v1: 26 January 2026

Review Article

The Vicarage Iconoclast: Whitehead, Leibniz, Relativity, and the Quantum

Preprinted: 29 July 2025
Peer-approved: 26 January 2026

Qeios, Vol. 8 (2026)
ISSN: 2632-3834

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This manuscript critically examines Alfred North Whitehead's metaphysical system as it relates to quantum mechanics, relativity, and Leibnizian philosophy, presented through an extended philosophical dialogue. It challenges Whitehead's core assumptions, particularly his interpretations of quantum discontinuity, internal relations, and the structure of spacetime. The author argues that Whitehead's metaphysics, rooted in subjective experience, prehension, and the primacy of simultaneity, is undermined by its misreading of both modern physics and Leibniz's metaphysics of substance and relation. Whitehead's rejection of continuous becoming and motion, his treatment of actual occasions as discrete experiential events, and his notion of "eternal objects" are scrutinised in the context of process philosophy and critiques from contemporary physics. The dialogue also engages with recent reinterpretations, notably those of Carey Carlson, Florian Vermeiren, and Michael Epperson, addressing causal set theory, quantum potentia, and decoherence in light of Whiteheadian metaphysics. The manuscript ultimately questions the coherence of Whitehead's system under relativistic constraints and critiques the theological and holistic presuppositions underlying his cosmology, and, by implication, any cosmologies assuming a wave function for the whole universe.

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Preamble

Whitehead was keen on dialogue as a vehicle for philosophical exploration. Concerning Galileo's *Dialogues on the Two Systems of the World*, he wrote that its dialogue form "is an essential element to its excellence. It allows the main expositor of the dialogues continually to restate his ideas in reference to diverse trains of thought suggested by the other interlocutors" (Whitehead 1922, vii). I think one can gain even more latitude in expressing difficult thoughts in a natural way by embedding the dialogue in a continuous narrative addressed to an unknown correspondent.[1]

My sources are manifold. I have been engaged in dialogue with Bill Sulis, a remarkably learned psychiatrist with PhDs in mathematics and theoretical physics, whose book, *Process and Time*, I reviewed for World Scientific Publishing.[1] I do not get into his theory of "informons" as a way to understand

 doi.org/10.32388/932RTK.4

the non-Kolmogorov nature of quantum probability, but the body of his book is a protracted investigation of a Whitehead-inspired approach to the philosophy of physics, which has certainly given me useful material. I have also quoted liberally from texts sent to me, unsolicited, by Carey Carlson, with whom I have had some email correspondence. I have never met him, so what is said in his name is partly quotations from those texts, and partly imaginative extrapolations from them.[2] For my understanding of Whitehead's theory of gravity, I am also indebted to Jonathan Bain, and his article on the subject.[2] Finally, I have also profited a great deal from exchanges with Florian Vermeiren, a bright young Belgian scholar, about how to understand relations in Leibniz's philosophy, a highly contested and complicated topic. He defends Whitehead's understanding of internal relations in his Deleuze-inspired thesis, now a book,[3] and proposes it as the correct way to interpret Leibniz on relations. The final version of the dialogue owes much to input from Ruth Kastner and Bill Sulis, and from *Qeios* reviews by Jo Edwards, Timothy Eastman, and Adrian Heathcote.[3] Where I have silently borrowed text from their published writings, I have footnoted those with a 'q.v.'

Had I composed this material in the form typical for publishing academic articles, I might have titled it "A Refutation of Whitehead's Metaphysics of Physics", or split it into several papers: "Whitehead's Interpretation of Quantum Theory", "How Whitehead's Metaphysical Presumptions Ruined his Foundations for Relativity Theory", "Whitehead versus Leibniz on Internal Relations", and so on. But I believe this approach is more interesting, and likely to elicit more engagement with the issues.

Whitehead, Leibniz, Relativity and the Quantum

"'*The Vicarage Iconoclast*'– isn't that a bit harsh?" I remember you protesting. "I mean, I get the reference to Russell's disparaging remark about Whitehead's philosophy, that in it there always remained something of the atmosphere of the vicarage, or words to that effect."[4] But Whitehead was trying —"bravely, in my opinion", you said— to create a new metaphysics that would be adequate to the completely different picture of reality presented by modern physics, especially quantum theory.

I pointed out that first you have to be clear about what picture of reality quantum theory presents —we are now a hundred years on from its inception and there is still no agreement about that. In the years between the World Wars, and for the rest of the twentieth century, I said, physicists were "so eager to throw away the existing foundations that they seized on any old planks of dubious philosophy to replace them."

"What do you have in mind? Bohr's Copenhagen Interpretation?"

"Perhaps to an extent, although not everything Bohr said lacked insight."

"Can you give examples?" you asked.

"Well, there is that statement of Bohr's which became a mantra for his one-time student, the great John Archibald Wheeler: in quantum theory 'there are no phenomena until they have been brought to a close by an irreversible act of amplification'."

"But doesn't that place the observer at the centre of reality? Wheeler himself speaks of this as if the observer creates reality."

"I know. But I was thinking of 'phenomenon' in a less subjective sense, such as the click of a Geiger counter or a pixel manifesting on a television screen. I think this notion of 'event' —a contingent outcome of an interaction process— is much more nearly correct than that implicit in many contemporary interpretations, where the events are taken to be values of wave function amplitudes."

"So that was not what you meant by 'old planks of dubious philosophy'?"

"No, I was thinking of philosophies like operationalism, a kind of rehashing of instrumentalism where theories are just codifications of possible experimental outcomes that say nothing about physical reality, and also the idealist phenomenalism implicit in the preposterous notion you just mentioned, that Quantum Theory —and Relativity too— both require essential reference to an observer. Although Whitehead resisted operationalism, he seems to have made the experience of observers foundational."

I saw you toss your head in that way of yours when you are starting to lose patience. You reminded me that Whitehead was no slouch when it came to relativity theory: "For decades his own theory was Einstein's only serious rival!"

"I don't for a moment deny his daring and innovation," I replied. "Defying Einstein at the height of his reputation to reassert the independence of the geometry of spacetime from the behaviour of physical fields was indeed audacious. He granted Einstein that spacetime could be curved, but held that it is a causally inert, uniform background, against which the dynamics of matter interactions, including gravity, play out."

"I thought that might appeal to you. Better than imagining spacetime as something that can act on or be acted on by matter, which is to make it quasi-substantial. In fact, I would have thought that you, as an expositor of Leibniz, would have been more sympathetic to Whitehead."

"Why do you say that?"

"Well, apart from his championing of Leibniz's relational space over Newton's absolute space, I was thinking of his attempts to replace the dominant 'materialist' philosophy by one based on organism. He also followed Leibniz in holding that all actual change is discrete, saying in his *Science and the Modern World* that the discontinuous transitions of quantum theory represent what he called 'actual occasions'."

Here I remember being somewhat taken aback, since my recollection had been that Whitehead rejected the idea of continuous transition altogether, on the grounds that there was no other way to resolve Zeno's paradoxes of motion than by having motion take place in discrete jumps.[5] But if his "actual occasions" could be thought of as modelled on quantum phenomena, where there is no actual phenomenon until it is manifested in some interaction, then his philosophy would make more sense to me. The process resulting in the audible click of a Geiger counter, a discrete event, could be analysed in terms of the path of a particle given off by some radioactive matter, a path that could be represented as continuous in space and time *after* the event; but there would have been no event until this process of amplification had been brought to completion. Whether or not that is what Whitehead meant, that at least makes sense to me.[6]

But when I later checked your reference to his *Science and the Modern World*,[4] I found that Whitehead had written of the necessity for a revision of concepts that required "some theory of discontinuous existence", adding that "What is asked

from such a theory, is that an orbit of an electron can be regarded as a series of detached positions, and not as a continuous line." I think that's awkwardly classical, talking of electrons as if they were objects performing one orbit at a time, so that the whole thing is brought into being "atomically in a succession of durations, each duration to be measured from one maximum to the other." Of course, Whitehead probably had in mind the Old Quantum Theory of Bohr and its discontinuous quantum jumps, since when he wrote *Science and the Modern World* Schrödinger's and Heisenberg's contributions were just about to be published. But in his later works he perseveres with this idea of "quanta of time" as a way of avoiding "the difficulty of Zeno".[7] So I was right about there being no continuous becoming in his conception, although he allows the coming-into-being of the continuous.[8]

When we were speaking, though, I was distracted by your reference to Whitehead's debt to Leibniz, so I replied to that, setting off a long argument which, happily, I had recorded on my cell phone, and my (admittedly editorialised) transcription follows. I said:

"Granted, Whitehead follows Leibniz in promoting a philosophy of organism — although I am not sure he means the same thing by it as Leibniz does... Still, it is true that he does adopt a version of Leibniz's monads, substances as living organisms, and even endows them with something like the faculties of perception and appetition that Leibniz attributed to all monads..."

"That's right. Whitehead thought of his monadic creatures as 'housing the whole world in in one unit of complex feeling'[9] —this is his analogue of Leibniz's idea of perception as the representation of the whole of the rest of the world."

"Yes, I can see how the 'housing the whole world in one unit' echoes Leibniz's talk of the created monad containing everything implicitly or virtually through its confused perceptions, and also how Whitehead's 'creatures' take off from Leibniz's living mirrors that are both active and vital."

"Exactly!" you replied. "And he seems to be channelling Leibniz when he says that in a sense everything mirrors the whole world from its own spatiotemporal standpoint.[10] But he does not blindly follow him, as I'm sure you are aware. Although he admires Leibniz for introducing monads, he says that for him a monadic creature 'is constituted by its totality of relationships, and cannot move.'"

"Cannot move? Well, here it seems to me that Leibniz's position is far superior to Whitehead's. Leibniz believed that monads, although not themselves extended, are always situated in an organic body through which they manifest themselves physically in the phenomena. This is not unlike the idea in modern physics of sources of fields (like charged particles) not having precise locations, but only *being* where they *act*. Borrowing terminology from the Schools, Leibniz said that monads are located *definitively*, i.e. where they are determined to be acting, and not *circumscriptively*, i.e. as existing at particular points of space at each time. Consequently, a monad—like your soul—can be said to be roughly where your body is doing its thing (and not in my body, for instance!), and the same goes for any other source of activity in the world."

"But that is a very classical view, don't you see?" (Here you were getting quite animated.) "Despite all the talk of units of activity, Leibniz is assimilating monads to the substance-property philosophy that he inherited from Aristotle and the Scholastics – whereas Whitehead is trying to persuade people that that old metaphysics must be discarded in the light of modern physics."

doi.org/10.32388/932RTK.4

"What is his critique of that? Surely not the corny criticism of Locke and Russell that substance is an empty term, a peg on which properties are hung like hats, but which vanishes when they are all removed!"

"Not quite. The error lies in the supposition that there is something that is characterised by essential properties, and remains the same individual as all its accidental relations and qualities change. Thus he says that his theory of monads differs from Leibniz's in that the latter's monads *change*, whereas in his own organic theory, they merely *become*."

"I know he said that – in *Process and Reality*, if I'm not mistaken[11] – but I can't see how it can be justified. For Leibniz an actual existent is 'something that by acting does not change,' a nice formulation he came up with in an early dialogue.[12] In other words, it is that thing that preserves its identity even while always becoming something different, like a caterpillar turning into a butterfly. It remains the same thing while its accidents change."

"Well, that is still to characterise what is the same individual by its essential properties, whereas for Whitehead it is defined by the relations it has at any time, so it cannot remain the same while its accidental relations and qualities change. But I do see your point. If we took a modern process philosophy perspective, we would expect the criticism to be that Leibniz held substances to exist from the beginning of the world until its dissolution, whereas processes are only of a limited duration. But," you insisted, "Whitehead wants to go further. On his view, the idea of a substance carrying an electric charge is merely a way of codifying how the charge moves about in relation to other things. To regard it as having a life history in which it continues its function of determining the diffusion of a pattern is a useful abstraction, but it is completely futile to conceive this as a concrete individual.[13] So his process philosophy is radically opposed to interpretations of modern physics in terms of particles, as if they are the underlying reality. In fact, there are good reasons for thinking that bosons and fermions are *indistinguishable* within their kinds, and so not interpretable as distinct physical individuals undergoing changes of state."

"I think if Leibniz were alive today he would probably agree with that. He took the hypothesis of atoms, for instance, to be a useful one for prosecuting mechanistic explanations, but one that left unexplained the underlying physical processes giving rise to the phenomena."

"Interesting. Nonetheless, I think Whitehead's point stands about the incompatibility between the substance-accident metaphysics which Leibniz upholds, and his idea of monads as sources of organic unity."

"How so?"

"Well, he praises Leibniz for initiating the philosophy of organism by making monads the ultimately real entities, since they are essentially processes of organising reality, 'fusing ingredients into a unity,' as he put it, 'so that this unity is the reality.'[14] But," you explained, "that depends on the acceptance of *internal relations* binding together all reality, whereas the substance-accident point of view is inconsistent with the reality of such relations. He allows that Leibniz's conception of monadic 'points of view' implicitly relates sense-data to events, but criticises Leibniz for then admitting such many-termed relations 'only on condition that they are purely qualities of the organising monads.' Whitehead credits Bertrand Russell with suggesting this analysis."[15]

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I replied that this is a mistaken interpretation of Leibniz, and one stemming from Hegel.[16] "Since each monad is effectively a world unto itself, Leibniz was not entitled to believe that everything is interrelated, and strove to avert the paradox by introducing the subterfuge of pre-established harmony – or so says Hegel. When Russell came to a serious study of Leibniz near the end of 1898 and saw him rejecting any purely extrinsic denominations, he interpreted this as Leibniz 'denying' external relations, in agreement with Hegel and his commentators. But, he insisted, Leibniz needed real many-termed relations, for instance, for his theories of space and time."

"As I was just saying," you replied, "Whitehead agreed with this analysis. He held that Leibniz was inconsistent in combining the two points of view on substance by making his monads windowless, while their passions merely mirrored the universe by the divine arrangement of a pre-established harmony.[17] I did not know this came from Hegel."

"Yes, it is in Hegel's account of Leibniz in *Lectures on the History of Philosophy* – Russell even marked up the relevant passages in his copy.[18] Russell's own distinctive contribution was to see Leibniz as committed to reducing every binary relation between two things to a pair of unary properties, with one belonging to each of them. This was a view that Russell himself had previously held, under the influence of Hermann Lotze (perhaps mediated by his tutor Seth Ward), and had just abandoned in late 1898, because it would not work for the asymmetric relations needed by mathematics and science. This bias against external relations Russell ascribed to Leibniz's commitment to the logic of the Schools. And once he saw this inconsistency so clearly revealed in Leibniz, he came to see it in all prior metaphysics. Whether you thought the ultimately real was substances (as in monadologies) or the Absolute (as in the monism of Hegel and Bradley), these metaphysics were all premised on the pre-eminence of subject-predicate logic."[19]

"Yes, this was part of Whitehead's motivation for rejecting substance-property metaphysics, although he also thought that its rejection was required by modern science. Still," you observed, "Russell and Whitehead took this insight in very different directions."

"They certainly did! Russell was scathing about internal relations—just read his review article of Harold Joachim's book!—whereas, from what you've said, it seems that Whitehead took them as fundamental to his new worldview.[20] Russell accused Leibniz of allowing his commitment to the doctrine of internal relations to blind him to the necessity of external relations for mathematical science. So Russell rejected internal relations—claiming that this was 'the one true revolution' in his own thought[21]—and made external relations existents in their own right, voiding their relata of any qualities on which they had to depend."

"For Whitehead that would be an example of the 'Fallacy of Misplaced Concreteness.'[22] He certainly agreed with Russell about the necessity of external relations for mathematical science, but not that such *abstracta* could then be taken as existents in their own right. But," you asked, "what were Russell's criticisms of internal relations?"

"Russell took what he called the 'axiom of internal relations' to be that every relation must be internal, that is, grounded in the natures of the terms it relates. Given the substance-property metaphysics, he held that these 'natures' would have to be unary properties of the substances possessing them. Now, take some

putative internal relation, such as 'being before A' as a state of B. One could also have 'being after B' as an internal relation or state of A, but there is still nothing to connect these two internal states together. There needs to be something else that connects them, to the effect that *x*'s being after *y* entails *y*'s being before *x*, and vice versa. But this will be a relation – moreover, an 'external relation, i.e. one implying no complexity in either of the related terms,' as Russell said in his book on Leibniz. So if Whitehead thinks that such external relations are just abstractions, how does he get around the objection?"

"Well," you replied, "he agrees with what Leibniz said in the *New Essays* about every term involving relations with all others, and thus leading to everything else in the universe.[23] But in Leibniz's philosophy, the internal relations are perceptions, and these are conceived passively: the thing perceived does not act on the perceiver, or vice versa, because there is no interaction between any two substances. Individual experience makes no contact with external reality; it just represents it, consciously (in apperception) or unconsciously. Whitehead rejects this notion of perception as mere representation, and proposes instead his notion of 'prehension', as the way in which the occasion of experience can include any other entity as part of its own essence. He says that 'Actual entities involve each other by reason of their prehensions of each other.'"[24]

"So when Whitehead talks of actual entities 'involving one another' in prehension, is he proposing that such entities or occasions directly act on one another, in opposition to Leibniz's denial of any influx from one substance to another?"

"Not quite. What he calls 'prehension' is not a representation of one actual entity in another, but the *presence* of one actual entity in another. You have to understand that Whitehead conceives actual entities as 'acts of experience arising out of data'. He describes an actual entity or occasion as 'a process of "feeling" the many data,' so that they ...."[25]

"Excuse me, did you say that for Whitehead what are actual are just experiences, feelings?"

"Yes, he explicitly says that 'apart from the experiences of subjects there is nothing, nothing, nothing, bare nothingness'. For him, 'process is the becoming of experience.'[26]

"But this is pure subjectivism!"

"Well," you began, "Whitehead says that this is an instance of what he calls the 'reformed subjectivist principle,' by which ..."

At this point our conversation was interrupted by someone calling you on your mobile phone, and I stopped recording. By a happy coincidence, it turned out to be Carey Carlson, an acquaintance of yours who is convinced that he has an interpretation of modern physics in the spirit of Whitehead. (He has written to me a few times, so I know something of his work.) As we have discussed, he claims to be able to construct quantum theory from causal sets, using the quantum of action to define energy ratios, and to be able to construct spacetime from causal links. But he is frustrated that his process physics interpretation has not found favour with Whitehead scholars. When you mentioned to him what we were talking about, and that I objected to Whitehead's philosophy as subjectivist, Carey asked to be put on speakerphone, so I began recording again.

"Subjectivism is not a problem!", he exclaimed. "On the contrary, I think that Whitehead can be understood to have solved 'the hard problem' of mind and

body! For it is only Whitehead's occasions, connected together by time-ordering pairwise relations, that constitute the universe. But I revise his theory a bit, since in my view, despite his wanting to avoid Descartes' 'vicious dualism,' Whitehead ended up with a dual-aspect theory after all. In *Adventures of Ideas*, he says that 'The universe is dual because each final actuality is both physical and mental.'[27] But I think occasions can be conceived as purely mental entities, having no intrinsic physical attributes whatever. They are point-like primitives of temporal structure."

"But all this talk of subjectivism needs qualifying!", you objected. "Whitehead rejects the idea of an underlying subject. There is no subject that encounters a datum. Rather, there is a datum 'which is met with feeling and progressively attains the unity of a subject.' He says that for this reason, 'superject' would be a better term than 'subject'."[28]

Here the conversation went back and forth between the two of you so fast that I was not able to catch everything that was said, although when I played it back afterwards I was able to retrieve some nuggets; and then when I joined in, I accidentally turned off the recording. First, Carey pointed to the debt that Whitehead had professed to Hume for his philosophy of organism.[29] Noting that Hume had seized upon his own experience of the moment, conceived as purely mental, as the only thing that survived his sceptical onslaught, Carey attributed this to both Russell and Whitehead as their starting points for building up the physical world.[30] You bridled at that, pointing out that the whole intention of both Whitehead and Russell (circa 1914) was to give a unified ontology, not one that was cleft into two disparate realms. For them subjective and objective were two complementary aspects of the *same* world: two different aspects of sense-data for Russell, whereas for Whitehead when one actual entity prehends another, it objectifies it as one of its data.

"There is a concrescence of a *res vera* out of subjective feelings," you said. "For Whitehead what becomes is always a *res vera*, and the concrescence of a *res vera* is the development of a subjective aim. Thus actuality is always private, but the objective side of an actual occasion is how it is added to the multiplicity of the universe and is thus part of the potentiality for a new unification."[31]

In defence of his subjectivist reading, Carey quoted from *Adventures of Ideas*: "The actualities of the Universe are processes of experience, each process an individual fact. The whole Universe is the advancing assemblage of these processes".[32] You countered that in order for the mere potentialities of mathematics to become real objects for the subject, according to Whitehead, additional content was required, and he claimed that this is supplied by the sense-data. And sense-data are eternal objects that connect the actual entities of the past with the actual entities of the present.[33]

"But," I butted in, "according to Whitehead eternal objects don't have any existence on their own; they stand in need of God to make them exist. In fact, the two of you have been quietly neglecting this whole side of Whitehead's philosophy, his theism. He even says that without the intervention of God there could be no order in the world."[34] At this you couldn't resist mentioning that I had called Whitehead "the vicarage iconoclast", and Carey wanted to know what I meant by that. I observed that God is mentioned two hundred times by Whitehead in the 533 pages of *Process and Reality*, then picked up my copy of it and quoted some aphorisms I had earmarked: "each temporal occasion embodies God, and is embodied in God. In God's nature permanence is primordial, and flux

is derivative from the World" (*PR* 529); and "the actuality of God must also be understood as a multiplicity of actual components in process of creation. This is God in his function of the kingdom of heaven" (*PR* 531). There is more on "the love of God for the world", and God as "the great companion —the fellow-sufferer who understands" (*PR* 532). "Sentiments from the vicarage," I said, "and a decidedly Christian one at that." Here I added, perhaps superfluously, that there is also a strong whiff of Hegel in Whitehead's cosmology, citing "the dynamic effort of the World passing into everlasting unity" (*PR* 530).[35]

At this point Carey summoned a retreat to the physics, quoting Whitehead from his 1922 book, *The Principle of Relativity*, about the meaning of "philosophy" in this connection: "It has nothing to do with ethics or theology or the theory of aesthetics" (p. 4). He also alluded to the quotation about the aim of science that Whitehead gave from Poynting on p. 5: "I have no doubt whatever that our ultimate aim must be to describe the sensible in terms of the sensible," which Whitehead described as the "keynote" for his whole book. This led to a discussion between all three of us on the philosophy of science. I pointed out that Poynting and Whitehead, like the positivists, were confusing the empirical method in science with the philosophical school of empiricism. There is no doubt that scientific theory must conform with experience and be tested in experiments, but experience and experiment need interpreting: they provide evidence to assess theories, not sensations out of which reality must be built.

"Again we are getting sidetracked," said Carey. "That is not what I meant about getting back to the physics. What I said about time relations between pairs of occasions constituting the universe is based on Whitehead's reading of relativity theory. This is how he defines 'contemporary events' without resorting to spatial relations or extension-in-space:

> It is the definition of contemporary events that they happen in causal independence of each other. Thus two contemporary occasions are such that neither belongs to the past of the other. The two occasions are not in any direct relations [of] efficient causation. (*AI* 251)"

Carey reminded us that he models what Whitehead calls "direct relations" among occasions by arrows representing an efficient causal relation between them. According to Special Relativity, any two such occasions are such that the cause is in the absolute past of the effect, so that the arrows also represent temporal succession. Any two connected by an arrow are in "breach of privacy"; no such breach occurs with contemporary occasions, since there is no possibility of an efficient causal relation between them, making them, in Carey's terms, "momentary monads", each one being contiguous with an earlier and a later occasion,[36] but independent of its contemporaries. "On this basis," he claimed, "one can obtain a four-dimensional manifold, and after defining relative velocities from this single time-parameter, there is no need to postulate a limiting velocity."

"Does this mean that Whitehead is rejecting Einstein's Light Postulate?" you asked. Before Carey could answer, I pointed out that it is indeed possible to construct Special Relativity without the Light Postulate. I explained that this has been done, independently, by several authors, but first of all by Alfred A. Robb in 1911, and in several subsequent publications, most notably in *A Theory of Time and Space*, published by Cambridge University Press on Russell's recommendation in 1914.[37] In fact, as Russell noted, this construction became

something of a lifelong obsession for Robb. “But, strangely,” I added, “there is no mention of Robb in Whitehead’s 1922 book (*The Principle of Relativity*), also published by Cambridge UP, despite his close working relationship with Russell in 1913–14. He does not seem to have engaged with Robb’s writings at all.”[38]

“That’s very interesting,” said Carey. “I had not heard this about Robb. But the genius of Whitehead’s idea is that all the actual relations between occasions are temporal, thus eliminating instantaneous spatial relations as anything real at all. The network of these relations of temporal succession then gives, not a linear time, but forking and convergent time sequences.”

“Again, the pre-eminence of temporal relations, and their constituting a partial not a serial ordering, was Robb’s whole point,” I replied. “He called this ‘a conical order’ because of the light-cone structure in 2+1 dimensional diagrams.[39] But although spatial relations are derivative for him, that does not make them unreal.[40] It just deprives simultaneity of its role as being constitutive of what is present. There is no such thing as one universal ‘now’ or ‘world-wide present’ according to relativity.”

“It depends what you mean by ‘present’,” you put in. “We have to distinguish the present of the observer’s experience, which is created within our minds and psychologically projected outwards onto reality, from the present of the larger reality within which the observer is embedded. The Universe itself might possess a concept of simultaneity; we simply will forever be unable to know what it is.”[1]

I tried to contest your last point, but Carey got in first: “Granted. But our experience of the present is all constituted from what is in our past. The stars we are seeing now we see as they were many years ago, and even objects close to hand we see with some delay because of the finiteness of the speed of light and the time it takes our brains to process the information we receive through the senses. Whitehead’s construction of spacetime in *The Principle of Relativity* is as a system of moments, where a moment is an instantaneous three-dimensional section of nature. But whereas in classical physics there is only one such moment through any event-particle *P*, in relativistic physics there can be an indefinite number of alternative moments through *P*, each corresponding to a different meaning for time and space.”[41]

“What exactly does this mean, different ‘meanings’ of space and time?” you asked.

“As I said,” Carey replied, “Whitehead started out from the principle that what is apparent in individual experience is a fact of nature. In relativity, because a moving observer will experience a different instantaneous three-dimensional section of nature from an observer at rest at the same event-particle or point-event, the meaning of simultaneity will be different in their different individual experiences. Thus two events that are simultaneous in one instantaneous space for one mode of stratification may not be simultaneous in an alternative mode. So you see there are in nature alternative systems of stratification involving different meanings for time and different meanings for space.”[42]

I couldn’t help interrupting again. “I’m sorry,” I said, “but here we have that intrusion of the observer into accounts of relativity physics that I mentioned earlier. As Howard Stein once said about this common talk of the observer’s *experiencing different presents*, ‘There is of course no such “experience”: the fact that there is no experience of the presentness of remote events was one of Einstein’s basic starting points.’[43] In this regard, I suspect that Whitehead, like

Russell, was influenced by their Cambridge colleague Arthur Stanley Eddington, whose successful eclipse expedition in 1919 confirming Einstein's prediction for the anomalies in Mercury's orbit made headlines around the world and blasted Einstein's name into universal consciousness, forcing philosophers of space and time to take account of his views."[44]

"A momentous occasion, to be sure. But what has Eddington got to do with Whitehead's mention of observers?" Carey wanted to know.

"Well," I replied, "it is true that Whitehead might have obtained this idea of the meaning of time depending on the observer directly from Einstein. But it was largely through Eddington's impressive *Space, Time, and Gravitation* that philosophers—especially in Cambridge—learned about Einstein's relativity. In it Eddington insisted that 'physical space and time are closely bound up with the motion of the observer', and that the observer is the 'proper source' of space and time. Echoing Minkowski, he held that 'only an amorphous combination of the two is left inherent in the external world', where they are united into spacetime, but—and this is the important point—that space and time are *not* united in 'in the relations of the external world to the individual which constitute his direct acquaintance with space and time.' He held that 'just in that process of relation to an individual, the order falls apart into the distinct manifestations of space and time.'"[45]

"Ah, but Whitehead warns against 'extreme subjectivist interpretations' of relativity," you noted. "He stresses that it is what is going on with the observer's *body* that is significant, not the observer's mind.[46] Still, I see what you are implying. Like Eddington, Whitehead holds that space and time will be given different meanings by two observers whose bodies are in relative motion to one another at the same point-event."

"Yes," I replied. "This is exactly what Whitehead says," and I quoted him from *Science and the Modern World*:

> In the modern theory there is no such unique present instant. You can find a meaning for the notion of the simultaneous instant throughout all nature, but it will be a different meaning for different notions of temporality. ([4] 110)
>
> The observed effectiveness of objects can only be explained by assuming that objects in a state of motion relatively to each other are utilising, for their endurance, meanings of space and time that are not identical from one object to another. … If two objects are mutually at rest, they are utilizing the same meanings of space and of time for the purposes of expressing their endurance; if in relative motion, the spaces and times differ. ([4] 120)

"What this means for Whitehead," I added, "is that observers in relative motion will not even share the same space or time. This is because relative to any given actual entity, there is a 'given' world of settled actual entities in its past, and really potential ones beyond that standpoint.[47] But which are past and which are future will depend on its state of motion—which, Whitehead maintains, defines its 'space-time system'."

"Right," said Carey, "this is precisely where relativity theory had its influence in Whitehead's formulation of his new metaphysics. He recognised that on a classical view the prior life-history of an object would be unique—would 'not

doi.org/10.32388/932RTK.4

vary in its spatiotemporal discrimination', as he put it.[4] So from the classical point of view, time is serial, and two contemporary actual entities define the same actual world—remember, two contemporary occasions are such that neither belongs to the past of the other, so that classically this defines a unique class of occasions, the simultaneous ones, all with the same past. But according to relativity theory, where simultaneity is relative to a given space-time system, this definition of contemporaries means that neither will belong to the 'given' actual world defined by the other."[48]

"But if no two actual entities are even in the same world," you exclaimed, "then we seem to have not just monadic creatures, but a radically atomised reality!" And I said that this philosophy put me in mind of the ancient Buddhist sect of the first or second century BCE, the Sautrāntikas, who held that the world was comprised of "point-atoms" or events (*dharmas*), each of which had a merely momentary existence …

"But occasions have duration," said Carey, "and this allows them to share approximately the same experience. Whitehead acknowledges that according to relativity what is simultaneous will vary with observers' motions, and that this raises the question whether two events can be said to be contemporaries without having to qualify which space-time system we are referring to. They can. As he reminds us, in Special Relativity 'one event will precede another without qualification, if in *every* time-system this precedence occurs.'[49] This gives us what Minkowski called the relations of absolutely before and after, and it is on these absolute time relations that the causal set theory approach is based."

"I don't want to sound like a broken record," I replied, "but what you are describing is precisely Robb's conical order. It is true that what we call point-events Robb called simply 'instants', but, in stark contrast to Whitehead's 'moments', Robb insisted that an instant 'does not range over the whole universe,' and that '*the only really simultaneous events are events which occur at the same place*.'"[50]

"For Whitehead," Carey replied, "that would again be an instance of the Fallacy of Misplaced Concreteness. He points out that there is no element in our immediate experience which possesses the character of simple location. An event in general is a nexus of interrelated actual occasions, and an actual occasion is the limiting type of an event with only one member. It is by a process of constructive abstraction that we arrive at the idea of a definite region of space or duration of time, and then by the Method of Extensive Abstraction that we arrive in the limit at the idea of an instantaneous moment of time. But in the concept of instantaneousness the concept of the passage of time has been lost. Events essentially involve this passage. Accordingly the self-contradictory idea of an instantaneous event—what you say Robb calls an 'instant'—has to be replaced by that of an instantaneous configuration of the universe."[51]

"If I remember correctly," you volunteered, "this was Whitehead's starting point in his own version of relativity."

"That's right," replied Carey. "He pointed out that distance is a purely spatial notion, so that in a relativistic world there are indefinitely many meanings of the distance of Mercury from Earth, for instance, according to the space-time system that you adopt. Einstein therefore modified the law of gravitation so that it would have the same form in all systems of reference, and this entailed that space itself would be warped. But Whitehead could not accept that space itself, which consists in relations between its points, could be affected by the contingent

arrangement of bodies in it, as Einstein had proposed.[52] Accordingly, geometry for him requires a spatial structure whose points are uniformly related, given by a global Lorentz-invariant inertial frame for each 'time-system'.[53] If motions are affected by a gravitational field—a Lorentz-invariant one—this will affect where bodies are in it, but not that space itself, which will remain uniform. Accordingly, while Einstein gave a formulation in which contortions of spacetime alter the invariance theory for measure properties, Whitehead adopted multiple space-time systems that each have the property of embodying Newton's Law of Gravitation. And while admitting the greater simplicity of Einstein's theory, he insisted that only his theory of gravitation is commensurate with the given facts of our experience as to simultaneity and spatial arrangement."[54]

"But what are these alleged facts of experience regarding simultaneity?" I asked.

"I'm very sorry," said Carey, "this has been a great discussion, but I have an appointment that I am already late for, so I must hang up. Thanks, guys!"

At this sudden turn of events you suggested carrying on our conversation. "It was just getting interesting!" you said. I agreed: "We have left so many issues hanging. For instance, I think Whitehead is absolutely right about concrete events necessarily involving passage, and having duration. I argued this in my recent book on the flow of time.[55] The point-events in spacetime are, as Whitehead says, *abstractions* (though useful ones), which can be arrived at through a limiting process. And the same goes for something like the distribution of matter in space at an instant, which again is an abstraction, though of course a very useful one for physics. And as he says in *The Concept of Nature*, there is no such thing as nature at an instant in sense-awareness."[56]

"This is related to his distinction between simultaneity and instantaneity, isn't it?"

"Yes," I replied. "Whitehead held that simultaneity must be understood in terms of an overlapping of durations. Two actual events (or actual occasions) that are not in the same 'moment' can be simultaneous in this sense, contrary to what Robb held, just because every actual occasion has a duration."

"Isn't this like what you and Steve Savitt proposed with your view of the present in relativity as having a spatiotemporal extent?"[57]

"Yes, and no. Once you recognise that concrete events have a finite duration, it follows that what is present to such an event will have a spatial as well as a temporal extension. That's the 'yes'. But for Whitehead a duration has 'temporal thickness' because it contains 'within it antecedents and consequents which are also durations which may be the complete specious presents of quicker consciousnesses.'[58] In other words, he conceives duration by reference to conscious experience. This is similar to Henri Bergson, who allowed that while durations are relative for the physicist, 'the duration of a phenomenon is absolute for my consciousness.' Subjectivism again!"

"But you and Savitt also invoke the specious present to justify your view that the present can be given meaning in relativity."

"Yes, but I think our view has been misunderstood. If a concrete event has a finite duration, then during that time there will be other physical systems with which it can interact many times. If the event is that of the construction of an individual's experience, then it is widely recognised that this physiological process occurs over some fraction of a second, the 'specious present' of the individual in question. During such a time, conceived as an interval of the proper

time on the worldline of a putative observer, physical interactions between a perceiver and objects perceived can go back and forth through extremely long distances. All such interactions would take place in a spacetime region enclosed between the backward light cone of the end of that second and the forward light cone of its beginning—a 'causal diamond' or 'Alexandrov interval', in the parlance. Savitt and I proposed that this would explain why objects in such a region are felt by the perceiver to be robustly 'present', perhaps accounting for the 'presentational immediacy' of distant objects that is so important to Whitehead."

"So how does that differ from Whitehead's view?"

"In my view, becoming in relativity theory is represented as taking place continuously along worldlines. Whitehead, like many physicists, has failed to see that in relativity theory the passage of time, and individual histories, are tracked by *proper time*, not by the time coordinate that he references with his notion of different 'time-systems'. The instants of coordinate time, as he recognises, are constructions used to track which point-events are strictly simultaneous with which. But they do not track durations, which are path-dependent in relativity theory, and measured by proper time; and *these* durations are entirely objective, unlike Whitehead's."

"That may be so. But it seems to me that your view is just false as an account of the present. Not even the moon is close enough that light could go back and forth between it and me observing it in a specious present, but even if it were, it would seem that it is only the light continually issuing from it that is necessary to my perceiving it as present. And the light from distant stars is part of my present experience, although the stars themselves are not, and may not even exist any longer. Moreover, I can't see how the convex sets of the double cones are significant structures for our sense of a specious present, since these are *topologically* defined, and have no intrinsic metric; they have no natural scale at all."

"To your first point, we concede all that. We were not claiming to account for the whole subjective experience of the present, which I grant would involve an analysis of the various physiological processes and limitations that are responsible for that experience. We were only trying to explain, in opposition to common claims that the 'now' is incompatible with relativity theory, that one can articulate a robust sense of the 'presence' of certain objects that is consistent with relativity theory, namely of those between which and ourselves there can be multiple interactions with our sensory organs during a specious present. And as for your second point, I explicitly asserted that what would be present to a given extended event (in the sense I articulated) would be relative to the extent of that event; we could define the present cosmological epoch in relation to a section of the proper time of the Earth's history, for instance."[59]

"That is not the impression I got from what Savitt wrote in defence of your joint view.[60] It seemed to me that he was explaining becoming as taking place in a succession of nows, linking the emergence of spacetime in discrete causal diamonds[61] (as in Sorkin's causal set theory[5]) to the succession of nows in an observer's 'common sense' experience, thus effecting a rapprochement between the 'scientific' and 'manifest' images."

"I can't speak for Savitt, of course, and perhaps this indicates a divergence of our views. The causal diamonds he invokes from fundamental physics are, of course, massively different in scale from the fractions of a second that constitute a

human observer's specious present. I'm not sure that what you suggest is in fact his view, but if so, it is redolent of Whitehead's in conceiving becoming as a succession of discrete events that correspond to the 'nows' of the observer's experience. But I hold that the becoming of events is independent of what observers perceive as now, and as I argued earlier, the ontology of physics does not need building out of observers' experiences."

Again, you tossed your head impatiently. "Look, Whitehead is not the naïve subjectivist you are trying to make him out to be. Yes, he talks about occasions in terms of what is immediately experienced by the subject, but what the subject immediately experiences is not just some bare sense-datum, it involves significant conceptualisation. For instance, one of the examples of an event that you give in your book is the building of St. Paul's Cathedral after the Great Fire of London.[62] Someone observing this event would not just see various stones, beams, pulleys, Wren atop his ladder, and so on, but in order to conceive it as an event would have to have some idea of the intention of assembling the stones and beams in order for this to have the unity of an event with a more or less discernible beginning and end. For Whitehead it is this appropriation of the event that gives it its significance, but this concrescence of the occasion is private, not public. Whitehead wrote of a rhythmic swing from 'the publicity of many things to the individual privacy', from the objectivity of the potential to the actuality of the occasion, and back."

At this point I remember explaining that I had no problem with the idea that some conceptualisation goes into the identifying of something as an event. The difficulty I find in Whitehead's metaphysics is in the idea that the occasion involves what is immediately observable to sense, which is then analysed in terms of simultaneity.[63] As I stressed, Whitehead appeals to "the immediate presentation through the senses of an extended universe beyond ourselves and *simultaneous* with ourselves," and then writes of "what *is now immediately happening* in regions beyond the cognisance of our senses" ([4] 116). "What is immediately presented in sense awareness," I insisted, "is, as Carey was saying, percepts of events that are in the absolute past of the time at which they are recognised. They are not *immediately* present to the senses, but *mediately* so."

"Yes," you replied, "but remember, simultaneity is not the same as instantaneity for Whitehead. As he says in *The Concept of Nature* (53), 'A duration is a concrete slab of nature limited by simultaneity which is an essential factor disclosed in sense-awareness.'"

"Whitehead is free to define terms as he wishes," I replied. "But he must at least be consistent. If durations are bounded, this will be bounded by what he calls earlier and later *moments*, that is, by earlier and later *instantaneous* slices through the world according to various time-systems.[64] These will *not* pick out events that are simultaneous in his sense, but in Einstein's. If this were not so, I would add, his definition of contemporaries (the one Carey quoted earlier) would not work. Simultaneity for him is supposed to be a property of a group of overlapping durations, but these durations are in turn supposed to involve in their concepts the whole of nature, and, like simultaneity, to be immediate to sense-awareness'.[65] In other words, despite recognising that events must be temporally extended, by invoking world-wide simultaneity Whitehead has not recognised that what is present is local, not global. And your experience of the present – the specious present – is something constructed by your brain in a fraction of a second, out of what your senses have perceived of the past."

"But in wanting to deny that an event is related to the whole of nature, you are thinking of the purely abstract external relations so dear to Russell. But the event itself is constituted by its internal relatedness to the rest of nature. This takes us back to the discussion we were having before Carey phoned. For Whitehead, an event (as an actual occasion) can be found in only one determinate set of relationships with everything else. This determines 'why an event can be found only just where it is and how it is,' so that, 'apart from that relationship, the event would not be itself.' This, he says, is the very meaning for him of internal relations."[66]

"You were saying earlier," I replied, "that it is through such an internal relation that an actual entity involves another by prehending it, and that Whitehead saw something similar in Leibniz's notion of perception?"

"Well, not exactly, since he criticises Leibniz for thinking of perception as mere representation, and therefore for not recognising the concrete reality of internal relations.[67] But I have been reading a book that has just come out by Florian Vermeiren, a young Belgian scholar who suggests that the key to understanding Leibniz's puzzling theory of relations is to see them as Whiteheadian internal relations."

"I don't see how, given that we agree Leibniz thought of perceptions as representations, not as interactions."

"But Whitehead's prehensions are not exactly interactions either. By one occasion being simultaneous with the rest of the world, Whitehead means that the rest of the world is present in it. In fact, each actual occasion is present in every other one."[68]

"So what does it mean for simultaneity to be a concrete internal relation for Whitehead?"

Here you explained that what Whitehead means by 'internal relation', according to Vermeiren, is quite different from the Lotzean or Bradleyan notion that Russell criticises. He says it has two main characteristics: first, it is *individual* to the actual entity (he quotes Whitehead's 'the relata modify the nature of the relation' from *Adventures of Ideas*, 201) and second, it is *essential* to it (he quotes 'each relationship enters into the essence of the event; so that, apart from that relationship, the event would not be itself' ([4], 180).[69]

"And he sees something similar in Leibniz?", I asked.

"Precisely. He notes that each substance for Leibniz has its own unique point of view, and this consists in its relations to things external to it.[70] These are its relations of situation, conceived as individual accidents, which are therefore individual in Whitehead's sense. But the complete individual concept of each substance includes everything that can be attributed to it, including accidents and relations, so these are part of its essence. Treating Leibniz's relations as internal in this Whiteheadian sense gives a radically new meaning to some controversial Leibnizian doctrines, such as his denial that there are any purely extrinsic denominations."

"I am not sure I see how. Russell took this denial to mean that all relations are for Leibniz internal as he understood the term, i.e. must be reduced to unary properties in each of the relata. But in fact Leibniz defined an extrinsic denomination as one that could arise or perish without the nature of the thing changing, which is not the same thing."

"That is Vermeiren's point," you replied. "If an intrinsic relation is internal in Whitehead's sense, then 'extrinsic' just means 'non-essential', so that a purely extrinsic denomination would be one that could change without the nature of the thing changing.[71] Therefore Leibniz's denial that there are any such should mean that for him relations are internal in the Whiteheadian sense. Do you agree with that as an interpretation of Leibniz?"

"Well," I conceded, "Leibniz does say that a thing cannot change its location in space without some change in its situations to other bodies. And he describes these relations of situation as individual affections or accidents of the embodied substance."

"There you have it! The idea that Vermeiren sees as implicit in Leibniz and taken up by Whitehead is precisely this idea of a space that is constituted by spatial relations that are individual. It is a space in which nothing can move without becoming another thing. This is why – in answer to your previous objection – Whitehead says that a monadic creature cannot move. What we take to be an enduring object is a multitude of actual occasions. Likewise, motion consists in a series of atomic, actual occasions; but these occasions *are* the creatures, each of which occurs when and where it does."

"But as I said earlier, this is completely contrary to Leibniz's understanding, and shows that there is something amiss with Vermeiren's assimilation of Leibniz to Whitehead. A Whiteheadian monadic creature is fixed in its location because its internal relations define it, and are essential to it. But for Leibniz the concrete situations of an embodied substance will be relational accidents, and such accidents are continuously changing."

"Oh, but I don't think Vermeiren was denying that there is a difference," you replied. "He acknowledges that for Leibniz a monad is more than its states, it is also the inner law of appetition bringing it from one state to another. For Whitehead, on the contrary, an actual occasion is nothing but its state."

"Yes," I replied, "but for Leibniz this is a crucial difference. Not only must the state be a state *of* something, it is also the case that reducing monads to their states and taking these states to be the actual entities would void his philosophy of its dynamism. I see something similar in certain interpretations of quantum theory, which want to take quantum states (or wave functions describing them) to be what is actual."

"That may be," you countered, "but the insight Whitehead got from Leibniz was his perspectivism, the idea that every substance contains as it were the whole world from its own point of view. For Vermeiren this means that it is only perspectivally distinguished from the substances with which it coexists. Thus the individuality of a Leibnizian monad does not come from a *separation* from the rest of the world, but from an individual perspective with which it *includes* the whole world. As Leibniz says, 'our nature extends everywhere' (GP IV.441/AG 49). Each monad is *ubiquitous* because each is included in every other monad."[72]

"Well, that is Whitehead, as we already saw above, where the rest of the world is really present in each actual occasion.[73] In fact, he explicitly says 'In a certain sense, everything is everywhere at all times.' ([4], 133). But it is not Leibniz. For him ..."

"I'm sorry to interrupt," you interrupted, "but isn't it curious that Carey Carlson saw all the actual relations between Whitehead's occasions as being *temporal*, 'thus eliminating instantaneous spatial relations as anything real at all,' whereas

Florian Vermeiren sees occasions as being essentially ubiquitous, *spatially* present in every part of nature? But you were saying…"

"Yes, that is curious, and I think it is related to Whitehead's trying to accommodate his views to a kind of quantum holism.[74] But we can come back to that. What I was saying is that, contrary to Vermeiren's assertion that monads *contain* the rest of the world, for Leibniz co-existent things are all *represented* in the state of an individual substance. Such a relation inheres in the substance, but the other co-existent things are reflected in that state, not contained in it. The relation does not actually include them, nor is it something existing apart from its relata and binding them together. That is precisely what Leibniz denies: there are no concrete relations with one leg in one substance and the other leg in the other one. Something *a*'s being 2 feet to the left of another thing *b* can be a relational accident of *b* at a certain time, as can *b*'s being 2 feet to the right of *a* be a relational accident of *a* at the same time. But when we abstract this relation, *a*L*b* or equivalently *b*R*a*, this will denote an extrinsic relation holding between any two possible objects situated in the same way as *a* and *b* at a given time. For Leibniz, space is an ordering consisting in such relations among possible coexisting things."

Here you deferred to my supposed expertise on Leibniz, and said you did not want to get bogged down in Leibniz interpretation. One thing you found interesting in Vermeiren's book, you told me, was this conception of space as consisting in Whiteheadian internal relations, where each position in space prehends the rest of space, and how he conceived this as anticipating Deleuze's conception of a space of intensive magnitudes – an *ordinal* as opposed to a *metric* space, that Deleuze calls the *spatium*.[75] In fact, you told me, according to Vermeiren Deleuze even attributes the origin of his theory of the *spatium* as a theory of distances to Leibniz.[76] But when I began to object to this theory you changed the subject back to Whitehead:

"Perhaps more interesting," you urged, "is the dynamism Whitehead introduces and its connection with the potential or the virtual. 'The reality of the future,' he writes, 'is the reality of what is potential, in its character of what is actual.' As Vermeiren comments on this, Whitehead 'understands the actual world which an actual occasion prehends as its "real potential"'.[77] He also quotes from Whitehead's *MT*, 136: 'Immediacy is the realization of the potentialities of the past, and the storehouse of the potentialities of the future.'"

This, you said, put you in mind of a Whiteheadian interpretation of quantum theory that came out some years back, by Michael Epperson, "and this takes us back to where we started: Whitehead and quantum theory." So I asked you for details of his interpretation.

"To explain this idea of potentialities for the future Epperson enlists Heisenberg's idea of *potentia* …" you began.[78]

"Ah, another one!" I interjected, "—and I am willing to bet that, like Heisenberg, he treats '*potentia*' as a plural, denoting real tendencies of quantum systems!"

"As a matter of fact, he does!' you replied. "That struck me too, since '*potentia*' is the Latin for 'power' in the singular. But what did you mean, 'another one'?"

In answer I told you about the PhD student I examined who—building on Ruth Kastner's invocation of *potentia* in her Transactional Interpretation of quantum theory—had made the same grammatical mistake.[6] He also wrote as though Kastner was the first to think of quantum amplitudes as real tendencies, so I had

to point out that many had done this before her, beginning with Henry Margenau (who in fact did so in print before Heisenberg with his "latency" interpretation),[7] but also Karl Popper, Nicholas Maxwell, Henry Krips, and Maurizio Suárez, with their propensity interpretations of quantum theory.[79] After a bit of discussion about all this, we got down to discussing the details of Epperson's reading of Whitehead, and I think I can remember what you said pretty clearly. At any rate, I was able to supplement it with quotations from Epperson's book, since after we spoke I had downloaded this as a freebie on Kindle, which I had been keen to try out anyway.[80]

"As I was saying," you continued, "Epperson relates these *potentiae* to Whitehead's real potentialities that Vermeiren had remarked on. He points out that for Heisenberg *potentiae* are not just epistemic possibilities, but fundamental constituents of nature, standing somewhere between possibility and reality. This he contrasts with information theory interpretations such as Qubism, where quantum states are conceived epistemically as merely encoding information, but also with interpretations that interpret the collapse of the wave function as though it involves several actualities that must be reduced to one. For instance, in the so-called GRW theory, a physical mechanism is postulated that causes several actual states—such as the states of being alive and being dead of Schrödinger's famous cat—to reduce to one in a very short time."[81]

I agreed that this was a good point, and that all too many proposed interpretations of quantum theory fail to properly distinguish the actual and the potential, treating the amplitudes of the wave function as if these are actual things that must go out of existence—or be shunted off to another "universe", as in the Many Worlds interpretation—when only one of many predicted possible outcomes comes to pass. "Events," I said, "are what come to pass in actuality, such as the detection of an alpha-ray, and according to quantum theory these events are objectively contingent. So, the fact that some occur rather than others is not something that requires explanation; what quantum theory predicts is the probabilities with which these events occur. It is true that the quantum probability amplitudes combine non-classically, but they still yield the probabilities with which certain events occur."

"I agree. I think the term 'collapse of the wave function' is really a misnomer. A quantum system is a stochastic system and measurement simply results in one of the possible outcomes of the stochastic process, which is the system.[1] But that's the beauty of Epperson's analysis," you continued. "He stresses that 'quantum mechanics does not include a mechanism for the actualization of *potentia*; it merely describes the valuation of *potentia*.' Each 'occasion' happens contingently, so we do not expect there to be such a mechanism. There is no 'collapse' of the wave function in the sense that two alternative actualities reduce to one; there is just a valuation of the alternative potential eigenstates belonging to the mixed state, in such a way that these alternative potential states become probabilities, and not just *potentiae*."[82]

You got a bit worked up about this point, continuing: "Outcomes in quantum mechanics arise stochastically, and are not determined exactly in advance, although once actualised the value is then fixed. But in much quantum interpretation, quantum probabilities are treated as if they are objects, as things themselves, when actually they are *about* things. This appears to be another example of the Fallacy of Misplaced Concreteness, again confusing the description and the thing described. Treating probabilities as if they are things

has always been, I think, a fundamental conceptual confusion in quantum mechanics."[1]

I mentioned that one of the usual objections to treating amplitudes of the wave-function as real is that there are any number of different decompositions of a given wave function into eigenstates of different physical variables – although to a large extent that objection is mitigated by the phenomenon of *decoherence*, where these decompositions effectively get limited to those compatible with the arrangement. The idea in decoherence is that application of the Schrödinger equation presupposes a closed system, where the pure state evolves with a characteristic quantum entanglement of its states. (In fact, quantum computing depends on being able to preserve such a pure state against the intrusion of the environment.) But in a realistic situation, the environment disrupts this, with the result that the interfering terms of the entangled states are dissipated and coherence is lost, so that we end up, effectively, with a mixed state that can be interpreted in terms of classical probabilities – e.g. those of interest to Schrödinger's unfortunate cat. (Of course, this does not eliminate quantum entanglement; it just dissipates it among a huge complex of physical systems.)

"It's interesting that you should mention the decoherence interpretation," you replied, "since Epperson appeals to Żurek's version of it to explain Whitehead's idea of 'negative prehensions,' interpreting these as the *potentiae* that are lost due to decoherence.[83] He sees the evolution of the quantum state as exemplifying Whitehead's notion of 'concrescence'. There is a positive prehension, as in the inclusion of facts about the specification of the environment and the detection apparatus, but also negative prehension, as in the negative selection producing decoherence, which we were just discussing. The quantum mechanical measurement or detection anticipates the concrescence of one novel fact or entity out of many potential facts or entities, that are themselves outcomes of antecedent facts or data."

"Facts *or* entities? I am not happy about this equivocating between facts and entities, although I can see that Epperson is being faithful to Whitehead in referring to 'facts' being determined, as opposed to particular events coming about, like the clicks of a Geiger counter. I would class the creation of facts as an epistemic matter, and the production of events as ontological. But I suppose this relates to Whitehead's attempt to avoid what he calls the 'Bifurcation of Nature' by holding that there are both subjective and objective aspects to the concrescence of an occasion?"

"Yes, although this is a very complex part of Whitehead's metaphysics, involving such delicate matters as a distinction between 'pure potentials' and 'real' ones, and three phases of concrescence, all of which Epperson explains in great detail. But the key point is what Whitehead calls 'the bipolar character of concrescent experience'. On the physical pole we have 'the objective side of experience, derivative from an external actual world,' and on the mental pole 'the subjective side of experience, derivative from the subjective conceptual valuations correlate to the physical feelings.' So the becoming of an event is constituted on the one hand by 'the determinateness of the actual world,' and on the other, by its conceptual prehensions of the indeterminateness of eternal objects.'[84]

"I have to admit," I put in, "I do not understand what these 'eternal objects' are. I thought they were supposed to correspond in some sense to Platonic ideas or universals. But earlier we heard them equated with sense-data."

doi.org/10.32388/932RTK.4

"In *Process and Reality* Whitehead says that if we don't like the term 'eternal objects', we can call them potentials. He says that these 'eternal objects are the pure potentials of the universe,' in contrast to the actual entities, which 'differ from each other in their realization of potentials.'[85] So, in linking these potentials with quantum theory, Epperson assimilates the 'conceptual valuations' of Whitehead's mental pole to the determinations of the wave function. He takes the orthogonality of the eigenstates into which the wave function is decomposed to illustrate the mutual exclusivity of Whitehead's potentials. He also makes much of Żurek's claim that 'decoherence is a consequence of the universe's role as the only truly closed system.'"[86]

"Interesting. But I can't say I am persuaded by appeals to the universe as a whole determining quantum systems. When we apply quantum theory, as you noted, we need to take into account the initial and boundary conditions by means of which we determine the state function for a system in a certain environment. But once a given quantum event has occurred, the environment will generally be changed, so that the boundary conditions determining future states of resulting systems will also have changed depending on the contingent fact of the event's having occurred. So, because of this contingency of the actual, we will not at any time have the universe as a whole, which would require some kind of absolute determinism of past, present and future at the time of any event."

"I'm sorry," you said, "I'm not doing a very good job of relating Epperson's argument. In general he seems to be very faithful to Whitehead's metaphysical scheme – but perhaps that is why it is so hard to explain! Let me try with a more comprehensible example that Epperson gives to explain Whitehead's potentials quantum mechanically. He asks us to consider the case of a travelling salesman who is in Hong Kong while his wife in California is about to give birth, and asks: at what moment does the salesman become a father? (a) at the moment the baby is born, or (b) at the first moment when the news could reach him?"[87]

I replied that this very much depends on what you mean by 'moment'. "Curiously," I couldn't help adding, "this conundrum is highly reminiscent of the example Leibniz uses to explain his doctrine that *there are no purely extrinsic denominations*, the case of the man whose wife dies in Europe while he is away in India. This was a stock example in Scholastic discussions about the reality of relations, typically given to show that not every change in an 'extrinsic denomination,' like becoming a widower, corresponds to a real change in the subject of the relation. Leibniz simply denied that this was so, insisting that any change in the widower's relations to everything else must have a basis in a change in the man's nature. This is because of the mirroring nature of monads we discussed earlier: every state of a substance expresses (however tenuously) everything else happening at the same moment. But then, as you can see, Leibniz's answer presupposes the classical idea of a *moment* as *extending throughout all of space*, at which time something determinate is happening at any of the places in this space."

"Whitehead wants to retain this idea of a moment as an instantaneous three-dimensional section of nature," you said, quoting his "I maintain the 'old-fashioned' belief in the fundamental character of simultaneity" from *The Principle of Relativity*. "As he explains there," you went on, "he adapts this idea to the new perspective introduced by relativity by allowing that 'the meaning of simultaneity may be different in different individual experiences,' as we discussed earlier. Thus where Leibniz talked about a relation *expressing* the rest of the world, Whitehead replaced this with his idea of an internal relation

involving a *prehension* of the whole universe. But each of these prehensions is in accordance with a meaning of simultaneity specific to each observer with its own spacetime system and time series. What is involved is an 'intellectual apprehension of a meaning to the question which asks what *is now immediately happening* in regions beyond the cognisance of our senses.'"[88]

"So, on this basis," I said, "I anticipate that Epperson would claim that (a) is the correct answer to his conundrum, since from the moment of the baby's birth in the mother's time series the *potentiae* for what happens to the father—the "pure potentials of the universe"—will change; it will not matter that no causal influence on the father can actually occur until information reaches him."

"Yes, that's right. Epperson claims that the first answer reflects 'the genetic analysis of the events,' where the histories of the salesman and his wife may be thought of as involving 'historically correlated quantum mechanical systems.' He argues that 'once those *potentia* [sic] associated with the salesman's history are affected – his "history" defining him not only by his past, but also by the *potentia* associated with his future (what he might be, might do, might be able to do, might be for others, etc.) – then in some sense he is affected, whether he is aware of the affection or not.' (193-94)."

"I'm sorry," I answered, "I just find this incoherent. We are agreed that whenever the salesman first learns of the baby's birth, the birth itself is in his absolute past at that time, since no influence can travel faster than light; and by the same token, at the precise instant that the baby is born, that event is not yet part of the salesman's history. In relativity theory, the *histories* of individuals are threads connecting events in the strict partial order we were discussing earlier – Robb's conical order. Genetic histories are not given by the coordinate times associated with different possible inertial reference frames from which the events are considered, as Epperson is supposing. At the time of the baby's birth there is no event of the father's learning of it that is part of the mother's history. The classical notion of a time at which everything else in the universe is happening simultaneously with a given event (according to the time coordinate of a given reference frame) is relativistically untenable."

"But," you replied, "to this Epperson would respond that the spacetime systems of the mother + baby and of the salesman are 'are entangled *extensively*, that is, *spatiotemporally coordinately*, with a shared environment,' which subsumes their local histories into one global history (193-4). Remember, he claimed that *reference to the whole of the universe* is necessary for decoherence, without which, he claims, 'one would be left with a bare superposition of practically infinite potential outcome histories of negligible individual intensity, belonging to a practically infinite number of spatiotemporally disconnected events' (194)."

To this I objected: "He is attempting to graft a classical-time evolution onto a relativistic spacetime. There is no such thing as 'the world at an instant' according to relativity. If the father has just fallen through the Schwarzschild radius of a black hole when the news of the birth reaches him, that event will have no time coordinate in the mother's rest frame. I know, you will object, that Whitehead did not accept General Relativity and distortions of spacetime. But even for a rotating frame of reference in the Minkowski spacetime of Special Relativity, which he does accept, it turns out that, as Dennis Dieks has explained, such locally defined Lorentz frames cannot be combined into one frame with a globally defined standard simultaneity.[89] Epperson's mother and baby, whom we may presume are safely ensconced in California despite the efforts of ICE and

Trump, are not in an inertial frame, but on the rotating Earth. So there is no unique global plane of simultaneity associated with their 'meaning of time'."

"Nevertheless," you answered, "the mother can envisage the father receiving the news, and calculate how this changes so many things in their lives. This is the mental pole of the event, and the one that carries meaning for her. Also, Epperson would say that this dipolar characterisation of events accounts for what happens generally with events that are spacelike related. This is the 'causal affection of *potentia* by logically prior actuality', as opposed to the 'causal influence of actualisation by temporally prior actuality' in the case of information reaching the father (196). Although no non-local process is required to go from one such event to another, the *potentiae* for each can be correlated, which explains how the correlations can occur between events in spacelike separated regions that violate the Bell inequalities, without countenancing non-local influences mediating them."

"I am not sure you are getting the main point. Epperson is trying to paste non-relativistic quantum theory onto a Minkowski spacetime, as if non-relativistic state functions evolve in coordinate time in each inertial reference frame, and then one worries about relativity afterwards. On the contrary, anything that evolves relativistically will have its evolution tracked by proper time, not coordinate time. I think that much of the discussion in the literature about non-locality suffers from the same faulty framing. But I should add that I think here Epperson is faithfully following Whitehead, who believed that there is no warping of spacetime, or of space or time, so that time dilation, for instance, is merely relative to the inertial frame."

"Well, yes," you said, "that comes out in Epperson's analysis of the Twin Paradox of Special Relativity. In his version there are two sisters, one who stays at home on the Earth, and the other who travels at 0.8c to the Hong Kong galaxy[90] twenty light years away, instantaneously reverses direction, and then returns at the same speed (200). He says that 'one cannot spatiotemporally distinguish between the sisters solely in terms of their mutual relations; for their individual reference frames, when so compared, are purely symmetrical' (213-14).

"But the sisters do not '*have*' individual reference frames! It is true that each sister can *consider* things from a reference frame in which she is at rest, and it is also true that when both sisters are moving inertially, then from the point of view of the rest frame of each sister the other's time will appear dilated, with perfect mutual symmetry. (And I do not want to be misunderstood when I say 'appear from the point of view of the rest frame': neither will be able to *perceive* anything that is strictly simultaneous with them according to this reference frame. Rather, this is what their calculations would show afterwards.) But what is crucial is the paths they take through spacetime. The journeying sister must have a worldline that is bent (and therefore non-inertial) in at least some section, in order to return to her sister. And when you integrate the proper time along her whole curved worldline in Minkowski spacetime, it is necessarily shorter than that along the straight worldline of the sister who remains at rest. This proper time is invariant; it does not depend on which reference frame is adopted to compute the overall motions of both sisters."

"Yes," you agreed, "I think Epperson goes astray here, since he claims that Special Relativity 'applies only to inertial reference frames' (200), and views time dilation and length contraction as simply frame-relative, as instances of 'the subjective variance of spatial coordination and temporal coordination' (197). So he thinks that to resolve the Twin Paradox one must have recourse to General

Relativity so that accelerations can be taken into account (201). All this is simply false, as you relate in your book on time.[91] Accelerations in Minkowski spacetime are represented as taking place along timelike curves. Realistically, as the travelling twin reverses direction to come home to Earth, she would follow a curved trajectory in spacetime, which, as you just said, is necessarily shorter than a rectilinear one in the Minkowskian metric. So when the twins reconvene, there is an invariant difference in their ages, not one depending on frame. But, as you said, here Epperson is trying to remain true to Whitehead's foundations. For he says that you can't compare the worldlines in spacetime, but instead must compare them 'as coordinated by an abstract extensive universal spacetime metric. Apart from this metric, there can be no congruence relations between the two worldlines.' (213-14). This relates to the early chapter in Whitehead's *Principles of Relativity*, where he claims that congruence can only be achieved by his Method of Extensive Abstraction."

"It does tally with what Whitehead wrote," I replied, "but it just isn't true. In fact, if Whitehead had read Robb,[92] he would know that you can indeed define congruence in special relativity in terms of relations among possible worldlines, without having to invoke the Method of Extensive Abstraction—which, I confess, I had always thought was just a method for defining points and instants from extended intervals, until I read that chapter."

"But surely, even if we put aside your objection to decoherence involving the whole world," you objected, "doesn't Whitehead's point still stand about the wave function being defined in terms of *configurations*, which will extend across spacelike intervals?"

"Relativistically, you can consider a state function at any time as defined across a spacelike interval that is orthogonal to the worldline of the system. That still does not give any physical connection across that spatial cross-section at an instant. Whitehead's notion of a moment that expresses 'the spread of nature as a configuration in an instantaneous three dimensional space' reminds me of Julian Barbour's conviction 'that the only true things are complete possible configurations of the universe, unchanging Nows.'[8] But although later in his book Barbour will instead take 'configuration space' to be the Hilbert space of quantum theory, in his early chapter he imagines spacetime paths in configuration space as if they are simply spatially extended, and takes this to show that 'time does not exist'. It is highly ironic to see Whitehead adopting a similar spatialisation of time given Bergson's influence on him!"

"That can't be right!" you exclaimed. "That would go against the whole tenor of Whitehead's philosophy, as a metaphysics prioritising the reality of becoming over that of being!"

"Well, earlier in our conversation, you'll remember, I was struck by his denial that actual entities move. The idea is that they simply exist, since each is determined by its actual internal relations with everything else in the universe. Consistently with this, he also denies change to anything actual." Here I quoted from *Process and Reality*, p. 92:

> The doctrine of internal relations makes it impossible to attribute 'change' to any actual entity. Every actual entity is what it is, and is with a definite status in the universe, determined by its internal relations to other actual entities. 'Change' is the description of the adventures of eternal objects in the evolving universe of actual things.

"Surely," I objected, "if 'eternal objects' are eternal, then they can't change or have any 'adventures'? And if that's all change is, there is no evolution to be had!"

"I don't think that is what he means by 'adventures'," you countered. "The idea is that all the potentialities are laid out across all space and all time, and are drawn upon in the creation of any actual occasion, or 'ingress' into it, in his terminology. But each occasion is an instance of becoming, and the actual world is formed by the continual accretion of occasions."

"We can return to this idea of the actual world being formed by accretion in a moment. But regarding change, I would like to point out that the philosophy of change Whitehead endorses here is essentially the same as Bertrand Russell's 'static theory of time', expounded by him in the first years of the twentieth century, and later taken up with enthusiasm by such philosophers as Jack Smart. According to this static theory, change in some quality occurs if there is a *difference* in this quality between one time and another. Thus motion consists 'merely in the occupation of different places at different times, subject to continuity ... There is no transition from place to place,' and no 'becoming' is involved." [9]

"But surely," you replied, "there is a difference between their philosophies that makes all the difference. As you said earlier, for Russell in that period, point-events are voided of all qualities: they are just the relata of eternal temporal relations. But Whitehead sees clearly that this is a mere abstraction from events as discrete items of becoming, and indeed shows Russell how to derive point-events from the extended events of experience by his Method of Extensive Abstraction. From then on, Russell takes the extended events of sense-perception as his primitives."

"Look," I replied, "I am perfectly happy with Whitehead's depiction of events as instances of becoming, and also his distinction of actual events from the merely possible ones predicted by the evolution of the quantum mechanical state function. The events that *actually* occur must be distinguished from the *possible events* described in our models and equations, just as *history* must be distinguished from *time*."

"Granted," you replied. "But of course this is possible from Whitehead's perspective precisely because he rejects Einstein's idea that spacetime is a manifold of events, that is, he rejects the notion that the behaviour of matter can depend on the structure of spacetime. But some of what you say seems dependent on that Einsteinian framework. For instance, what you said earlier about the time difference of the twins depending on their paths through spacetime seems to entail that the path is the *cause* of this difference. On the contrary, the path is an effect, not a cause. It expresses a difference in history due to the cause, which is reflected in the difference in proper time. To make spacetime a cause seems to me to require making spacetime a thing, an object, but that would run counter to the idea of a Processist worldview."[1]

"I agree that any actual change in the difference in the ages of the twins is caused by the actions undertaken by them that result in the difference of their paths through spacetime. But so does any *possible* change in their ages depend on the paths they *might* take. My point is that spacetime structure encapsulates the possible behaviours of objects: *worldlines represent possible trajectories of processes*. Spacetime does not have to be an actual thing in order for it to be affected by changes in the distributions of matter-energy in it, since those changes will result in different possible trajectories of processes."

doi.org/10.32388/932RTK.4

"So," you asked, "where do you think all this leaves the *potentia* interpretation?"

"That would take us too far afield to discuss in full. As an interpretation of Whitehead's philosophy, it is certainly intriguing. But as an interpretation of quantum theory, I think it suffers from the same defects as Whitehead's own misreading of relativity theory, unless it can be put into a properly relativistic form. I note that Ruth Kastner has attempted to do just that, reading relativistic *potentiae* in terms of Feynman's possible histories approach, and with the probability amplitudes existing in what she calls a 'pre-space' or quantum substratum, which is a relativistic counterpart of Hilbert space called Fock Space. But again, this would be a whole other topic to discuss."

"I don't know Kastner's interpretation well, but from what you say, her idea of 'pre-space' agrees well with Whitehead's notion of the extensive continuum, which is also not supposed to be the space-time continuum of events. It is instead more akin to a mathematical collection of possibilities and their interrelationships. This is what Whitehead wrote:

> The second metaphysical assumption is that the real potentialities relative to all standpoints are coordinated as diverse determinations of one extensive continuum. This extensive continuum is one relational complex in which all potential objectifications find their niche... (*PR* 103).

So," you suggested, "perhaps we could see Kastner's extension of her theory of *potentiae* to the relativistic domain as a way of correcting Epperson's interpretation of Whitehead?"

"Actually, no. It's more nearly a reworking of her own earlier version of Cramer's transactional interpretation of quantum theory in response to criticism that it was non-relativistic.[93] As it happens, Ruth has just emailed me to say that she views Epperson's interpretation of quantum theory as failing to give a correct interpretation of Whiteheadian metaphysics."

"Wow, that's interesting! Tell me more!"

"Well," I replied, "it would take me too long to explain all the details of her 'transactional interpretation of quantum theory'. But the gist is this. 'Transactions' are paired couplings of what Cramer called 'offer waves' and 'confirmation waves' propagating in 'pre-space'—that's the space, remember, in which she says the *potentiae* are located. In that pre-space there are multiple 'offer waves', corresponding to the usual quantum "ket" state vectors $|\Phi>$, pure potentiae propagating into the future (pre-space future), but these remain merely potential unless they meet a complementary 'confirmation wave' from that future, represented in Dirac's notation by a 'bra', $<\Phi|$. When the two waves couple, if certain conditions are met, they produce an interaction or *actualised transaction* with a certain probability. This is an actual event in regular spacetime."

"So she views the transition from potential to actual in quantum theory as an actual physical process?"

"Precisely! One of the striking features of her interpretation is her claim that by this means she has derived the Born Rule and also given a physical interpretation of the collapse of the wave function, the non-unitary process described by Von Neumann. For in an actualised transaction the probability of the outcome ψ_k is given by the weight $|c_k|^2$ of the associated projection operator $|\psi_k><\psi_k|$."

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"But in our earlier discussion, we had rejected the idea that the so-called 'collapse of the wave function' should be interpreted as a physical process, and saw that as one of the positive features of Epperson's interpretation."

"That's right. And this is exactly why Ruth rejects Epperson's analysis. She wrote to me that 'since he has no physical collapse (non-unitarity), his *potentiae* can never be actualized, so I view his model as falling seriously short of Whiteheadian metaphysics'. On the other hand, for her an *actualized transaction* exemplifies Whitehead's idea of an active prehension."

"Whether we take her side or Epperson's, then," you said, "depends on how we view the so-called 'quantum measurement' problem, and I don't think we are going to be able to resolve that issue here. It will get us too deep into quantum theory interpretation. There is support for Epperson's stance, for instance, in the 'modal interpretations' advanced by Jeffrey Bub or Dennis Dieks,[94] where there is no physical 'collapse of the wave function', although there are determinate events at the beginning and end of any stochastic quantum process. But as we noted, Kastner's interpretation offers a robust solution to the measurement problem by identifying a physical process by means of which potentialities become actualised. Concerning Whitehead, though, her reading of his 'active prehension' as a physical interaction goes against what we had concluded earlier, that 'prehensions are not exactly interactions either'."

I agreed. "I am sympathetic to her construal of actual events as results of interactions of some kind. I said earlier that if Whitehead's 'actual occasions' could be thought of as modelled on quantum phenomena, as the actual phenomena manifested in some interaction, then his philosophy would make more sense to me. But given what we have been discussing since, it seems to me that it is too physicalist as an interpretation of his notion of concrescence, given the 'private' nature of Whiteheadian 'actual occasions'."

"You mentioned that Kastner conceived these actual events as occurring in spacetime, as opposed to the propagations of *potentiae* taking place in her pre-space."

"Yes, here she was distinguishing her view from John Cramer's, since he wanted all the transactions to be taking place in a presupposed spacetime. His idea that confirmation waves allowed retro-causation in what he called 'pseudotime' attracted much criticism. Kastner insisted that her possibilist approach answers those objections, since the transactions all occur in pre-space, which is a space of possibilities, not actualities."

"And Kastner sees this as agreeing with Whitehead's relational conception of spacetime?"

"Yes," I replied. "In contrast to spacetime substantivalism, where points are conceived to exist even where they are not occupied by events, for her 'there are only concrete events whose collective features contain all the necessary qualities to account for the observed symmetries and phenomena conventionally associated with spacetime' —here I am quoting from her recent book which I have to hand.[95] That seems to agree with Whitehead. In fact, it is her reading of Whiteheadian concrescence as consisting in the actualised transactions of quantum theory that leads Kastner to see spacetime as a structure emerging from these events and their relations."

"So spacetime for her is something actual that gradually emerges?"

"That's what she says in her book: 'the structured set of events that constitutes the spacetime manifold emerges from the extra-spatiotemporal *quantum*

substratum comprising physical *potentiae*, that is, entities described by quantum states. This domain is characterized by Hilbert space structures and processes.' (p. 200). Thus the past grows, and is extruded from the present. But 'there is no actualized future' (70)."

"Then this is like the causal set theory of Sorkin that Carey was talking about on the phone with us," you reminded me. "It seems very compatible with the Whiteheadian process perspective. Events occur discretely, and as they happen they add to spacetime in a growing block. But the future is open."

"Kastner explicitly acknowledges the compatibility of her view with causal set theory (pp. 200 ff.). But this idea of the accretion of actual events constituting spacetime is not Whiteheadian in one crucial respect: Whitehead rejected Einstein's idea that spacetime is composed of actual events, and as I mentioned earlier, I agree with him on this. I think spacetime is best understood as connoting a structure of possibilities for trajectories of processes and so forth: a trajectory in spacetime is distinct from any actual process traversing it. (One might have expected Kastner to see this, with her emphasis on possibilism.) Whatever actual processes have contingently happened up to some point in spacetime will certainly affect the structure of possibilities for processes in the future of that point. But I think that much of the discourse about 'the accruing of events', 'growing spacetime' and 'the open future' is misconceived."

"Why?"

"Well, spacetime is a four-dimensional entity, not a spatial volume. Time is included in it, so spacetime couldn't *grow* unless there were another time dimension, but that would involve a different physics. And look at how you just described that 'growing block': 'As events occur, they add to spacetime.' As they occur now? This assumes a now extending across the whole cosmos. In this vein George Ellis, for instance, conceives of expanding spacetime in terms of the worldlines of all matter gradually increasing from the Big Bang until now, so that the present could be thought of as an uneven hypersurface consisting in all the events bounding these worldlines at the opposite ends to their origin in the Big Bang. But again, worldlines are four-dimensional: they already include the temporal component. So how could they 'grow' without presupposing a time outside spacetime? Also, the very idea of events accruing is odd. Past events existed at the time at which they occurred, but they do not exist now (at the time of our present conversation). We can remember them, and we have adequate evidence that they occurred when they did in the relationships they did. But they no longer exist now: there is no receptacle in which they can accrue. Also, at any point in spacetime it will be true to say that events are occurring, and that there are more of them that have occurred than there were earlier. So the idea of an advancing now seems unwarranted."

"But now *you* seem to be committing yourself to a static universe!", you exclaimed.

"On the contrary, I hold that the universe is in the process of becoming wherever and whenever you please. You do not need a moving now in order for there to be becoming. Each event is itself an instance of becoming, and when it occurs it is happening now, i.e. at the time of its occurrence. What deceives us about all this is that during our conscious lives, we are aware of more and more events having occurred. But we conceive of ourselves as *remaining the same* throughout, and that gives us the impression of time as something moving past us, as if we are static rocks in its racing stream. But as I wrote in my book, I think the correct way to understand the reality of time flow is to see it as consisting in the fact that

doi.org/10.32388/932RTK.4

processes are intrinsically future-oriented transitions from a local past toward a local future, so that, for instance, a motion is not only a passage over a certain space, but also a passage through a certain time. I think you can see how that opposes Russell's static theory of change as mere difference."

"Yes, but I still can't see how you avoid a block universe view if every event happens in its own now."

"Well, when Carey called us, that event was happening now at that time. But it took place about half an hour ago. Similarly, from a cosmological perspective, our conversation, and indeed all humankind's recorded history, has taken place some 13.8 billion years after the Big Bang, according to current theories and evidence. That was 13.8 billion years *ago*, i.e. 13.8 billion years *before now* (in this cosmological sense). So *now* might be relative to what events we are talking about, but it is not arbitrary or subjective or unphysical, as is often alleged."

"But what about the future? The appeal of the growing block model is that it makes room for an open future, so that things in the future are not presently determined. Without this there can be no novelty!" (Here again you were getting riled up.)

"*The* future is a notion still based on the fallacious conception of time flow as involving a moving now that confers some privileged status of reality on all the events it has passed through. But that presumes the events are already somehow *there*, waiting for the moving now to pass through them (—in what time?!). The truth is more prosaic. It is that from the standpoint of *any* event in the universe there is an empty future, an imaginatively projected spacetime region in which no events have yet occurred as of the time of that event —a future containing possible events, events that could occur, but not actual ones. What pulls against that is that we can easily *imagine* future events, and picture them as easily as we can picture past events. So we imagine them as really spread throughout this mental space, giving rise to our tendency to spatialize time, rightly decried by Bergson. For, conceiving all events as laid out in spacetime is fine if we are calculating and predicting. But there is no perspective from which one can view the universe as a whole being generated through its entire history, except in the human imagination or in simulations."

Here you agreed with me: "The block is an abstract, theoretical construct. To actually realize it would require observing the universe from outside, since relations to each locus of becoming would not be accessible to an observer within the universe. A vantage point from which we are able to consider all events as if they have happened is simply a mathematical fiction —certainly a useful one, since we are able to ascribe certain properties to such a manifold in order to help predict future possibilities, such as whether the universe will collapse back on itself at some future juncture. But the vantage point is a pure fiction. To believe otherwise is to commit the Fallacy of Misplaced Omniscience."[1]

"That is indeed one of the fallacies Whitehead cautions us against," I agreed. "But I think you can see how this applies to his own cosmology. For this very kind of God's-eye view permeates his philosophy in the form of the internal relations by which an individual can only be defined with respect to the whole universe. Such a view was endemic to the Hegelian holism that he and Russell drank in with their mother's milk. Relativity is very conducive to this point of view, which is why, when the philosophers with whom Whitehead mixed were confronted with Einstein's new theories, their typical reaction was to see it as confirmation of their neo-Hegelian philosophy. For them, everything was relative to the individual's point of view, including space and time, but these perspectives were

doi.org/10.32388/932RTK.4

still defined relative to the whole universe, as if this were something to which we all have immediate access in the present."

Here you told me that you had read much the same criticism expressed in an article on Whitehead's philosophy by Niels Vigo Hansen, which you quoted and gave me the reference for: "The ideal, positive, and unmediated existence of a universal present may be the continuation, into apparently post-theological thinking about time, of a deeply ingrained, Western theology of omnipotence and omniscience."[96]

"I could not have expressed it better myself!", I remarked. "And the same goes for the idea of a 'wave function of the entire universe,' so often taken for granted in the foundations of physics. Quite apart from all the difficulties of understanding what this mathematical construct could possibly be a probability amplitude of, its very concept again presupposes a God's-eye view, encompassing all the contingent interactions of everything, past, present, and future. Whitehead's merit, I would say, was to have laid bare this spirit of theism in cosmology, with the honesty and good humour for which he was renowned. It is true that there is a kind of immanent theology in his philosophy too, whereby the divine consists in the creativity issuing in each occasion, a kind of holy ghost engendering the universe from within. His iconoclasm is also to be commended, as we agreed —at any rate, some radical rethinking of our assumptions seems called for by the continuing impasse in the foundations of modern physics. However, as I believe we have concluded, Whitehead's philosophy is vitiated by his 'old-fashioned' assumption of the primacy of simultaneity; and this is a vitiating feature not just of his philosophy, but of much contemporary cosmology and philosophy of physics too, and we can thank him for inadvertently drawing it to our attention."

Statements and Declarations

Funding

No specific funding was received for this work.

Potential Competing Interests

No potential competing interests to declare.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Author Contributions

R. T. W. A. was the sole author and is responsible for all aspects of the manuscript.

Footnotes

[1] Here I took some inspiration from Samantha Harvey's novel *Dear Thief*, where the dialogue is embedded in a letter with a much ampler narrative.

[2] Carlson has a website where his papers are available: https://temporalsuccession.com.

[3] These are in *Qeios*, respectively.

[4] Writing up our discussion in this form allows me to give scholarly references, which I am sure you will appreciate! (I'll do the same with other quotes that occurred in our discussion.) I looked this one up, and it is from Russell, *Portraits from Memory and Other Essays*[10]: "Whitehead's theological opinions were not orthodox, but something of the vicarage atmosphere remained in his ways of feeling and came out in his later philosophical writings."

[5] I critiqued Whitehead's atomist resolution of Zeno's paradoxes of motion in my 2019 book[11], chapter 2.

[6] This seems to agree with what Whitehead concludes in *Process and Reality*, "that in every act of becoming there is the becoming of something with temporal extension; but that the act itself is not extensive, in the sense that it is divisible into earlier and later acts of becoming which correspond to the extensive divisibility of what has become" (*PR* 107). The *PR* references are to my edition of his book: Alfred North Whitehead, *Process and Reality: An Essay in Cosmology*[12]. There now exists a revised edition with different pagination: *Process and Reality: Corrected Edition*[13]. I have given page numbers from that edition, where I have them, after a slash, e.g. *PR* 339/155.

[7] These quotations are from [4], 135–136. I could also have quoted: "Temporalization is not another continuous process. It is an atomic succession. Thus, time is atomic (i.e., epochal)" ([4] 185).

[8] Cf. *PR* 53: "There is a becoming of continuity, but no continuity of becoming."

[9] Whitehead says exactly this at *PR* 124.

[10] He says something very like this at [4], 91: "In a certain sense, everything is everywhere at all times. For every location involves an aspect of itself in every other location. Thus every spatiotemporal standpoint mirrors the world."

[11] I was right. It is on p. 124 of my edition of his book.

[12] Actually, Leibniz uses this to characterise God, although his use of the plural —"those things which by acting do not change"—seems to open up the possibility for his monads, which have not yet appeared fully fledged at this stage of his thought.

[13] I found the passage that you were referring to at [4], 154–155.

[14] You were quoting Whitehead from [4], 155.

[15] Yes, I see he does, in his footnote on the same page.

[16] I was referring to my article in the 2018 [14].

[17] Again, this is from [4], 155.

[18] I make this case in my "Hegelian Roots" paper of 2018, if you want to get the exact references to Russell and Hegel.

[19] I discuss all this in my forthcoming book with Nick Griffin, *Russell on Leibniz*, which contains the relevant citations from Russell.

[20] Indeed, I see now that whereas Russell accused the whole tradition of being committed to internal relations, Whitehead took the opposite view: "It has been usual, indeed, universal, to hold that spatio-temporal relationships are external. This doctrine is what is here denied." ([4] 115)

[21] Russell said this in his *My Philosophical Development*[15].

[22] For Whitehead's discussion of this fallacy, see *Science and the Modern World*, pp. 52, 53, 56, 58.

[23] The quotation is: "there is no term which is so absolute or so detached that it does not involve relations and is not such that a complete analysis of it would lead to other things and indeed to all other things" (*New essays*, II, xxv, 10: A VI, 6: 228).

[24] Here you were quoting from *PR* 29.

[25] I found these quotations at *PR* 65 … .

[26] … and these at *PR* 254, 252.

[27] I found the exact quotation in *Adventures of Ideas*[16] (p. 245) and substituted it for Carey's paraphrase.

[28] See, for example, *PR* 339/155.

[29] This is a recurrent theme in Whitehead, but a particularly clear example occurs at *PR* 253, where he says that "the philosophy of organism entirely accepts the subjectivist bias of modern philosophy. It also accepts Hume's doctrine that nothing is to be received into the philosophical scheme which is not discoverable as an element of subjective experience" (*PR* 253/).

[30] I quote from the text Carey sent me: "Hume, surveying his own privacy as a monad, drew attention to the present moment of his experience as the surest reality that could survive his skeptical reasoning. Hume's momentary monad — conceived as pure sentient mentality — was taken up by Russell and Whitehead as the paradigm constituent of the physical world."

[31] I have substituted this quotation (*PR* 254/) for your paraphrase of it.

[32] *Adventures of Ideas*[16]. Again, I inserted the exact quotation from (*AI* 253). Whitehead expresses the same view in *Process and Reality*: "Each actual entity is conceived as an act of experience arising out of data. It is a process of 'feeling' the many data, so as to absorb them into the unity of the individual 'satisfaction'" (*PR* 65), and, as he wrote further on, this opened the way for "a rational scheme of cosmology in which final reality is identified with acts of experience" (*PR* 217/143).

[33] Whitehead discusses this at *PR* 97/.

[34] "Thus the many eternal objects conceived in their bare isolated multiplicity lack any existent character. They require the transition to the conception of them as efficaciously existent by reason of God's conceptual realization of them" (*PR* 530/). The bit about "the intervention of God" is from *PR* 377/.

[35] I might have added that the theism is also redolent of Spinoza's: "Whatever exists expresses in a certain and determinate way the power of God." (E1P36D, G II.77/C I.439)

[36] I think Carey had in mind this passage: "A purely temporal nexus of occasions is continuous when, with the exception of the earliest and the latest occasions, each occasion is contiguous with an earlier occasion and a later occasion" (*AI* 259).

[37] I discuss Robb's philosophy of time in my 2023 paper[17].

[38] This is also true of *The Concept of Nature*[18], as well as of the various papers on space and time Whitehead read to the Aristotelian Society between 1913 and 1922, collected in *Interpretation of Science*[19].

[39] As I pointed out in my book on time, Minkowski does not call them "light cones"; this seems to have been a contribution from Robb that seeped into modern physics by the mediation of those familiar with his work.

[40] I could have quoted Robb here: "the theory of space becomes absorbed in the theory of time, spacial relations being regarded as the manifestation of the fact that the elements of time form a system in conical order: a conception which may be analyzed in terms of the relations of after and before."[20]

[41] These are more or less quotations from *The Principle of Relativity*[21].

[42] Again, Carey is quoting Whitehead almost verbatim from *The Principle of Relativity*[21], p. 67.

[43] Howard Stein, 1968, 16, n. 15.

[44] Whitehead reveals that he was present at the Royal Astronomical Society when Eddington, Dyson and Davidson dramatically announced the results of their expedition to Mauritius to test Einstein's General Theory of Relativity by observing a solar eclipse.

[45] My quotations from Eddington's *Space, Time, and Gravitation: An Outline of the General Theory of Relativity*[22] are from the Preface (vii), and p. 51. José M. Sánchez-Ron[23] comments on Eddington's book's huge influence on contemporary philosophy, and quotes the following passage from it, which is certainly remarkably redolent of Whitehead: "Our whole theory has really been a discussion of the most general way in which permanent substance can be built up out of relations; and it is the mind which, by insisting on regarding only the things that are permanent, has actually imposed these laws on an indifferent world." (p. 197).

[46] This is at [4].

[47] Whitehead says this at *PR* 101.

[48] Here Carey could be summarising Whitehead's argument on *PR* 102, where he says that the influence of relativity theory is important "even at this early stage of metaphysical discussion".

[49] Carey is quoting from Whitehead's discussion at [4] 121.

[50] This is from Robb's *The Optical Geometry of Motion*[24].

[51] In this paragraph Carey is alluding to what Whitehead says in [4] 58 and *PR* 124, but the concluding two sentences are direct quotations from *The Principle of Relativity*, p. 7. Cf. also "An instant of time, without duration, is an imaginative logical construction" ([4] 65).

[52] Cf. Jonathan Bain: "The relations between events must be uniform and cannot be affected by objects." (Bain, 566).

[53] Carey's point is supported by this quotation from Whitehead: "The theory of the relativity of space is inconsistent with any doctrine of one unique set of points of one timeless space." (*CN* 136)

[54] Here Carey was paraphrasing what Whitehead himself said in [4] 122, so in reporting that, I have used Whitehead's own words as much as possible.

[55] That's *The Reality of Time Flow* that I referenced in footnote 4 above.

[56] Here I was referring to his discussion from *The Concept of Nature*[18] on p. 57.

[57] Steve Savitt and I discovered that we had come to much the same view about the present in relativity theory in an email exchange back in 2003. For recent presentations see chapter 6 of my *Reality of Time Flow*, and Savitt's "I ♥♦ s [I Love Diamonds]"[25].

[58] Here I am quoting from *CN*, 56.

[59] Cf. what I argued in [26]. According to the definitions I give there, "*Any segment of a worldline will have a region of spacetime that is present to it*" (149).

[60] See Savitt, "I ♥♦ s [I Love Diamonds]".

[61] "Causal diamonds are of course not actually diamond-shaped any more than light-cones are cone-shaped; in each case this is just the shape of the representation with one dimension neglected."

[62] This occurred in my analysis of Bergson's attack on the spatialisation of time, p. 45.

[63] Cf. "We must observe the immediate occasion, and *use reason* to elicit a general description of its nature." ([4] 46).

[64] Thus: "I will use the term 'moment' to mean 'all nature at an instant.'" (*CN*, 57); "The world is a succession of instantaneous configurations of matter." ([4], 50), and "A moment expresses the spread of nature as a configuration in an instantaneous three dimensional space. The flow of time means the succession of moments, and this succession includes the whole of nature." (*Principle of Relativity*, 7).

[65] Here I am quoting from Whitehead's discussion in *The Concept of Nature*[18].

[66] You were quoting from [4], 114–15.

[67] "Accordingly for him [Leibniz] there was no concrete reality of internal relations" ([4], 140).

[68] Here you could have quoted Whitehead from *Process and Reality*: "Every actual entity is present in every other actual entity" (*PR* 79).

[69] You forwarded me a PDF Vermeiren had sent you of his book, *A Geometry of Sufficient Reason*[3], for which thanks. He argues this on p. 54.

[70] On p. 47 Vermeiren cites Leibniz's *Principles of Nature and Grace*, (GP VI: 598), and also GP II: 249 and A II 2: 80. He discusses Leibniz on situations on pp. 98 ff. and in the footnotes on pp. 113–14, and his doctrine that there are no purely extrinsic denominations on pp. 101ff and 231, and in the footnote on p. 168.

[71] Yes, I see now. Vermeiren discusses all this on p. 34 in the footnotes, and pp. 90–98. See also his glossary entry on p. 242.

[72] Thus Vermeiren: "Their individuality does not come from a *separation* from the rest, but from an individual perspective with which they *include* the whole universe. Each monad is ubiquitous because each is included in every other monad." (p. 4). As he explains, "each thing extends as far as its relations go. In

other words, each thing is *ubiquitous*. This idea is most explicitly formulated by Whitehead", in opposition to what the latter calls "simple location" (see §4.3).

[73] "Every actual entity is present in every other actual entity" (*PR* 79).

[74] Cf. Whitehead: "There is a spatial element in the quantum as well as a temporal element" (*PR* 434/283).

[75] Here you were referring to Gilles Deleuze[27], ch. V and esp. p. 231.

[76] See Vermeiren's discussions on pp. 137, 218, 212 n.170, and 227–234 of his *Geometry of Sufficient Reason*.

[77] The Whitehead quote is from *PR* 103/65; Vermeiren's discussion is on p. 60 of his book.

[78] Heisenberg writes: "The probability function combines objective and subjective elements. It contains statements about possibilities or better tendencies ('potentia' in Aristotelian philosophy), and these statements are completely objective, they do not depend on any observer; and it contains statements about our knowledge of the system, which are of course subjective insofar as they may be different for different observers." ([28]). This hardly constitutes a detailed theory, of course, but it is a much-quoted observation.

[79] Popper proposed his propensity interpretation of probability in 1959, and Maxwell advanced his "Quantum Propensiton Theory" in 1988; these theories are described and ably critiqued by Mauricio Suárez, who defends a "selective propensity" interpretation in his article "Quantum Propensities"[29]. See also Henry Krips[30]. It turns out, as I subsequently discovered, that in 2018 Kastner and Epperson co-authored a paper on the *potentia* interpretation with Stuart Kauffman as a third collaborator, but they do not mention any of these predecessors.

[80] Michael Epperson[31]. My page references are given to the Kindle edition.

[81] This encapsulates Epperson's discussion on pp. 69–70.

[82] Here you were elaborating on what Epperson says on p. 87: "Put another way, quantum mechanics does not include a mechanism for the actualization of potentia; it merely describes the valuation of potentia (via the complex coefficients α and β)—the valuation of the alternative potential eigenstates belonging to the mixed state, such that these alternative potential states become probabilities, and not just potentia."

[83] On pp. 97–98, Epperson appeals to Wojciech Żurek[32].

[84] The quotations are from *PR* 423 and *PR* 72, respectively.

[85] You were quoting from Epperson's book, p. 155, and Whitehead's *PR* 226/149.

[86] Epperson quotes from the article I cited by Żurek, p. 84.

[87] This is at p. 193 of Epperson's book. From now on, I will just include page numbers from this book in parentheses in the text.

[88] You took these quotations from *The Principle of Relativity*, pp. 30, 67 and 116, respectively.

[89] I am alluding to Dennis Dieks (2004)[33].

[90] I have never heard of the “Hong Kong galaxy”; I think it must be a fictional invention on the part of Epperson, although he does not say so.

[91] I am glad you agree with my analysis there, given in Chapter 5.

[92] Robb’s constructions are given in his *Optical Geometry of Motion*. As I explain in my 2023 paper cited above, Robb’s work was later built on and given a superior foundation by E. C. Zeeman[34] and by A. D. Alexandrov[35]).

[93] J. G. Cramer[36]. See R. E. Kastner[37].

[94] See Jeffrey Bub[38] and Dennis Dieks[39] .

[95] Ruth Kastner, *The Transactional Interpretation of Quantum Mechanics* (Cambridge: Cambridge University Press, 2022), p. 221.

[96] Hansen, N.[40]. Q.v. Sulis[1]. In a recent email to me, Bill also commends Hansen’s argument that the lack of attention paid to Whitehead’s ideas has less to do with their readability and more to do with prevailing worldviews: “It is very difficult to grasp the idea because of an implicit metaphysics, probably one that projects a particular theological content into a tradition which is no longer aware of *being theological* [emphases mine]” (Hansen, 2004, p. 151).”

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Declarations

Funding: No specific funding was received for this work.
Potential competing interests: No potential competing interests to declare.