FQXi Essay Contest 2017
Wandering Towards a Goal: How can mindless mathematical laws give rise to aims and intentions?

Wandering Towards Physics:
Participatory Realism and the Co-Emergence of Lawfulness

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ABSTRACT

Q-Bism's champion Christopher Fuchs recently wrote: "Since the advent of quantum theory, (…) there has always been a nagging pressure to insert a first-person perspective into the heart of physics."[1] As a tribute to the "participatory universe" idea put forward in the late 1970's by John Archibald Wheeler, he proposes to call "participatory realism" this general way of dealing with the thorny issues of the interpretation of quantum mechanics. This article presents an approach I call "co-emergentism", which combines participatory realism and the hypothesis that abstract structures constitute the fundamental level of reality. In every day life, we experience the first-person perspective of being a conscious agent (with intentions, goals and at least apparent free will) in a community of conscious agents, embedded in a physical world that obeys strict (yet probabilistic) laws with implacable regularity. Co-emergentism proposes that, within the infinite, mostly chaotic and lawless "Maxiverse" of all abstract possibilities, abstract structures that correspond to conscious agents "resonate" with each other, and with abstract structures that correspond to stable, regular physical environments. This process delineates coherent domains within the space of all possibilities, and insures that most conscious observers that are sophisticated enough to run essay contests about the fundamental nature of reality find themselves in worlds that are surprisingly large, long-lived and extremely regular.

> No way is evident how physics can bottom out in a smallest object or most basic field or continue on to forever greater depths (…) [the] possibility presents itself that the observer himself closes up full circle the links of interdependence between the successive levels of structure.
>
> John Archibald Wheeler, *Genesis and Observership*[2]

In his 1979 essay "Frontiers of Time"[3], John Archibald Wheeler imagined a peculiar version of the game of twenty questions:

> About the game of twenty questions. You recall how it goes—one of the after-dinner party sent out of the living room, the others agreeing on a word, the one fated to be questioner returning and starting his questions. "Is it a living object?" "No." "Is it here on earth?" "Yes." So the questions go from respondent to respondent around the room until at length the word emerges: victory if in twenty tries or less; otherwise, defeat. Then comes the moment when we are fourth to be sent from the room. We are locked out unbelievably long. On finally being readmitted, we find a smile on everyone's face, sign of a joke or a plot. We innocently start our questions. At first the answers come quickly. Then each question begins to take longer in the answering—strange, when the answer itself is only a simple "yes" or "no". At length, feeling hot on the trail, we ask, "Is the word 'cloud'?" "Yes," comes the reply, and everyone bursts out laughing. When we were

> out of the room, they explain, they had agreed not to agree in advance on any word at all. Each one around the circle could respond "yes" or "no" as he pleased to whatever question we put to him. But however he replied he had to have *a* word in mind compatible with his own reply—and with all the replies that went before. No wonder some of those decisions between "yes" and "no" proved so hard!

In the regular version of the game, some word is selected before the questioner starts to ask questions. But in this version, the final word "emerges" from the interplay of all the participants. Of course, Wheeler envisioned this story as an allegory for the strange world of the quantum. As he goes on to explain,

> There was a "rule of the game" that required of every participant that his choice of yes or no should be compatible with some word. Similarly, there is a consistency about the observations made in physics. One person must be able to tell another in plain language what he finds and the second person must be able to verify the observation.

Can we read in this story even more than Wheeler intended, and suppose that the physical world itself emerges from the interplay of the participants in the "game of life"? It doesn't seem possible: if the participants owe their existence to the physical world that they inhabit, they cannot exist prior to it and cannot bring it into existence… unless one allows for a *strange loop*, like in those Esher drawings where two hands mutually draw each other, or where an ever-ascending staircase arranged in a loop comes back to its starting height. Strange loops are fun to contemplate in art and in playful philosophy, but surely, one cannot seriously consider using the idea as a solution to the riddle of existence?

And yet, the alternative is to satisfy yourself with a *straight* chain of explanation, starting with some principles that are taken as axioms. That's what standard "theories of the Universe" do. What kind of "tower of explanations" you wind up with depends on the axiomatic foundations you choose. If you are so inclined, you can take some God (or gods) as your foundation. Or you can be introspective, realize that everything you really know for sure about anything is what exists in your consciousness, and take "mind" as your foundation. If you put your faith in the objectivity of physics, you may take the laws of physics as your foundation. Even though these laws are not in their final form, they are sturdy enough, from a practical and pragmatic point of view, to build on them a very impressive tower. Our modern world of satellites, computers and cell phones is a testimony to the success of this approach.

Yet, from a deep conceptual and philosophical point of view, all these foundations suffer from a fundamental weakness: they do not seem simple and "self-evident" enough to serve as an ultimate, "rock-bottom" foundation—some deeper level seems required to explain them. God, at least in his more traditional incarnations, is a being more complex than the Universe: if you take Him as your foundation, you only bury the problem one level deeper, because now, you must explain where He comes from and why He exists. Mind (or consciousness) also seems to be a complex, sophisticated concept that might require some deeper level to justify its existence. As for the laws of physics as we know them today, they are clearly not truly fundamental (they are not even mutually compatible), although we can hope that a simpler unified law will eventually be discovered. Even then, this law would have some *arbitrary* characteristics, unless somehow it turns out to be the only logically possible physical law, which is an outcome that almost no one still believes possible. Since this law would not be a necessary, "self-evident" truth, its existence would need to be justified by some deeper level of explanation.

As we can see, finding a fundamental "ground of being" that is truly worthy of the name is quite a problem—we could call this the **hard problem of foundations**. If only "nothing" could be taken as the foundation of everything[4]… what could be simpler and more elegant, not to mention so, so Zen? Well, there might be a way to make "nothing" into a suitable foundation, by considering something that is equivalent to nothing: *the infinite ensemble of all abstractions.* An abstraction is something, like a circle

or the number 42, that exists without having to be embodied in a concrete way. Mathematics is the study of abstract structures, so we could speak instead of the *infinite ensemble of all mathematical structures*, or, more simply, "all-of-math". For those that have a difficult personal relationship with math that goes back to their school days, it might be strange (yet somehow comforting) to learn that all-of-math is equivalent to nothing. But it's true in a very real sense, because all-of-math contains, overall, *zero* information.[5] If you want to specify some subset of mathematics, you have to do it explicitly, and this description contains information (the bigger the subset, the more information you need to specify); but if you want to talk about the infinite ensemble of all abstractions (most of them never contemplated by any mathematician in history, of course), you can just say "all-of-math", which takes almost no time and contains essentially zero information! For me, the fact that abstractions are the most fundamental thing you can possibly imagine, and that the ensemble of all of them contains no information, makes them the ideal foundation for a theory of the Universe. I agree with science-fiction author Greg Egan when he says, "I suspect that a single 0 and a single 1 are all you need to create all universes. You just re-use them."[6]

The idea that our universe is nothing more than a mathematical structure "seen from the inside" has been called the **Mathematical Universe Hypothesis (MUH)** by Max Tegmark.[7] If the basic level of reality is an abstract mathematical structure, our universe just *has* to exist, since among all possible mathematical structures, there has to be at least one that corresponds to our world. Moreover, all mathematical structures that contain substructures that have the right properties to correspond to self-aware observers exist physically: it is the very fact that they are "perceived from within" by those self-aware substructures that makes them physical. Consequently, the MUH implies an infinite *multiverse* that contains every possible physical reality and generates every possible conscious experience: the **Maxiverse**.[8]

Several philosophers have argued that all possible worlds exist. For David Lewis, to make sense of logical statements about what could have happened in our world but did not, every possible world must be as real as ours.[9] For Robert Nozick, all possible worlds must exist on logical "egalitarian" grounds.[10] Peter Unger argues that an extreme rationalist should believe in the existence of all possible worlds, because in this case the whole of reality is less *arbitrary* than if only some worlds exist and others don't.[11]

Recently, Tegmark has updated the name of his theory to the **Computational Universe Hypothesis (CUH)**. A computation is a sequential abstract structure. Since the flow of time seems to be an inescapable aspect of conscious experiences, one can make an interesting parallel between the sequential nature of computations and the apparent flow of physical time. Physicists have a fondness for whimsical acronyms, so I cannot help but propose the **Infinite Set of All Abstract Computations (ISAAC)** as a name for the basis of the CUH. To respect rigorous mathematical nomenclature, this infinite ensemble should be called a *class* instead of a set, but it would spoil the acronym!

Suppose that the ISAAC is the basis of all existence, and that it generates the Maxiverse. The hard problem of foundations is solved, but we now run into another one: the **hard problem of lawfulness (HPL)**. If every possibility exists within the Maxiverse, irregular and chaotic worlds should greatly outnumber regular and predictable worlds like ours. Our type of universe would then be highly unlikely, which would make the Maxiverse hypothesis somewhat problematic—although David Lewis has argued that if you believe that every possible world exists, the lawfulness that we observe in our world is no more mysterious that if only one or some worlds exist.[12] Of course, one can try to solve the HPL by invoking the **anthropic principle**, the logical necessity that we observe a world regular enough to sustain our continuing existence. Somehow, this does not seem to be enough: our world is just *too* regular. Alexey and Lev Burov have argued that the observed extreme constancy of the fundamental constants of physics is hard to reconcile with the idea that our universe is a random sample within all the possible universes that could support our existence.[13]

To address the HPL, I propose to supplement the Maxiverse hypothesis with the **Co-Emergence Hypothesis (figure 1)**: within the ISAAC, abstract structures that correspond to conscious agents "resonate" with each other and with abstract structures that correspond to stable, regular physical environments. This process delimitates coherent, lawful domains within the abstract space of all possibilities, the regular world that we observe being one of them. By "resonate", I have in mind something similar to Wheeler's famous analogy of the Universe as a "self-excited circuit" **(figure 2)**. As an abstract principle that operates within the ISAAC **(figure 3)**, co-emergence is *atemporal*: it is not a process that takes place in time, since there is no "meta-time" with respect to which the ISAAC could change or evolve.

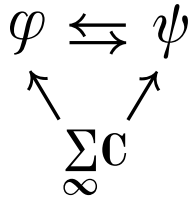


Figure 1. The co-emergence hypothesis: abstract structures that correspond to stable, regular physical environments (φ) and those that correspond to the experiences of conscious agents (ψ) "resonate" with each other and co-emerge within the infinite set of all abstract computations ($\sum_{\infty}$C).

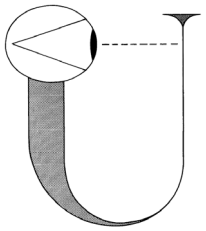


Figure 2. A symbolic representation of Wheeler's Participatory Universe: "The universe viewed as a self-excited circuit. Starting small (thin U at *upper right),* it grows (loop of U) and in time gives rise *(upper left)* to observer-participancy—which in turn imparts 'tangible reality' to even the earliest days of the universe."[14]

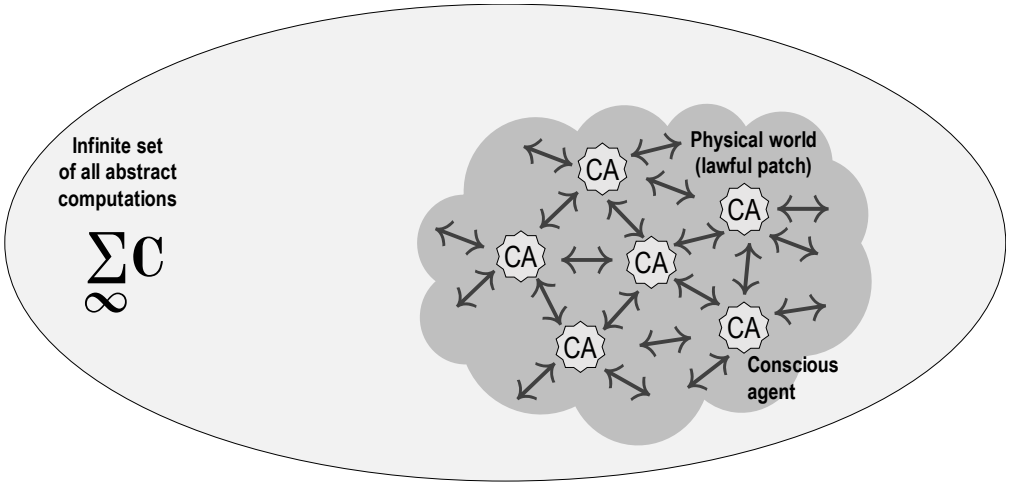
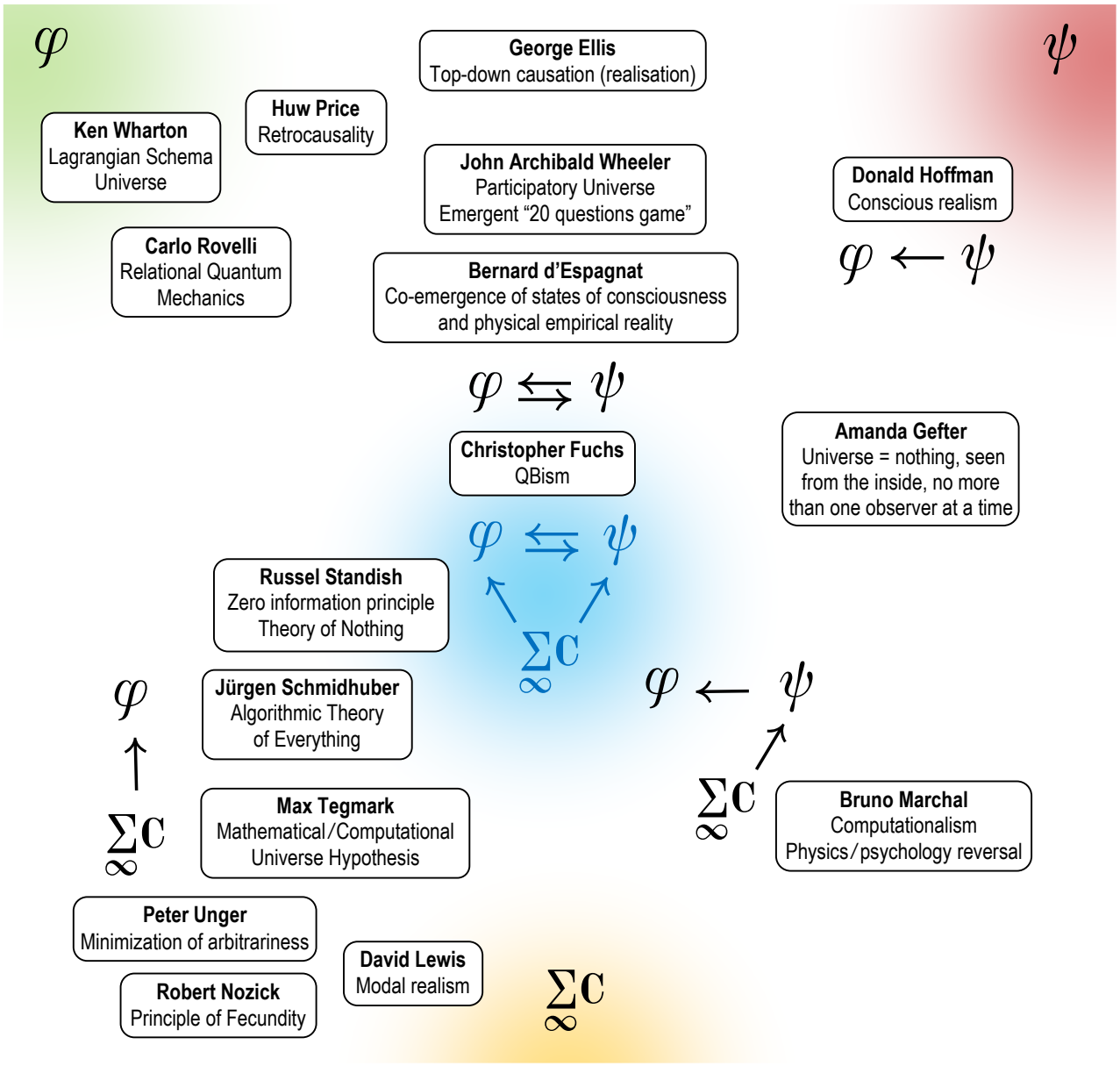


Figure 3. Co-emergence operates between several individual conscious agents (CA) and their shared physical environment, delimiting a "lawful patch" within the mostly chaotic space of all possibilities.

Co-emergentism has affinities with many ideas that have been proposed over the past decades as ground work towards the goal of building a physically and philosophically satisfying "theory of everything" **(figure 4)**. The term co-emergence itself has been used by Bernard d'Espagnat to describe the relationship between states of consciousness and physical empirical reality. However, for d'Espagnat, consciousness and physical reality do not co-emerge from the set of all abstractions, but from a "veiled reality" that "lies beyond our subjective abilities at describing".[15] Co-emergence has also some similarities to what Ian Stewart and Jack Cohen call *complicity*, the process by which "two separate phase spaces join forces to 'grow' a joint phase space that feeds back into both components".[16]

Figure 4. The co-emergence of co-emergentism.



Even though the ISAAC is atemporal, in the physical universes that exist within it, conscious observers perceive the flow of time: the concepts of causation and causality can be applied. For co-emergence to make sense, it is beneficial to extend the notion of causality to include both directions of time, hence the relevance of the ideas of Huw Price about retrocausality.[17] As noted by Ken Wharton[18], the Lagrangian formulation of physics, in terms of path integrals and stationary action, can offer valuable insights about the deep logical structure of our world: in a "Lagrangian Schema Universe", explanations need not always be in the Newtonian form "from t to $t + \mathrm{d}t$", which leaves room for two-way causality and co-emergence.

Emergence is usually understood in terms of properties of a system that exist at a higher level of description and have no equivalent at a lower level: one classic example is the *fluidity* of water, which has no meaning at the level of the individual molecules. In the co-emergence of a physical lawful environment and the community of conscious agents that observes it, emergence works both ways. Consciousness, with its power of agency and volition, emerges out of a physical level of description where interactions take place according to "mindless" laws, while the rigid laws that obey the physical

interactions are, in some real sense, an emerging consequence of the existence of a community of conscious observers that share between themselves a coherent story about a lawful and stable world. Current and future research on the topic of top-down causation (or "realisation"), by George Ellis[19] and others, can help in understanding the details of how co-emergence operates within the ISAAC.

My conception of co-emergence has been greatly influenced by the ideas of Russell Standish, himself elaborating on the work of Bruno Marchal[20] and Jürgen Schmidhuber[21]. In his book "Theory of Nothing"[22], Standish writes:

> Consciousness (…) exists entirely in the first-person perspective, yet by the Anthropic Principle, it supervenes on (or emerges out of) first person plural phenomena. (…) However, we also have the third-person world emerging out of consciousness (…) The Anthropic Principle cuts both ways—reality must be compatible with the conscious observer, and the conscious observer must supervene on reality.

The tension between an objective, third-person description of the world, and a subjective, first-person description, is of course at the heart of the difficulties physicists have been having, for almost a century now, to give a satisfying interpretation to quantum mechanics—especially to the "projection postulate" that links the quantum world, evolving unitarily according to the Schrödinger equation, and the classical world where we always observe a single outcome for a particular experiment. Of all the interpretations of quantum mechanics, QBism, a relative newcomer, "resonates" particularly well with co-emergentism. In QBism, every observer has his own wavefunction, which is a description of his own knowledge or belief about the system. According to QBism, quantum mechanics is a theory of the relationship between each observer and the physical world. In the words of Christopher Fuchs, one of the main proponents of QBism,

> Quantum mechanics is a single-user theory, but by dissecting it, you can learn something about the world that all of us are immersed in. (…) it's not that the world is built up from stuff on "the outside" as the Greeks would have it. Nor is it built up from stuff on "the inside" as the idealists (…) would have it. Rather, the stuff of the world is in the character of what each of us encounters every living moment—stuff that is neither inside nor outside, but prior to the very notion of a cut between the two at all.[23]

According to Fuchs, QBism, as well as related interpretations of quantum mechanics like Relational Quantum Mechanics, developed by Carlo Rovelli[24], should be labeled *participatory realism*, an homage to the "participatory universe" idea of John Archibald Wheeler.

In **table 1**, I consider six more-or-less "hard" problems of physics / metaphysics, and I contrast how co-emergentism addresses them with the way they can be addressed by general theories of the Universe based on other foundations. Unfortunately, within the scope of this article, there is not enough space to discuss in detail all the entries in the table. I have already mentioned the hard problems of foundations, lawfulness, and of the interpretation of the projection postulate in quantum mechanics. The problem of *free will and effective intention* is an interesting one. In every day life, we experience the first-person perspective of being a conscious *agent*: we have goals, act with intention and have an impression of free will. We believe that our goals, intentions and willful actions have an effective causal impact on what happens in the world. Of course, in most theories of the Universe, if we consider the whole of reality and we do not allow for a "meta-time" with respect to which this "whole" can change or evolve, our goals, intentions and free will cannot be *globally* meaningful, even if they *locally* mean something to us. However, in co-emergentism, the properties of the local lawful physical patch that conscious agents find themselves in is co-determined by the actions of the agents, so one can argue that goals, intentions and free will, even if they are still globally meaningless, somehow acquire more significance.

Table 1. Hard problems and where to find them

Problem of	**God first**	**Mind first**	**Physics first**	**Math first**	**Co-emergentism**
Foundations What is the fundamental level of existence?	Moves the problem one level deeper: what explains God's existence?	"Mind" might be too complex to be the fundamental level	Why these laws? Why these initial conditions?	Easy! Math is abstract, abstractions simply are	The infinite set of all abstract computations
Lawfulness Can we explain why our world obeys laws with such implacable regularity?	God: "I am the law!"	If you start with sane mind(s), you get a lawful world… but what about insane minds?	Easy… if you take for granted the laws of physics	Hard problem! If every possible world and conscious experience exists within "all-of-math", shouldn't most be chaotic?	Lawfulness is a local "resonance" defined by the interplay of conscious agents and their physical environment
Free will and effective intention Do our goals, intentions and impression of free will have an effective causal effect on what happens?	God allows it if He so pleases	For all we know, free will and the ability to act intentionally towards goals might be a basic attribute of consciousness	In any real sense, probably not (and quantum randomness does not help), but you can console yourself with compatibilism	No, because no matter what, everything happens to some version of you in the Maxiverse anyway	Might be locally significant within our co-emergent "lawful patch", even if globally, everything still happens anyway
Interpretation of the projection postulate How does the quantum wave-function "transition" to the observed classical world?	Maybe God made quantum mechanics to annoy physicists, or keep them occupied forever	The problematic "intrusion" of the observer in quantum mechanics makes "mind first" more believable	It's been almost a century and we still don't know!	Same problem as "physics first"	The problematic "intrusion" of the observer in quantum mechanics might be a sign that co-emergentism is on the right track
Delusion Can we know that the world we observe in our waking lives is not a charade or a prank?	A "fair-play" God would not allow his creatures to be deceived (Descartes' argument)	A conscious experience can never be *wrong* in itself	Simulation and Boltzmann brain problems	Same problem as "physics first", exacerbated by the intractable measure problem in the infinite Maxiverse	If you try to push your reasoning too far away from your observed reality, it may no longer apply
Solipsism Can I be reasonably sure that I share a world with other conscious beings?	If God does not deceive us, there are other conscious beings in the world	Always a possibility… maybe we are all one mind anyway	If we are not deluded, other humans, being physically identical to me, should equally be conscious	In all-of-math, there are isolated structures that are effectively "solipsistic minds", but their proportion is hard to evaluate (measure problem)	The lawfulness of the physical environment co-emerges via the relationship between conscious agents, even if each conscious agent has his own irreducible viewpoint

The *problem of delusion* would deserve an article of its own. The possibility that "deluded" observers (simulated beings within the computers of advanced civilization, or freakish "Boltzmann brains" fluctuations) outnumber "non-deluded" ones has recently kept some physicists awake at night. In the Maxiverse spanned by the ISAAC, there are of course an infinite number of deluded observers, and an infinite number of non-deluded ones. But if co-emergentism is true, what really matters is the immediate, local relationship between the community of conscious observers and the physical reality they observe. In **figure 3**, if you move too far out, the cloud that symbolizes our lawful patch dissolves into the relative chaos that characterises most of the ISAAC: physics becomes indeterminate, or most likely simply irrelevant. Could it be that, when we worry about the proliferation of deluded observers, we try to push our reasoning too far away from our observed reality, into a realm where it no longer applies? In the same way, could the dead-ends we have been encountering over the past decades in fundamental physics (the failure to unify quantum mechanics and general relativity, the proliferation of solutions in the landscape of M-theory) be interpreted as signs that we are nearing the edge of our patch of lawfulness in the space of all possibilities?

The *problem of solipsism* would also deserve an article of its own—in a form given "new life" by the recent developments in physics, like QBism and the black hole firewall paradox.[25] No sane physicist actually argues that he is the only conscious being in the universe. It's just that some fundamental coherence problems arise when we try to combine the first-person viewpoints of different observers into a single third-person "truly objective" reality. It is as if physics is trying to tell us that the world arises out of the point of view of single observers, even if they do in the end form a community that observes a single unified reality **(figure 5)**. Of course, elucidating the relationship between first-person singular, first person plural and third-person point of views is of crucial importance if we hope to clearly articulate the meaning of co-emergentism.

Figure 5. You drive alone, at night, on a desert road. The sky is full of stars. Suddenly, you see a sign by the side of the road…

For now, co-emergentism is only a working hypothesis. Like many speculative hypotheses concerning the foundational questions of existence, it hasn't yet reached the point where it can claim to have strong results or to make detailed predictions. In other words, it does not have a "shut-up and calculate" aspect that can provide reasonably comfortable day jobs for physicists. But research continues, and things might change. Donald Hoffman has been exploring a working hypothesis he calls *conscious realism*: he takes consciousness as the ground of existence, and is trying to make physics emerge out of the interaction between conscious agents, by applying a generalized abstract form of the principles of natural selection.[26] It is an ambitious enterprise, but if it succeeds, it could provide a starting point for developing a fully-fledged theory of how conscious agents can co-emerge alongside their environment, and make their little corner of the Maxiverse a safe, cozy place to call home.

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