers). An example is a laser. The atoms that emit the photons are 'just' conglomerations of field excitations and exist in the quantum substratum, not in spacetime. If the previous sentence seems surprising, remember that Ernst Mach railed against the idea that atoms were real because they were not directly observable. We have become so accustomed to the concept of atoms that we have forgotten that they are not directly observable: we never really 'see' an atom. We can image small numbers of atoms through interactions with devices such as a scanning tunneling electron microscope, but those images are created from transactions between the apparatus and the imaged sample. The transactions result in a measurable current, and there are variations in this current (fewer or more transactions) depending on how many or few atoms comprise a given portion of the sample. The changes in current are rastered onto a two-dimensional surface to yield a kind of 'image' of the scanned surface, with regions corresponding to larger currents being identified with atoms. Thus we are not really 'seeing atoms'; we are seeing a representation of changes in the transacted current due to interactions between an electron offer wave current and atomic absorbers" (68).

[67] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 74, 91.

[68] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 65-66.

[69] The same relocation directly addresses an influential argument for the block: the inference from the relativity of simultaneity to the equal reality of past, present, and future events (Rietdijk, 1966; Putnam, 1967; see also Stein, 1968, for a relativistic rejoinder). That inference is commonly taken to show that any objective becoming conceived as a globally advancing present within the spacetime manifold would require a preferred foliation forbidden by special relativity. On the present account, however, becoming is not a process occurring within spacetime at all. Rather, determinate spacetime events arise through transactions in the pre-spatiotemporal quantum substratum. Frame-dependent simultaneity assignments pertain only to the emergent manifold of already actualized events, while its invariant structure consists in the partial causal order constituted by actualized transactions. Because this growth requires no preferred foliation, it is compatible with Lorentz invariance. Kastner (2016) develops the affinity with Sorkin's causal-set program, whose classical sequential-growth dynamics has likewise been proposed as a model of objective becoming compatible with relativistic covariance (Sorkin, 2007); see also Kastner (2025a).

[70] Whitehead, *Process and Reality*, 248.

Whitehead's location of valuation in the dipolar occasion's mental pole. The completed transaction is then concrescence reaching satisfaction as a "spontaneous symmetry breaking"[71] whereupon the until then indeterminate event attains objective immortality as a datum for subsequent transactions.

This dipolar structure lets us draw a further connection. The actualized transaction—an emission–absorption event whose termini are connected by a null interval—illustrates, at the physical level, what Whitehead calls causal efficacy, that is, the conformal inheritance of settled actuality whereby a present occasion takes up its predecessors as efficacious for its own becoming. Two events are timelike separated when a signal traveling slower than light can connect them, null or lightlike separated when only light itself can connect them, and spacelike separated when no physical signal can pass between them. In RTI these three relations do not stand on equal ontological footing. The emergent discrete manifold is constituted solely of null intervals, the invariant links established by actualized photon transfers. Massive systems participate as emitters and absorbers, remaining in the quantum substratum.[72] Timelike relations therefore arise derivatively, along the chains of successive actualized events associated with persisting massive systems, whose internal clocks (i.e., strictly local periodic processes yielding a locally increasing index) supply the parameter functioning as proper time.[73] In both the constitutive null links and the derivative timelike chains, the relevant connection is not merely geometrical but causal, marking the passage from real potentiality to determinate fact.

The boundary of the light cone is therefore not a mere limit inscribed in a coordinate grid. It marks the extremal condition of causal transaction, the luminous seam at which physical possibility can be knit into actual event. Spacelike-separated occasions, by contrast, find their Whiteheadian analogue in contemporary occasions that are neither in one another's causal past nor in one another's causal future, and therefore not mutually efficacious in their respective becomings. Whitehead's principle that contemporary actualities "happen in causal independence of each other" here receives explicit relativistic expression.[74]

Such contemporaries are not directly inherited in causal efficacy. They are indirectly displayed, or coordinately exhibited, in presentational immediacy. Presentational immediacy objectifies the contemporary world as an extensive continuum under the aspect of potentiality, as divisible but not yet divided, spread out for possible division but not disclosed in its actual atomic constitution. This does not mean that the contemporary world is wholly unrelated to causal efficacy. Its presented locus is indirectly implicated through the overlapping causal pasts shared by the percipient occasion and the relevant contemporary occasions. But the contemporary world, as contemporary, is not itself causally operative upon the percipient occasion. It appears as co-present extensive potentiality, not as inherited efficient fact.

The light cone is thus the physical exemplification of Whitehead's distinction between an efficacious causal past, a merely co-present contemporary world, and a causally relevant future. Whitehead assigns to causal efficacy not only the inheritance of the past but the partition of the extensive continuum into past and future. This separation, he writes, "lies with the mode of causal efficacy and not with that of presentational immediacy," while "the mathematical measurements, derivable from the latter, are indifferent to this distinction."[75] The arrow of time is therefore borne

[71] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 66, 73-76.
[72] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 147, 203: the fermionic matter fields and bound states "are not transferred by way of offers and confirmations in transactions." The spacetime structure grows by photon emission and absorption events, so that the manifold "is really constituted solely of null intervals," while systems with rest mass remain in the extra-spatiotemporal quantum substratum.
[73] Kastner, *The Transactional Interpretation of Quantum Mechanics* (2022), 206–207.
[74] Whitehead, *Process and Reality*, 61. For Whitehead, this point "lies on the surface of the fundamental Einsteinian formula for the physical continuum."
[75] Whitehead, *Process and Reality*, 170.

by causal inheritance and not by measurable geometry. This is akin to the asymmetry that, in RTI, enters only with actualization. Further, on this reading, the metric itself is understood to be derivative. For Whitehead the extensive continuum is, in its full generality, the mere potentiality of extensive connection, lacking even "the relationships of metrical geometry," which are "additional determinations of real potentiality arising from our cosmic epoch."[76] For Kastner, as we've seen, spacetime is also not a self-subsistent substance or "container" but the relational order of actual events, membership in which is achieved by the transactions themselves.[77] On neither account is the metric the stage on which actualization is performed. It is, rather, a structure precipitated by it. The recovery of the Einstein equations as an emergent, entropic consequence of transactional activity converges with Whitehead's thesis that metric spacetime is a derivative achievement, not a primitive container.[78]

The pairing of causal efficacy with presentational immediacy is not, however, a bare dyad. In Whitehead's account, their integration into intelligible experience requires a mediating third, *symbolic reference*, in which the perceptual immediacy of the contemporary world is interpreted through the felt causal inheritance of the past, and the felt inheritance is in turn made specific by the presentational display. This triadic structure of past inheritance, present display, and their integrative reference is akin to what Eastman, developing C. S. Peirce and James Bradley, refers to as the input–output–context structure of every actual relation, without which coordinate analysis would give us only isolated events lacking any interpretive coherence.[79] In Kastner's RTI framework, the physical analogue of this mediating third is not symbolic reference in the perceptual or psychological sense, but the actualized transaction itself. The offer wave opens a field of physically real possibility, the confirmations specify the relevant absorber responses, and the transaction integrates these poles into one determinate event. The triadic pattern is therefore preserved at a more general ontological level as inherited condition, presented or available possibility, and decisive integration. Whitehead, Eastman, and Kastner thus each refuse to treat the coordinate domain as self-explanatory. Intelligibility requires not merely coordinates, nor merely events, but the mediating activity by which potential relations become determinate, interpretable, and historically efficacious facts. On this reading, the frameworks here being compared are not merely dipolar but triadic. Their convergence recovers the ingredients of intelligibility that spacetime actualism's reification of the coordinate domain had obscured.[80]

The foregoing correspondences converge on an important recovery that reaches past modern physics to the ancient mystery of what it means for anything to be affected by another. RTI restores to physics something the bifurcation of nature had made unthinkable: the reality and efficacy of *receptivity*. The prehensive aspect of field behavior is made explicit and quantified in the active receptivity of absorbers, so that the transaction reflects the mutual relatedness or solidarity of actual occasions against the unilateral, emission-first picture that treats reception as passive. In process-relational terms, this receptive moment is not the inert half of an otherwise active process but is itself a *decision*. Across the field of eligible absorbers, and amidst relevant alternative *potentiae*, the mental pole's selective response contributes a new component fact to the creative advance. This shift is convergent with certain strains of Eastern thought, exemplifying in particular the Yin pole of the Taoist polarity. Western science, in contrast, has tended to recognize only the Yang of active emission. Whitehead himself located the philosophy of organism nearer to certain strains of Indian and Chinese thought than to the European tradition, precisely because

[76] Whitehead, *Process and Reality*, 66.
[77] Kastner, *The Transactional Interpretation of Quantum Mechanics*, 72-73, 200.
[78] Schlatter and Kastner 2023.
[79] Eastman, *Untying the Gordian Knot* and "Implications of Triads as Primal," *Holistic Science Journal*: 3 in 1, Vol. 5, 4/2026.
[80] Whitehead, *Symbolism: Its Meaning and Effect* (New York: Fordham University Press, 1985); *Process and Reality*, 168–183.

the one makes process ultimate while the other makes static fact ultimate.[81] Read this way, RTI is not merely consistent with Whitehead's cosmology but is a worked out, quantified expression of it.

8. Conclusion: Toward an Integrative Cosmology

Our two test cases, drawn from opposite ends of the scale of nature, exhibit the same convergence. At the largest scale, the cosmological manifold is revealed to be a coordinate abstraction whose absolutization mistakes the limit of a map (the singularity) for the causal origin of the universe. At the smallest, the quantum transaction generates determinate events from an order of real potentiality that conditions without determining them. In both, the apparent world of enduring physical bodies in spacetime is actual but not fundamental, since it arises from a process of actualization whose constitutive features—prehension, decision, the entertainment and evaluation of possibility, the directedness of aim—are not eliminable froth or mere "psychic additions"[82] but the engine of the creative advance that issues, eventually, in knowers.

Cosmology is possible only because possibility is ontic. A finished block universe has no room for the becoming that a properly evolutionary cosmology sets out to describe, and so a strictly spacetime actualist cosmology cannot account for its own history. And cosmology is possible, in the reflexive sense, only because the universe is the kind of process that can flower into beings who measure, conjecture, and care about truth. Whitehead's account of coordinate division grants physics all that is needed for accurate measurement of actualized spacetime while heading off the reification of actualist metaphysics. Dividing the satisfaction of an actual occasion coordinately yields prehensions that *might have been* but *were not* separated.[83] Spacetime actualism is the systematic collapse of these might-be divisions into divisions that *are*. It reifies the divisible into the divided, coordinate abstraction into concrete fact. The manifold of points and instants that actualism mistakes for the finished furniture of the universe is in truth a record of *possible* standpoints, the coordinate shadow cast by actualities each of whom enjoyed its quantum *in solido*, whole and undivided. To mistake that shadow for the substance is the fallacy of misplaced concreteness writ large. A cosmic morphology of completed abstract divisions, treated as accomplished facts, leaves no room for the potentiality that all inquiry presupposes. An already actualized block universe of pregiven coordinates may include the cosmologist's physical worldtube, but it cannot include the cosmologist as inquirer. It contains the theorist only as one more configuration in the coordinate grid, never as a living entertainment of alternatives that remain genuinely open. Spacetime actualism thus saws off the onto-epistemic branch upon which it is perched.

Whitehead's account of consciousness as a late and occasional achievement suggests why the actualist mistake is so natural. Consciousness arises late in the integrative process, illuminating with clarity the sharply defined products of earlier phases of integration. It apprehends the clean deliverances of presentational immediacy, including the distinct regions and instants of the coordinate scheme, leaving the genetic process from which they issue in comparative penumbral dimness. We can draw a striking empirical formulation of this asymmetry from Kauffman's account of quantum measurement in the double-slit experiment. We never apprehend the coherent wave, only the spots, the localized outcomes registered once a determinate event has occurred.[84] On the process-relational reading, this is a consequence of the concrescent phase-

[81] Whitehead, *Process and Reality*, 7.

[82] Whitehead *The Concept of Nature*, 29.

[83] Whitehead, *Process and Reality*, 283-285.

[84] Kauffman, *Humanity in a Creative Universe*, 133.

structure of experience itself. The coherent superposition is dim not because it hides behind a screen we cannot pierce separating the quantum from the classical, but because it belongs to the early genetic phases of concrescence, wherein the reception and valuation of real *potentiae* transpire beneath the later irradiating flash of consciousness. As Whitehead puts it:

> "Consciousness flickers; and even at its brightest, there is a small focal region of clear illumination, and a large penumbral region of experience which tells of intense experience in dim apprehension. The simplicity of clear consciousness is no measure of the complexity of complete experience. Also this character of our experience suggests that consciousness is the crown of experience, only occasionally attained, not its necessary base."[85]

What quantum theory describes as indeterminate superposition and what experience undergoes as vague, massive, as yet inarticulate feeling are then the germinal phases of a concrescence still actualizing itself. Consciousness, then, does not look on at the transaction from outside but is a concrescence achieving its satisfaction, feeling itself as the affirmation of this against the negation of that. We apprehend only the decided spots because there is no standpoint prior to that culmination from which the coherent superposition could have been an object of awareness, for awareness is precisely what the completed decision *is*. The coherent penumbra is dim because it is the womb of consciousness, and consciousness can no more turn to illuminate the darkness that bore it than a flashlight can go looking for the dark.

Consciousness is a late arising phenomenon that all too easily mistakes its region of clearest light for the primitive constitution of nature. This is the understandable but unnecessary perspectival root of spacetime actualism. Its correction requires the deliberate discipline of speculative philosophy. The process-relational alternative re-roots inquiry in the same process it is attempting to know, restoring to the universe both the expansive openness that makes its evolution statistically measurable and the intensive depth that makes it capable of coming to know itself.

Healing the bifurcation of nature does not mean adding a humanistic flourish to a finished physics, nor retreating from the rigor of the coordinate scheme into vague mysticism. It means recognizing that the same creative process the physicist studies in its low-grade, repetitive, measurable habits is the process that, in its higher reaches, *becomes* the physicist's own thinking, valuing, and wondering. Fact and importance, the conjecture and the dream, the measurable and the felt, are abstractions from a single experiential reality. What science holds apart as methodological convenience, metaphysics must reintegrate. A cosmology adequate to its own possibility must be able to honor at once the precision of the coordinate domain and the creativity of the genetic process from which it arises. Toward such an integrative cosmology, in which the achievements of physical science and the real emergence of knowers within nature are at last thought together, transactional physics and process metaphysics jointly point.

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[85] Whitehead, *Process and Reality*, 267.

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