OMNISCIENCE

The new science of the Cosmos

By Andy Ross

Introduction

The theological term "omniscience" means knowledge of everything, and today we see the Cosmos as embracing everything, or at least everything that is not delusory. Cosmology, the science of the Cosmos, is our modern analog of the old striving, as Stephen Hawking put it in his brief history of time [27], to know the mind of God.

In 2006, having just watched the movie *What the Bleep Do We Know* (and read the book [4]), I resolved to summarize my views on what we know about everything – the Cosmos – in the form of a bullet-point slide show that might somehow evolve into a bleep-worthy presentation. That further evolution remains pending, but the slide deck is still interesting.

Today, the slides recall primarily the struggles of a thinker still deeply entangled in the mathematical obsessions of his student years, trying earnestly to use his formal insights to wider effect in the service of science. But the time was not yet ripe to fill out those insights except in the most cryptic and programmatic way. This moves me to offer the present review.

My plan here is to quote the text from each of the sixteen slides in turn, under its structural heading, and then to answer the questions each text raises in paragraphs of new notes, commenting, explaining, and adopting my present perspective on the issues. The outcome should be a transformation of what began as an esoteric work of mathematical mysticism into a potentially fruitful perspective on the entire enterprise of systematic science. Along the way, a psychologically alert reader might also enjoy seeing how a thinker who had not yet cooked his ideas down to a digestible form is revealed as an early pioneer, perhaps, of a new science of the Cosmos.

The first quoted word may already pose problems, so let me gloss it right away. The acronym MIPH, also written *miph*, was my term of art for the potent combination of mathematics, informatics (or computer science), and physics. It deliberately evokes a resonance with the word "myth" of older vintage. I coined the term in my 1996 science-fiction novel *Lifeball* [45], which contains a lot of clunky stuff as well as a scattering of neat ideas, so skip the novel but do try to enjoy the following exegesis.

MIPH 1: Logic

A formalized language makes a useful structure:

- Scientific theories are linguistic constructions that aim to provide true descriptions of nature.
- If the language of a theory is formalized, the benefit in terms of clarity about the logical status of the theory can be significant.
- Such a language may include zero-order propositional variables and the standard truth-functional connectives.
- It may also include first-order functional notation for predicates, object variables, and quantification.

Formalizing a language involves making it amenable to logic, so that true statements and valid inferences are easier to identify. To a good approximation, it tidies up the syntax of the language sufficiently to enable a computer to verify the semantics for that syntax, for example, to identify the ontology that underlies the semantics. In effect, once you have translated the language, or the relevant parts of it, into program code, you know you have something that can be useful for scientific purposes.

The wider picture here is that science is often a matter of making conceptual models of some field of concern. These models are equivalent to computer models, and science becomes the enterprise of modeling nature, or parts of it, on the basis of mathematical structures that reflect the empirical patterns in the experimental data for that science. Scientists do many things, but a central part of what they do is to make mathematical models of data, of the sort we know from computer simulations.

Historically, the use of logic in this way to support science began in the nineteenth century with the work of pioneers like George Boole and Gottlob Frege. Mathematical logic grew quickly on this foundation and became theoretically secure with the work of Kurt Gödel, Alan Turing, and many others [11]. This soon led to a general theory of computability, and the way was clear for later workers to develop the digital revolution that is still transforming our world.

MIPH 2: Sets

Start with a null description and build up discretely:

- A standard way to understand the logic of a scientific theory is to say it describes a domain of objects that have various properties.
- The theory is true if the objects exist and have the stated properties.
- The objects exist if their identifying descriptions are true.
- Set theory provides a frame within which such identifying descriptions can be constructed and assigned certain basic formal properties.
- A dynamic set theory starts with zero and builds up as far as necessary, in what looks formally like a standard recursive process.

Set theory and formal logic grew up together. The language of axiomatic set theory is the language of mathematical logic. Frege made a start, Bertrand Russell and Alfred North Whitehead took the story further in their trilogy *Principia Mathematica* [49], and mathematicians like Ernst Zermelo and Abraham Fraenkel defined the formal structure that underlies all modern set theory [21]. The Zermelo–Fraenkel (ZF) axiomatization of set theory is now regarded as the standard logical foundation of all of classical mathematics.

The standard model of the ZF axioms is a cumulative hierarchy of sets forming a ranked structure based on the empty set as foundation. This has the curious consequence that the logical foundation of mathematics is nothing, the empty set, and the justification for mathematics must be found in the tidiness of its syntax and the internal elegance of the ontologies we can build up on the empty set to provide a semantics for that syntax. The ranking function, by the way, was first defined by John von Neumann, who thus made the ordinal number sequence the backbone of the hierarchy.

Sets, on this picture, are abstract objects with two sides. Seen from above, they are elements that can be assembled as members into further sets. Seen from below, they are classes, the classes of their members. At the bottom, the empty set is the class of nothing, a pure element. At the dizzy and undefined top of the hierarchy, pure classes like the universal class cannot be seen as elements on pain of contradiction. As Russell pointed out, the class of all sets that are not members of themselves cannot be a set too, or it would be a member of itself. Today, we say no set can be a member of itself, and each set has a higher rank than its members. ZF is the theory of such sets.

MIPH 3: Worlds

Interpret universal sets as worlds with centers:

- Set theories comprehend sets with limited numbers of members and also sets including everything so far.
- Such universal sets are seen first as classes and comprehended later as elements in more comprehensive classes.
- Universal sets serve as formal analogs of worlds for subjects located inside them.
- Such worlds have centers and provide a model for located subjectivity, as in everyday human experience.
- The formal model is a metaphor justified by the light it sheds.

The concept of a world has been a favorite among logicians ever since Saul Kripke invoked it as the basis for his formal semantics, or model theory, for modal logic, the logic of necessity and possibility [12]. Roughly, a necessary truth is true in all possible worlds, and a possible truth is true in at least one world. A world is a set of objects with certain properties, or more concretely, a model for some domain of discourse. More abstractly, a world is a set, a ranked universal set in particular, containing all the sets below some rank. Formally, defining that world is a matter of defining a mapping between those ranked sets and the objects in the relevant domain of discourse. Those objects constitute the ontology for that domain and are said to exist in that world.

The concept of a world is also a favorite among researchers in the nascent science of consciousness. Over a hundred years ago, William James saw the elements of consciousness as forming a succession of worlds, strung out in time, so that the conscious subject experienced each world in turn as his or her conscious mind inhabited successive moments of now, also known as moments of specious present. Such Jamesian worlds, also known in the community as phenomenal worlds or worlds of experience, I called *mindworlds* in my 2009 book of that name

[46]. I had introduced the term in my talks at several conferences over the preceding decade, and I hope it will survive.

Modeling a mindworld as a ranked universal set is a natural first step toward formalizing the science of consciousness. The special benefit is that each such world has a history coded into its ranked initial segments and invites assimilation as a member into further such worlds as time goes on. Here the empty set, of rank zero, is the origin of consciousness in its primordial moment of being, and the rank ordinals define the timeline along which the consciousness grows into ever more fully realized worlds. These worlds are strictly analogous to the possible worlds of modal logic, where some depth of realization is achieved that corresponds to the realism of the concept of possibility in play.

Mindworlds are centered. Formally, they are centered on the empty set, which with each step up the rank hierarchy becomes ever more surrounded by further structure in a more richly articulated phenomenal world. In such a world, consciousness has a place, which gives the subject thus embodied a *Dasein* in the sense defined by Martin Heidegger [30]. Also, such a consciousness acquires ever more properties, understood as class membership (or extensionally, following Gottfried Leibniz) in the series of ever more extensive ranked worlds. Hence it becomes ever more richly true to say “there is something it is like” to be that conscious subject, to recall the criterion for consciousness made famous by Thomas Nagel and now widely shared in the consciousness community [26].

MIPH 4: Method

Build up layer by layer by reflecting universal sets:

- We have a formal foundation in a logical syntax including set-theoretic ideas and a null base.
- We also have a general strategy for going from level to level in a formal structure by comprehending new layers of sets in a growing cumulative hierarchy.
- We can start a recursion that reaches as far as our experience does, to reflect in a logical formalism the ongoing process of comprehending centered experiential worlds.

The process of pushing forward through successive worlds of consciousness has a formal analog in the process of defining ever higher ranks in the cumulative hierarchy of sets. We call such sets pure because they are ultimately founded on the empty set, which corresponds in consciousness to that fact that a mind is ultimately rooted in pure being. And we call such sets well founded because they have higher ranks than their members, which disallows membership chains that go round in circles, and which corresponds in consciousness to the fact that a timestamped world, once visited, can never be revisited, but only reconstructed in memory or a simulation.

In set theory, the process of pushing upward is simple. Each ranked universal set is the power set of all sets of lower rank, which is to say the set of all the sets that have as members any combination of the sets so far. Technical questions about which such combinations are definable aside, the result is a mushroom cloud of ever more vertiginously towering abstractions that gets wider as it grows upward. The main constraint on this growth is the difficulty of handling the syntax and defining its semantics as we voyage ever deeper into the transfinite realm where infinities pile onto infinities beyond all known limits. This is a glass bead game, in the sense made famous by Hermann Hesse in his novel of that name [31].

Mathematicians are traditionally Platonists, in the sense that they believe the realm they explore is a timeless structure, beyond all change and decay, where truth once established remain eternally so and where any meaningful question is true or false [51]. But the gaps in this picture of set theory, exposed over a few decades by Russell, Gödel, and many others, force us to recognize the importance of epistemological limits in mathematics, which translate into the existence in our formalism of something analogous to time. For me, this something takes the form in set theory of the ordinal rank dimension of the cumulative hierarchy. Any consistent set theory we can formulate is reflected or has a model in some initial segment of the hierarchy – this is known among set theorists as the reflection principle – and hence invites replacement by an incrementally augmented theory with a slightly bigger model reflecting it in the hierarchy.

You may have an uneasy feeling that all this is looking rather murky and dangerous. If so, you are not alone. This feeling is exactly why the early set theorists started small (with nothing) and built up cautiously, step by step. The result is that the more modest theories they came up with are as safe as houses. They provide us with a reliable construction kit for worlds of consciousness. The most exciting part of the picture is the process of stepping upward through the worlds, of moving from moment to moment along the timeline of conscious experience.

The history of philosophy can offer some inspiration here. The great philosopher G.W.F. Hegel defined his notoriously slippery dialectics by moving from moment to moment in phenomenal experience in a process he called *Aufhebung* (which translates rather unhelpfully as sublation), where in the usual account the contradiction between thesis and antithesis is sublated in a new synthesis. German philosophers are often happy to say that Hegel's dialectical logic [29] is great, but more mathematically inclined philosophers in the analytic tradition established by Frege and Russell tend to dismiss it as a sloppy mess that makes no sense. As a self-willed student within the latter tradition, I resolved to find some sense there. I found it precisely in the concept of sublation as a characterization of the process of stepping from world to world in consciousness. All the rich historical material Hegel mined to fill out his great historical dialectics became available to describe the growth and development of minds and of knowledge. My trump card was the formal machinery of set theory to put all that loose stuff onto a firm foundation.

MIND 1: Consciousness

The synthetic unity of apperception creates a self:

- Consciousness brings subjective experience to a unity, which in a Kantian approach we can call the synthetic unity of apperception.
- The unity of consciousness creates a growing structure in a dynamic process we can model as the recursive construction of a cumulative hierarchy.
- The growing structure can be understood intuitively as a self.
- The subjective continuity of experience is essential to a self, and a recursive construction from a null foundation is a natural way to model the temporal growth and inward transparency of a self.

The nature of a self is a contested topic in consciousness studies, and some philosophers, such as Daniel Dennett, dispute that the concept corresponds to anything real at all [16, 18]. Others, such as the neuroscientist Joseph LeDoux, see the concept as serving the role once served by that of the soul [37, 38]. A self, in this view, is the temporal and brain-bound analog of the eternal soul once dimly envisaged by René Descartes and earlier religious thinkers. The Cartesian picture of the soul was that it is like a homunculus in the brain, sitting as a spectator of the Cartesian theater staged by the brain on the basis of its sensory input and the thoughts that input awakens. The immaterial soul enjoys the show put on by the material brain. Dennett thinks this picture is nonsense and points to the potential infinite regress as we seek to explain the homunculus with another, doubly inner mini-homunculus.

The solution here is to see the self as a logical construct by which the cerebral neuronet looks back at its own activity. This view of the matter is favored by Douglas Hofstadter, who has worked long and closely enough with Dennett to share most of his views here [34]. The self is a construct that may be more or less perfectly realized, depending on the nature of the person embodied in it, and may be well organized or not, enduring or transient, for relatively minor reasons. In principle, any neuronet with sufficient logical powers, including an artificial one, can construct or develop or grow such a self. There is no Cartesian or divine magic required to conjure it into existence.

The great philosopher Immanuel Kant developed a (rather arcane) vocabulary to discuss this issue more deeply. Kant saw the self as bringing the variety of sensory inputs and thoughts to a synthetic unity of apperception. The various inputs he called the manifold of phenomena, and he saw the essential role of the self as to bring that manifold to a unity. In my set-theoretic picture, this corresponds to mapping the input to the various sets in a ranked universal set and allowing the logic of the self to roll that universal set around a logical loop through the null set to create a centered world. The logically strange business of looping is something Hofstadter has written at length about, for example in his book *I am a strange loop* [33].

The process of crunching a manifold of phenomena to a synthetic unity conjures up a primordial image of a simple mind cycling through its history of states, down to zero, in order to comprehend its present phenomenal input. Once a neuronet has a reasonable level of logical sophistication, the logic mapping its route through a succession of states before bringing its core state to a synthetic unity can be arbitrarily indirect. This gives us leeway to use all the tricks of computer modeling to explain how it might go. The point, every time, is to bring a mass of disparate stuff to a unity that reflects a single selfish mind acting in a coherent manner.

MIND 2: Phenomenology

The manifold of phenomena is given as sensorium:

- A self has experience or interacts in a changing world.
- The changing world is a manifold in which many parts are folded together in a unity that has some level of ongoing stability, for example some number of dimensions.
- The parts are initially phenomenal but are soon revealed as having a foundation in sensory experience.
- The sensorium is the theater of phenomenal experience and entertains the self with a passing show.
- The self is a cumulative construct from the elements of previous shows.
- The process is a bootstrap fed by new waves of phenomenal input.

The sensorium (another Kantian term) is like a Cartesian theater for an embodied mind. An embodied mind is an agent, or an implementation or realization of a rational ego, and the ongoing drama of how such an agent grapples with the sensorium is the drama of cognition. This drama is also the central plotline of Kant’s critique of pure reason [35], which led him to regard his own contribution as like another Copernican revolution in thought, in his case to achieve a new understanding of phenomenal reality as shaped by the categories of thought. These categories include such things as unity, causality, spatial location, and temporal succession, and his idea was that they are innate and serve as the key building blocks of a rational ego.

In my terms, the categories are sorting criteria or filters through which the multiplicity of inputs that make up the phenomenal manifold are mapped in a stepwise reduction process to the synthetic unity of apperception, or in set theory the null set, through the self-loop that generates the reduced feedback for selfish agency in the ongoing cycle of conscious activity. All this has a direct analog in artificial neuronets, which in this view can implement agency and consciousness just as readily in principle as human brains in human bodies. In practice, the main hindrances are firstly that we cannot yet build neuronets with the required complexity and secondly that we still have only crude ideas about how to architect or program or teach artificial neuronets to present a convincing appearance of conscious agency.

The strange or paradoxical nature of the looping through which a logical construct develops the architecture of conscious selfhood is something Hofstadter has had a lot of fun emphasizing over the years [32]. But many other people have come to similar conclusions. Rodolfo Llinas wrote about the I of the vortex [39], Thomas Metzinger wrote about the ego tunnel [41], and I wrote about the puppet or analog self who acts in a mindworld like an avatar in a virtual reality [46]. In set theory, the paradox is brought to an almost painful peak in the idea that the topmost universal class in a ranked world, which is not yet a set on pain of contradiction, is therefore null, a member of the empty set, which takes us down the rabbit hole in another loop of the whole strange hierarchy. My attempts to explain this idea in Oxford some forty years ago fell on deaf ears – for good reason when one sees just how revolutionary it is. In psychology it looks bizarre and in mathematics it looks downright destructive.

MIND 3: Epistemology

Layers of ontology build up to reflect past worlds:

- Each layer of phenomenal input creates a new layer of elements.
- The elements are defined in terms of previous input and constitute a cumulative structure that we see as a world built upon past worlds.
- At each moment, all the elements so far define a layered ontology.
- The dimension ordering the layers appears to the self for which they are the parade of past worlds as the dimension of experienced or historical time.
- Time thus defined is primarily epistemo-ontic in nature.

Since I first had these ideas, ontologies have become an established part of the process of preparing applications in database design. But in my student days the main source of insightful work on the topic was the American philosopher Willard Van Orman Quine, who had launched his career by updating and revamping Russell and Whitehead’s work on set theory [44]. Quine became famous (or notorious) among philosophers for his opinion that any ontology – any set of objects defining an application area or a world in science or everyday life – could be “reduced” to sets, by which he meant mapped to certain sets in a way that perfectly preserved the logical articulation of those objects [43].

As a student of set theory, I was very taken by Quine’s idea and the visions it conjured up of an ambitious program to demolish “ontological slums” and erect clean logical architectures in their place. I saw how well the idea worked within mathematics and saw in principle how it could work in tandem with a program of developing transformational grammars, as pioneered by Noam Chomsky, for natural languages.

My bigger vision was that the idea would work too for a rational psychology along Kantian lines. All the categories in all the possible minds that might crunch down a manifold of phenomena to a synthetic unity could be reconstructed in set theory, and all the resulting ontologies – all the contents of any world entertained by any conscious being anywhere in the universe – could be mapped to sets. In each specific instance, they could be mapped to the sets within some ranked initial segment of the cumulative hierarchy corresponding to a Jamesian world of consciousness.

Recall that the dimension along which successive worlds of consciousness for a subject are ordered is an epistemological dimension. As subjects, we find our knowledge growing step by step as experienced time unfolds for us. This is epistemology in action, growing an ever more richly stocked garden of ontological plants to populate our mindworlds. I saw this shuttling back and forth of epistemology and ontology as a clear example of a dialectic in the Hegelian sense. Using set theory, I had reconstructed the Hegelian dialectic as a logically rigorous process, at least in principle, as convincingly, I dare say, as Quine reduced all the ontologies of all the worlds to sets.

There was more to come, but it took me decades to work it out. In all this talk of epistemo-ontic dialectics, we have the rudiments of a philosophical theory of time. The obvious problem was that in the twentieth century the theory of time became the preserve of physicists, and their best theories of time are highly mathematical and hard to understand. Despite a fair student acquaintance with the physics of time, I needed more time myself to reach out confidently to the frontiers – where it now turns out that the best accounts of time are in the conceptual warzone where quantum mechanics overlaps with general relativity. In other words, if my new view of time had any cash value at all for physicists, it would have to help us advance toward a theory of quantum gravity. That was and is a tall order.

MIND 4: Psychology

A self is a structure of layers budding from layers:

- The formal psychology that emerges from the layers is that of a self, embedded in a succession of momentary worlds, where each world is a centered construction based on a sensorium.
- The sensorium brings a manifold of phenomena to a synthetic unity via the process of apperception.
- Each momentary state of the self reflects a centered world and is equal and opposite to it in a way that admits exact definition in set theory.
- As a self grows in time, it occupies a succession of momentary forms, each reflecting an ontology of things comprehended so far.

During my work on mindworlds, I had become convinced that a self and its world are equal and opposite in almost a Newtonian sense. We could almost build a calculus to describe the process of growing a selfish mind in one and the same process as we define a succession of worlds of consciousness strung along a subjective time dimension. Any world with the right logical configuration reflects a self, and any self is reflected in a suitable mindworld or succession of mindworlds. This, for what it’s worth, is exactly the (rather solipsistic) concept of the self that the young Ludwig Wittgenstein seemed to have had in mind when he wrote the oracular and almost mystical propositions through which he became famous and almost revered among philosophers in Cambridge and Vienna in the years between the two world wars [19, 58].

The neuroscience of the process of developing or growing a selfish mind was what primarily concerned me during my “decade of the brain” (which ran a few years later than the world’s official Decade of the Brain and in my case was triggered by reading David Chalmers’ big book *The Conscious Mind* [9], following his 1995 article in *Scientific American* [8]). The brain can be pictured from moment to moment as like a lump of wax, ready to be impressed by a pattern of sensory input in a moment of specious present, where the input is conducted away into the cerebral neuronet for filtering and aggregating and more convoluted logical processing, until it passes through the eye of the needle of the synthetic unity of apperception and becomes the trigger for an action cycle via the motor neurons. In this respect, the brain is a digital input-output machine, optimized by evolution and learning to perform action cycles that benefit its host organism in some way.

Thus conceived, the brain is logically equivalent to a Turing machine, a computer, a cognitive processor. It could be replaced by a box stuffed with silicon chips programmed to perform the same input-output mappings, so that if we replaced the body, too, with a robot body, the combination would give us a behaviorally equivalent machine artifact. Chalmers' big claim in his big book was that it remained an open question whether this artifact was conscious. He claimed that as a matter of logic, even if it behaved with perfect humanity, it could still be a zombie. Indeed, so far as David was concerned, you or I could be a zombie too. Nothing an empirical scientist is in a position to do can prove otherwise. This is his famous hard problem. For all of us, it was solipsism on steroids.

My response was essentially to define the problem away in terms of mindworlds. Consciousness is simply what you get when you implement a logical architecture that loops regularly through an action cycle that reduces a sensorium to a unity and then acts on the result. The inner phenomenology of the looping spiral – the epistemo-ontic dialectic – is just what it is to be conscious, by direct appeal to Thomas Nagel's criterion for what it is to have an embodied *Dasein*. After years of exposure to this concept of mindworlds, David seemed unconvinced [10], and obviously it remains possible to insist on the hardness of the hard problem and the mystical inscrutability of consciousness against all odds, so I rest my case. Think of my mindworlds story as a footnote to cognitive science, if you must, and let the C-word remain a warzone.

The mindworlds story does formal justice to the respective works of Kant, James, Wittgenstein, and a large number of modern philosophers and neuroscientists. It goes some way toward rehabilitating the Hegelian dialectic (though not its Marxist–Leninist or Maoist variants) and offers a fertile field of potential applications for formal logic and set theory. Pursued more fully, mindworlds might offer a paradigm for psychology that lifts it from the "pseudoscience" status to which Karl Popper, in his day, understandably condemned it. All this is a decent legacy, I think, for what seemed when I was young to be a rather wild idea.

TIME 1: Becoming

Reality grows and cannot be manifest all at once:

- The set theory metaphor suggests that reality cannot be manifest to us as a final eternal structure.
- It reveals itself in time, and time goes on beyond any momentary form of an experiencing subject.
- Cosmology is doomed to be an incomplete science.
- Each temporal slice of reality reveals a world that will be embraced and superseded in more comprehensive worlds.
- Layers of elements come into being as existing elements in a universe that is becoming ever fuller or more detailed or determinate in time.

Around the turn of the century, Stephen Hawking gained fame by mooting the possibility that physics was approaching a final theory, a complete and consistent story of life, the universe and everything. Toward the end of the nineteenth century, the British physicist Lord Kelvin had mooted a similar claim, shortly before quantum theory and relativity blew it away. Soon afterward, Gödel proved in logic that nontrivial mathematics can never be proved to be both complete and consistent [22], so you might think Hawking would have learned some humility.

Transposed to set theory, the Gödel result becomes a proof that any consistent theory with a model in some initial segment of the cumulative hierarchy can only be proved to be consistent in a theory whose smallest natural model is a larger initial segment of the hierarchy. The implication seems to be that we, as beings living in mindworlds with models in such initial segments, are condemned to keep moving forward or upward through the hierarchy if we are to gain the secure knowledge that we seek about our successive mindworlds. Our own epistemo-ontic dynamic – our own dialectic – propels us forward in time, *nolens volens* (willy-nilly), at a rate determined by the physics of our incarnation, our implementation in biological wetware.

It need hardly be stressed that this result applies to cosmology just as fatefully as it does to any other theory that we might entertain from within any mindworld we happen to inhabit. Cosmology is a discipline whose theories are defeasible. The history of cosmology during Hawking's lifetime bears this out as convincingly as anything else. Until about fifty years ago, the steady-state theory of cosmology was orthodox enough to be held by Hawking's peers and mentors, such as Fred Hoyle and Dennis Sciama, and only since then has our study of the cosmic microwave background (CMB), together with mathematical work like that Hawking did with Roger Penrose [28], convinced us that the big-bang theory is indeed the plain fact of the matter. No one seriously doubts that further revelations are forthcoming, for example as we study the deeper implications of superstring theory [23] or cosmic inflation [24], so the best we can say is that there is progress. We now agree that the heliocentric model of the solar system is fact, that galaxies are in fact aggregations of billions of stars, that the geometry of spacetime does in fact reflect the distribution of mass and energy, and so on, all of which supports a ratchet model of knowledge, just as the logic of the set-theoretic dialectic suggests.

Current speculations in cosmology top out in mathematical conjectures that have only the slenderest support in hard fact. Cosmic inflation, where the observable universe expanded exponentially from quantum to macroscopic size in its first yoctosecond before it slowed down to the gentle expansion calibrated by the Hubble constant, seems good as far as it goes, but the further idea entertained by Andrei Linde and others that our big-bang universe – our "Hubble bubble" – is just a little bubble in an exponentially roiling ocean of eternal inflation that seethes with further bubbles [42], an ocean that Sean Carroll calls the cosmic bubble bath [6, 7], is best regarded here and now as an amusing myth, rather like the picture of a stack of tortoises supporting the flat Earth in a much older myth.

One feature of our big-bang cosmology that offers a good metaphor for the wider idea that our knowledge grows in time is the clear fact that our Hubble bubble expands in time. Our cosmic event horizon is set by the CMB, which records that fact that the universe was opaque until about 12 teraseconds after the Big Bang (ABB). The finite speed of light means that we look back in time as we look out in space, but we cannot look back in time more than about 13.7 billion years (some 432 petaseconds), at which point the CMB fogs the view. Given universal expansion, the remotest objects we can see were over 13 billion light years away as we see them but are probably now much further away, perhaps at some 50 billion light years. Our Hubble bubble is what we call our past light cone, the cone within which anything we can possibly see now must have been located. Actually, "cone" is not quite the right word, since the zone of visibility expands steadily outward from a few centimeters in size for the latest nanosecond until it shrinks down again to a rather small region as we approach the CMB in our deep dive into the past.

Given the relativistic constraint on causal relations, the past light cone is also a cone of possible causal connection with our present mindworld. Chains of causal connection all begin and end within it, and zero ABB is the earliest moment of time that can possibly matter for us. For the purposes of physics, the past light cone of our present mindworld is the direct analog of the initial segment of the cumulative hierarchy within which we expect to be able to model anything and everything that concerns us. In this way, the growth of our Hubble bubble is the physical analog of our logical ascent through the cumulative hierarchy. The caveat is of course that we might change our cosmological beliefs more casually, given the right evidence, than we change our logical ones, for which the only evidence that counts is mathematical.

A further caveat is that the laws of physics need to be explained within the facilities afforded by the cumulative hierarchy, whereas contemporary cosmologists are often content to accept the deeper laws of physics as given, in our universe at least. This naturally gives rise to visions of a multiverse, in which universes of every possible kind proliferate in wild confusion [25]. Max Tegmark has written as plausibly as anyone about how these visions arise in physics [54, 55]. He explains that multiple universes at various levels are needed to accommodate the various levels of apparent arbitrariness in the world we live in. For example, in the "many worlds" interpretation of quantum mechanics currently championed by David Deutsch, there are worlds, that is universes, spawned by each and every possible outcome of each and every quantum jump in the world around us. As another example, in the M-theory generalization of superstring theory put together by Ed Witten, any of the possible settings of the fundamental constants can be instantiated in a big-bang universe, perhaps as another bubble in the cosmic bubble bath, and there are at least the fifth power of googol possible combinations.

TIME 2: Probability

The past is real, but futures are virtual or probable:

- Scientific theories aim to predict events that still lie in the future relative to the present world in which the subject is embedded.
- Future events do not yet exist. They are virtual and may at best be assigned probabilities to come into existence.
- Classical mechanics describes events and predicts them with probability approaching one, but epistemological problems limit its applicability.

Albert Einstein and Kurt Gödel used to think the future was just as fixed as the past [59]. For them, the only difference between them was that we haven't yet visited the future. Gödel even found a solution to Einstein's cosmological equations that "proved" the possibility of time loops in a rotating universe. Neither of them quite appreciated how deeply the concept of probability is embedded in any worldview that accommodates quantum theory.

The classical worldview in which past and future are eternally fixed in a relativistic "block" universe that you can slice along any given timeline stands opposed to the quantum view that everything in the past is fixed and everything in the future is in flux, still poised in a set of virtual possibilities, waiting for us to come along and realize one possibility as our next present moment, then another one, and so on, breaking step by step the symmetry of all possible futures that looms before us. The contradictory nature of the clash between these worldviews is not yet sublated (or as Hegel would say, *aufgehoben*) in a consistent theory of quantum gravity.

Set theorists face a similar contradiction between Platonists on the one hand, who imagine the entire cumulative hierarchy stretches, eternally complete, into an ultimate infinity of infinities, just waiting for us to come and explore it, and constructivists on the other, who think we make it up as we go along. My view here is simple. The Platonists can't be right, on pain of the contradictions illustrated by Russell's set-of-all-sets paradox and Gödel's incompleteness theorem. The constructivists aren't right either. We can't make it up because we don't have free will when it comes to mathematical truth. It makes itself up, and we find ourselves going along for the ride. Also, a constructed universe that stops at some ranked level and loops to nothing again right there is no less paradoxical than the maxed-out Platonist totality. I think we just have to face the fact that reality is paradoxical, like a Möbius band or like the strange loop formed by Hofstadter's ego. The trick is to sort it out in such a way that it is and remains internally consistent.

All that said, we don't simply launch ourselves unprepared into each future moment. We build theories and use them to assign probabilities to the various possible futures we confront. Classical mechanics allowed us to do so with maximal epistemological prejudice: What it predicted was assigned probability one, and any other outcome had probability zero. However, it was vulnerable to what philosophers know as a Sorites paradox: The tiniest measurement error would result, after a sufficiently long chain of deductions, in false predictions, or at best in complete uncertainty. This is the transition to chaos that famously bedevils weather forecasts.

Before quantum mechanics came along, classical mechanics confronted this problem in statistical mechanics, which was the foundational science for thermodynamics. Attempt to predict the movement of molecules in a gas led to a statistical theory of probable outcomes in which the previously mysterious concept of entropy was given a clear logical definition. Imagine each of the possible distributions of positions and velocities among gas molecules in a box as defining a microscopic state of the gas. *A priori*, before we have any reason to think otherwise, each such distribution is as probable as any other. There is a symmetry between all possible microstates. Now imagine all possible macroscopic states of the gas in terms of pressure, temperature, and so on. Each of these macrostates can be realized by any one of the microstates in a certain subset of the set of all microstates. Now, by simple arithmetic, the probability of a given macrostate can be calculated from the relative number of microstates that can realize it. Ludwig Boltzmann worked all this out and defined the entropy of a given macrostate as proportional to the logarithm of the relative number of microstates that can realize it.

The second law of thermodynamics, that the entropy of a closed system always tends to increase, is basic to the theory of heat engines and much of chemistry. Boltzmann's definition showed why it was true: Without external input, systems tend to evolve in the direction of increasing probability. This seems almost a tautology, but in fact it reveals a deep truth about time. The arrow of time has a definite direction – toward increasing entropy. If the universe is a closed system – and it is hard to see how it could not be – then its entropy, or its disorder, roughly speaking, will increase steadily and inexorably, toward the "heat death" of thermal equilibrium that ended the story in Hawking's brief history of time.

The relativistic block universe is doomed to run down to a heat death. Metaphorically, God needs to reach in and wind up its clockwork to keep it going. In my set-theoretic story, any universe embedded in a ranked initial segment of the cumulative hierarchy will be left behind as ordinal (epistemo-ontic) time moves on. To stay current, it has to keep growing and changing at the leading edge.

Equilibrium is a kind of symmetry. Breaking the equilibrium of a system in mechanics is like breaking the symmetry of a system in mathematics. Think of a pencil balanced in unstable equilibrium on its end. A slight touch will disturb its equilibrium and break the symmetry of directions into which it can fall. Similarly, a ranked universe (an initial segment) is poised in a symmetry between topping out in nothing at all and topping out in a bigger ranked universe. Topping out in nothing is equivalent to collapsing to the null set, and perhaps recycling in a way Carl Friedrich Gauss would have described in modular arithmetic or Friedrich Nietzsche would have called eternal recurrence. In such a universe, time would loop. Topping out in a bigger set is what happens when time marches on.

TIME 3: Quanta

Discrete elements of experience are quantized:

- Quantum mechanics represents an epistemological advance from the naïve stand of classical mechanics.
- Future events are seen as virtual and different possible futures have different probabilities to come into being.
- The realized form of a self in a world helps determine the probabilities of realization of alternative possible future events.
- It is an empirical discovery that the elements of experience are discrete, with finite and measurable values.
- The continuum model of reality is a heuristic device for emphasizing the open-ended nature of experience in the phenomenal manifold and the impossibility of exhausting it in a discrete process.

Quantum mechanics began with Max Planck and Albert Einstein’s discovery that electromagnetic radiation is quantized as discrete photons and Niels Bohr’s discovery that such photons can explain the stability of atoms. With wave-particle duality and Werner Heisenberg’s uncertainty relation between complementary observables such as position and velocity or energy and time, theorists realized that the quantum of action, the Planck constant, is the fundamental constant of nature that sets the scale of the discrete steps that characterize reality as we know it.

The picture of mechanics that emerged was that a particle did not simply travel from A to B along a certain line at a certain speed. Instead, it was awkwardly represented by a wave function that gave the probability of its following this or that trajectory at this or that velocity. Erwin Schrödinger wrote an equation for the propagation of this wave function, and suddenly physics students had to master a whole new formalism. Paul Dirac cleaned up the formalism with his Dirac algebra [53] and went on to formulate quantum electrodynamics, QED, which Richard Feynman later said explained everything in nature except gravitation and nuclear phenomena [20]. Later still, QED was generalized to electroweak theory, quantum chromodynamics (QCD) was developed to describe nuclear phenomena, the underlying dynamics of these theories became known as quantum field theory, QFT, and all these quantum theories were used to build the Standard Model [50, 57].

The Standard Model is a magnificent achievement, surely the greatest human intellectual achievement in history to date. The physical platform it provides for our understanding of nature and reality is far and away the best we have. But it fails to accommodate general relativity, which remains our best theory of gravity, and so the problem of building a theory of quantum gravity is our next frontier challenge. Essentially, the fields of QFT define the distribution of mass-energy in a spacetime taken as a fixed background, whereas the geometry of spacetime in general relativity depends on the distribution of mass-energy. This is a classic chicken-and-egg problem, or perhaps another example of a strange loop.

In the perspective offered by quantum theory, things in our past determine a classical landscape, by and large, where facts are facts and systems have definite states. By contrast, things in our future are somehow up for grabs: systems are generally in superpositions of states, which somehow “collapse” into definite states when we interact with them. Seen through the lens of information theory, our past is an actual landscape determined by a large number of bits and our future is a virtual landscape defined by an unknown number of qubits. A bit is either 0 or 1, whereas a qubit is generally in a superposition of 0 and 1, like a fragile little bubble, which collapses or “pops” to 0 or 1 when we interact with it, for example when we measure it [5].

In my set theory model, a ranked mindworld is defined by a set of bits, whereas the next mindworld that is in the process of becoming appears as a vista of qubits. The process of stepping forward from mindworld to mindworld is a matter of popping the qubits to define the next rank of bits in our newly ranked mindworld. We might even define an existential question: "Does this mindworld exist?" A qubit poised between 0 and 1 codes the answer. If it pops to 1 and the world exists, with a rank, then another world-in-waiting is coming into being above it.

TIME 4: Spacetime

Logical worlds accumulate in a growing spacetime:

- Time and space appear to form a continuum because they seem inexhaustible for a discrete process.
- Given relativistic spacetime, worlds that are built up cumulatively by means of a discrete recursion seem to be embedded in a spacetime continuum.
- For philosophical reasons the antinomy of discrete versus continuous for spacetime may be irresolvable.
- Spacetime may be discrete in the small, at the Planck scale. Then each comprehended world is also discrete in the large.
- Only the universe of stacked logical worlds and the spectrum of virtual futures stretching to infinity will seem continuous.

Together, the Planck constant, the speed of light, and the gravitational constant define a fundamental set of units analogous to the conventional set defined by meters, kilograms, and seconds. The fundamental units of space and time are extremely tiny – but they are not zero. If we take these units seriously, spacetime is granular at what we call the Planck scale. This is the first step in developing a theory of quantum gravity.

In classical physics, spacetime is a continuum, infinitely divisible, with no minimum scale. This view of spacetime survives in modern QFT more by default than by choice. No one has yet worked out in sufficient detail what happens when we impose a finest granularity at the Planck scale. But work on this question is ongoing in the loop quantum gravity (LQG) community, the more famous members of which include Lee Smolin [52] and Carlo Rovelli [48]. Their basic idea is that spacetime is a network of binary links at the Planck scale. These links support the pattern of connectivity, for example in terms of causal relations, that implements the familiar properties of smooth spacetime at more macroscopic scales.

Within the family of approaches pursued in the LQG community, the work on causal set theory (CST) done by Rafael Sorkin and others excited me greatly in 2006. You can find more detail in my book *Mindworlds*, but the basic idea is that "causets" of events reflect the causal relations between those events, and the asymmetry of the causal relation (either A causes B or B causes A but not both) defines the arrow of time. An example of a causet for a set X is the set of events in the past light cone of X, reaching down to zero ABB.

The spacetime structure we can expect from such theories is discrete, indeed finite, reaching up only to the surface in the present moment where the past shades into the future. Spacetime is defined only for events that have already popped into existence, and from there on we face a complex manifold of virtual spacetimes in some kind of superposition. Early work in the causal dynamical triangulation (CDT) community suggests that a Feynman path integral over all possible spacetimes might return the geometry predicted by general relativity [3, 40]. For my money, some such LQG/CST/CDT approach to building spacetime is the second step in developing a theory of quantum gravity.

A more recent proposal that now excites me is that entanglement relations define the Planck network underlying spacetime. Entanglement is the most perplexing feature of quantum reality because it contradicts the principle of locality, and for this reason Einstein refused to accept it [1]. The principle of locality says that events A and B can only be correlated if a causal chain links them with an unbroken series of local links. By contrast, the quantum view is that systems can be, and indeed generally are, in entangled states such that remote events A and B in those systems show correlated properties even if no possible causal chain now links A and B locally. Experiments clearly confirm that such entanglements are pervasive in reality. The mathematical theory is clean and clear, and embedded already in Dirac algebra, and the only challenge is to make friends with the phenomenon, not as a bug but as a feature of reality.

Unfortunately, work in this field is still far too technical to gloss informally. For example, LQG theorist Paola Zizzi recently interpreted quantum spacetime using quantum computation and the holographic principle to generate a discrete de Sitter universe with a Planck time foliation such that each Planck pixel encodes one qubit [60]. This defines a mathematical duality between entanglement and spacetime geometry, but it’s hard to imagine.

My gloss on entanglement is that it shows spacetime growing, budding forth at the leading edge, to push apart disparate properties of things independently, so that not all the aspects of a composite system are separated at once. The pervasiveness of entanglement shows something more, namely that popping a qubit down to a bit can have huge consequences. If a qubit is entangled with a host of others, popping one can pop them all, nonlocally, willy-nilly, across the universe. For example, my observing the polarization state of a photon from a remote star will pop the polarization state of another photon entangled with it from birth but now many light years away. We cannot know in advance where these entanglements are, but they define a highly nonlocal network at the Planck scale that appears in quantum systems as entanglement and adds up on a macroscopic scale to our familiar spacetime, or at least it does if this vision pans out correctly.

For my money, again, some such theory embracing entanglement is the third and perhaps final big step in developing a viable theory of quantum gravity. By reducing the arrow of time to the logic of disentanglement, to the process of popping qubits down to bits, as if the course of history were a long march over a cosmic sheet of bubble-wrap, it would represent a complete revolution in our understanding of spacetime. But as you can see, all this is very much work in progress.

LIFE 1: Evolution

Generations of life forms reflect past environments:

- A living organism is the physical embodiment of a growing self.
- The organism grows into forms reflecting the unity of its sensorium and is realized as the organism processes input from successive momentary constellations of the phenomenal manifold.
- Generations of life forms thus reflect histories of involvement with their embedding worlds, where the features of those worlds manifested in the sensorium help interactively to shape the life forms.
- Different life forms compete in an evolutionary struggle to assimilate alien worlds and remain sovereign selves.

We whose selfish minds reflect a spacetime universe in which mass-energy is distributed in some interesting fashion are implemented as organisms on a biological platform built from proteins whose construction is specified by base sequences in genomes written on DNA molecules. The machinery in the platform evolved over billions of years in environments hosted by planet Earth. The organism the machinery builds has an ongoing unity that reflects the directed nature of the processes we experience as a selfish mind.

When Charles Darwin first formulated his theory of evolution by natural selection, he regarded the unit of selection as the organism [15, 17]. Since then, Richard Dawkins has argued persuasively that the real unit of selection is the gene, the functional unit in the genome [13, 14]. On this view, genes survive as functional patterns through successive incarnations in many species (for example, the homeobox gene has survived at least since the last common ancestor of fruit flies and humans) and cooperate with each other to build organisms as their temporary survival machines. In a software metaphor, genes are chunks of functional code and cannot be said in anything but a metaphorical sense to harbor a selfish lust to survive. They just do what they do, and ever more complex organisms result over evolutionary time.

The question of what constitutes the unity and identity of an organism remains unanswered in this story. My suggested answer is that it emerges in the phenomenology of a selfish mind. A human mindworld is a sophisticated construction, but primitive analogs of such minds should inhabit quite humble organisms. For any vertebrate organism, eating, mating, and similar behaviors generate sensory input to its central nervous system that must be orchestrated to generate action conducive to the survival of the organism. The orchestration of that inner phenomenology will naturally involve the emergence of an inner self with drives that urge the organism to behave as it does. A mind with a selfish architecture is thus only to be expected in an organism evolved though an ancestral history of natural selection.

Such evolution will naturally lead to organisms with minds that locate the boundary of the self at the spatiotemporal boundary of the organism. Caveats over kin altruism or having no concept of time aside, this has always been the default expectation in the evolutionary story. But with regard to civilized human beings, this looks more like an ideological assumption than a scientifically defensible premise.

The logic of the growth and development of a mindworld in an existentially challenging environment will naturally lead to the projection of an analog self-puppet or avatar within the mindworld, and this avatar will naturally attract most of the selfish interest of the organism hosting the mindworld. But the possibility of a radical epistemological rupture – a total surprise, say, as a predator sneaks up from behind – must always limit the depth of the identification of the organism with its avatar. Also, in a civilized human mindworld at least, my avatar is just one puppet among a large number of interdependent puppets in a highly organized environment, so much so that looking after the interests of my avatar alone would count as psychopathic or criminal behavior. For both of these reasons, no organism, least of all a human one, can rest content with its own mind game but must constantly be learning and adapting, replacing each timestamped mindworld with a new one as fast at its neuronet allows.

Once a mindworld is decoupled from the puppet self of the avatar within it, the logical way is clear to much bigger identifications. In human communities we all understand the majestic plural and its use to identify with a wide community, and we are increasingly familiar with the idea of identifying with the whole of life on planet Earth [47]. A wider identification, even a cosmological one, is natural [56].

LIFE 2: Cognition

Cognitive evolution is organismic epistemology:

- Evolution occurs at the cognitive level in mammalian brains.
- Competing resolutions of phenomenological conflicts result in sovereign interpretations of phenomena that shape the realization of alternative possible futures.
- The synthetic unity of apperception of the resulting self is reflected in a world with a specific physical constitution supporting a reigning interpretation at the cognitive level.
- Epistemology is the study of such cognitive development continued to the level of scientific theories and philosophies.

Organisms that reproduce by means of a mechanism that enables their properties to be inherited give rise to Darwinian evolution. Other kinds of evolution are similar. Mindworlds tend to be preserved within their successors, and ranked universal sets, which are their formal prototypes, are subsumed entire as proper subsets of the universal sets that succeed them. Contention at the boundary of a mindworld, as new facts are added and force changes elsewhere, suggests that mindworlds will be reproduced at later moments only in adapted form, and that adaptation will reflect the operation of an evolutionary dynamic, or indeed a dialectic, in which cognitive input-output cycles give rise to directed action in a changing environment.

For civilized human beings, mindworlds are largely cultural products that serve as the vehicles for transporting knowledge and ideas more widely through human history. As knowledge grows and ideas change, the mindworlds of the relevant people will grow and change accordingly, again in a dialectic for which we can in principle trace the logic down to an underlying set-theoretic model.

Just as in thermodynamics we can distinguish microstates from macrostates and use the distinction to define entropy, in a cultural theory of knowledge, or epistemology, we can distinguish microworlds from macroworlds, where a microworld is a specific mindworld hosted by some person at some time and a macroworld is a generic or envelope mindworld averaging over a more or less defined set of people over a more widely bounded time period.

Perhaps too we can define an analog of entropy for a mindworld using the relative number of people within some community who host that mindworld in their cerebral neuronet. We can even generalize the rise to a macro level by defining a hierarchy of macro levels, up to extremely general macroworlds such as the worlds of Islam or Ptolemaic cosmology or classical physics.

Continuing this line of thought, we might go on to define the new academic discipline of comparative "worldology" to evaluate mindworlds in relation to each other. Fifty years ago, Thomas Kuhn shook up the philosophy of science, as worldology might then have styled itself, with his concept of paradigms and paradigm shifts [36]. For him, scientific revolutions, such as the move from classical to quantum physics or from steady-state cosmology to big-bang cosmology, were characterized by paradigm shifts, where the respective mindworlds before and after were the paradigms. In such paradigm shifts, the logic of the respective mindworlds before and after can be relatively easy to define, so that the novelty involved can even be characterized, sloppily perhaps but still nontrivially, in terms of the thesis-antithesis-synthesis pattern of the Hegelian dialectic. Whether worldology at this level can be a fruitful discipline is moot, but I wouldn't write it off completely.

The merit of contemplating comparative worldology for a moment is that it focuses attention on the evident fact that any field of knowledge peaks in a topmost concept, a world, reflecting the synthetic unity of apperception of the selfish mind embodying the mindworld reflecting or containing that knowledge. The essence of knowledge, on this account, is its hierarchy of ever more general concepts, culminating in the unity of a world. This essential fact is the key to modeling such knowledge in some initial segment of the cumulative hierarchy in order to isolate its logic. Recalling that the self of the cognitive subject reflects such a world, the ultimate world of cosmology, notional and theory-laden as it may be, reflects a godlike mind that rises above the micro concerns of everyday folk. Perhaps we should say that such a godlike mind dissolves into nirvana, for no mind that relaxes in the cosmic bubble bath can resist dissolution.

LIFE 3: Control

Neuronets balance alternatives for motor control:

- In human brains, neuronets implement the logic of subjective worlds as well as their development in the sensorimotor interaction that results in ontic and epistemic progress.
- The coupling of neuronets to the physical environment of cognitive agents via the sensorium generates an ongoing crystalization of reality as a series of momentary worlds.
- In neuronets, sensory input causes electrochemical imbalances that the net then seeks to balance.
- As impulses flow through a neuronet and activate various logic elements, thought and action take shape.
- Ideally, an ongoing self-loop retains control of the unfolding process.

The dynamic logic of looping and growing mindworlds along a time-like dimension finds a remarkably close parallel in the physical operation of a cerebral neuronet. Our brains import sensory signals, filter them to isolate patterns and group them to locate conceptual outlines, and build models that can predict how such inputs might continue in future. If the models do so successfully, they serve as engines for generating motor outputs that can steer us, the organisms hosting the brains, along a trajectory that remains adaptive in evolutionary terms. By a process of trial and error, the models are refined and updated to optimize our trajectory and reduce the frequency of painful collisions.

This entire story works as well for an artificial neuronet (ANN) built into a robot body as for a wet brain in a human body. In both cases, the carrier signals for the input and output are essentially electrical. In our meat brains the signals are relatively slow electrochemical pulses, whereas in an ANN built using present technology they are digital blips conveyed by electrons, and in future ANNs they may be blips conveyed by photons. In any case, the key point is that an inner model is built and maintained to reflect the salient features of an external environment. The inner model forms a virtual reality in the sense familiar to digital gamers. A mindworld is a virtual reality, and we, the gamers, are avatars inside that reality – at least that’s the story our current technology paradigm invites us to tell.

The problem with that story, in a metaphor, is that somewhere the rubber has to hit the road. We have a direct interface with physical reality that impacts us whether the inner model accommodates it gracefully or not. The sensory input from moment to moment overrides the predicted input from the model – at least it should do, or we’re in trouble – and we feel a cognitive dissonance that reflects electrochemical imbalances at various key points in our cerebral mindfield. As our cortical circuitry resolves the dissonance into some kind of harmonious melody once more, a sense of being in control resumes, and we, the owners of that brain, go about our business again.

A cerebral mindfield is a pattern of electrical excitation distributed across the cerebral cortex that fluctuates in complex ways, like music, carried by radio-frequency electromagnetic waves. These patterns are detectable, in a rather crude way, by some modern brain-scanning techniques, and the general picture that emerges is that the overall character of the music reflects the various states of consciousness we may be in. The field of electromagnetic excitations across the cortex is the physical carrier of a mindworld, or at least it is in my more ambitious speculations on this topic (and in those of Jim Al-Khalili and Johnjoe McFadden [2], for example). Such fields consist of photons, in this case deep radio photons with frequencies in the decahertz range, and the suggestion is that within the packaging of a human body these photon fields give rise to the phenomenology we enjoy as the crowning glory of our conscious lives.

Photons are amazing things. In free space they travel at the speed of light, which in relativistic spacetime means they define what we call null geodesics along which time ceases to flow. If you imagine a photon as a tiny clock, it registers no time at all between emission at its source and absorption at its target, even if its target is half a universe away from its source. This conjures up an image of a cerebral mindfield as a timeless zone, a little moment of eternity, before its carrier photons decohere and a new moment begins to form. Given the photon frequencies in the mindfield, decoherence considerations plus the uncertainty principle suggest that a moment of specious present for the mind embodied in those briefly coherent photons might endure for hundreds of milliseconds. This corresponds reasonably enough with our observed phenomenology and suggests to me that some such mechanism may well be at play here. But the story quickly gets technical, and to say more in this essay would be out of place.

LIFE 4: Reality

Cosmology accommodates ultimate transcendence:

- Self and world reflect each other in an ongoing process of epistemo-ontic transformation with a set-theoretic logic.
- If this process can operate at the societal level, the resulting self-structures can assume cosmic proportions.
- For an individual who seeks to transcend limited forms of self, such cosmic possibilities can seem overwhelming.
- Self-transcendence is a physical process, and the Cosmos in which it occurs can be defined like any other world.
- We can define an envelope cosmology to embrace all our science so far and allow self-transcendence within it.
- We have no reason to try to limit the scope of scientific method.

A mindworld is a mathematical structure, or rather an information structure like a virtual reality. By contrast, a mindfield is a physical structure, perhaps a photon field playing over the cerebral neuronet. In an artificial mind, the photons of its mindfield might code the bits and qubits of its mindworld in a systematic way – although we can be sure that the coding in a human brain is approximate and haphazard, if any such coding can be identified at all. In either case, it will likely be a long time before science catches up with such coding and lets us read or write the codes in any effective way. This whole story is a hostage to future developments.

The more interesting claim for now is that cosmology, much like any other science, is modeled in a structure of worlds that bears a partly analog relation to the reality the scientific discipline purports to describe and explain. At some level, there is an isomorphism of structure between representation and reality, much as there is in a television image of a natural scene. In any mindworld that makes ambitious claims about its reality, there is likely to be serious dissonance, too, where the representation fails to do justice to the reality. In the conception of truth this claim invites, we are naturally drawn to the metaphor of our shooting for a target – the truth – and generally missing. This is the metaphor Karl Popper seemed to like, since it suggests that we are generally wrong, but the general drift of our attempts, in all probability, brings us closer to the truth.

In cosmology, the theory of everything, the chance of our hitting the target would seem to be vanishingly small, if not identically zero. The truth about everything recedes at least as fast as we can possibly approach it, which is the sort of outcome we should expect if we reflect carefully on Gödel's famous theorem about arithmetic. This theorem shows that a consistency proof for a theory big enough to contain arithmetic can only be formulated in a stronger theory, for which a stronger consistency proof would be required in turn, and so on *ad infinitum*. In the slogan I coined decades ago when I studied the theorem, truth outruns provability. It does so in mathematics, and therefore it does so in cosmology.

Yet cosmology clearly does advance as a science. Our increasing confidence in theorizing about our solar system, our galaxy, our big-bang universe, the multiverse, quantum gravity, and so on shows a clear ratchet toward stronger and more veridical theories. Their truth content, in a fairly safe sense, increases as we continue our research. In Popper's metaphor, our shots land closer to the target. Given the partly analog nature of our mindworlds, this suggests that our minds become ever better tuned to ever more comprehensive domains in reality. Our minds expand to universal dimensions and maintain some kind of grip on the truth as they do so. This is reassuring, even to humble human beings whose minds are mostly preoccupied with relatively trivial things. Whatever disappointments might befall us in an unknown future, we can aspire to cosmic consciousness as we pursue the aim of better understanding the Cosmos.

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