Is the string landscape distributive in the universe

and might it manifest a Peano cosmic consciousness?

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A consequence of 10d supersymmetric string theory is the existence of a universal subspace called the Calabi-Yau Compact Manifold (CYCM) which is composed of a 3D array of discrete units of 6d compactified space. The recent astronomical evidence that Sommerfeld's fine-structure constant varies slightly across the visible universe (from north to south in an Earth perspective) suggests that the flux windings in the discrete 10^-30 cm diameter CYCM units may vary similarly across the universe. String theorists estimate that the flux has 10 quantum states while winding through the 500 or so holes in each CYCM unit, so that there are about 10^500 possible windings, the so-called string landscape. Such a large number is more than enough possible windings to fill many good size universes with distinct CYCM units. If the discrete and distinct CYCM units are also numerable, they may have the properties of a Peano arithmetic and possibly manifest an invisible emergent collective cosmic consciousness that permeates the entire universe, separate from human physical consciousness.

Key words: string theory, string landscape, fine-structure-constant, Calabi-Yau compact manifold, Peano arithmetic, cosmic consciousness, mind/brain duality.

"all things not forbidden are mandatory"- Murray Gell-Mann

Introduction

It certainly is a leap of faith to believe in a connection between metamathematics (or mathematical logic) and consciousness. Yet that is exactly what some philosophers, namely John Lucas, Douglas Hofstadter and David Chalmers, seem to be claiming, as well as of course scientist Sir Roger Penrose and even mathematician Kurt Gödel. Gödel's Incompletenes Theorems are considered to be the greatest achievements of metamathematics and the connection to consciousness can be traced back to those theorems. Nevertheless, the actual connection is a postulate supported at most by intuition and circumstantial evidence.

One might suppose that the connection is by way of information. Both consciousness and information do not seem to be material. However there exist mathematical theories of information but not consciousness. In this regard Gödel's Incompleteness Theorem (which says that for Peano arithmetic, the arithmetic of positive integers, there will be "true" statements that cannot be derived from its axioms) in some sense goes beyond mathematics because the "true" statements appear like magic. Is consciousness like magic? Perhaps.

In 1951 in a Gibb Lecture at Brown University, Gödel extended his thinking to the human mind: "So the following disjunctive conclusion is inevitable: Either mathematics is incompletable in this sense, that its evident axioms can never be comprised in a finite rule, that is to say, the human mind (even within the

realm of pure mathematics) infinitely surpasses the powers of any finite machine, or else there exist absolutely unsolvable diophantine problems of the type specified"[Lucas(1996)] (ie., Diophantine problems have only integer solutions. See Wiki: Truth). Lucas believes that Gödel considered the first statement to be more likely. So Gödel apparently believed in a connection between metamath and the human mind, if not human consciousness.

It is beyond the scope of this paper and admittedly beyond my understanding to delve into Gödelian logic, which seems to be self-referential proof by contradiction, except to mention that Penrose in *Shadows of the Mind*(1994), as confirmed by David Chalmers(1995), arrived at a seemingly valid 7 step proof that human "reasoning powers cannot be captured by any formal system". Penrose(1996) sums up his position with this remark: "But the very force of Gödel's logic was sufficient to turn me from the computational standpoint with regard not only to human mentality, but also to the very workings of the physical universe." Penrose uses this as a basis of non-computational quantum collapse theory for human physical consciousness in *Shadows.* But this paper is more about the very workings of the physical universe.

Still one bothersome aspect of the whole argument 'that human consciousness must be non-computational' is that it is based on Peano arithmetic. Yet there is no evidence that brain neurology has Peano properties. In my humble estimation, in order for any system to be characterized by Peano arithmetic, each of its elements must be discrete and distinct, and collectively capable of being counted (numerable). I do not see how the human brain could have such properties. However, it seems that the universe may.

The Shape of Inner Space

An underappreciated consequence, if supersymmetry string theory were true, is that this universe is inhabited by an invisible crystalline subspace. This subspace, called the Calabi-Yau Compact Manifold CYCM, is an "inner space" in the sense that it is inside everything including every particle of physics. Professor Shing-Tung Yau, the head of Harvard's Math Dept., describes the CYCM at length in his recent book "The Shape of Inner Space(2010)". He has made it legitimate to think that the nature of our universe includes an invisible subspace that contains the laws of physics.

According to S-T Yau this invisible subspace is composed of a discrete 3 dimensional array of fairly close-packed, roughly spherical elements of curled-up compactified dimensions, the 6 extra dimensions of 10d superstring theory. On the scale of things the compact scale lies between the string scale and the Planck scale. Each CYCM unit is about 1000 Planck lengths across whereas electrons, quarks and strings are some 12 orders-of-magnitude larger and the atomic scale yet another 6 orders-of-magnitude [Wiki: Orders-of-Magnitude(length)]. As a result particles at the string scale each contain about 10^{36} CYCM units and each CYCM unit contains about 10^9 Planck unit volumes. Atoms each contain 10^{54} or more CYCM units.

In his book Yau says that each CYCM unit is a complex inner connected ball of 6 dimensional curved membranes that contains about 500 topological holes. A constraining flux winds through all these holes. Yau explains that the so-called 'String Landscape' comes from the assumption that each line of flux might have 10 quantum states. The conventional thinking is that the CYCM therefore has 10^500 possible windings and as many different possible universes assuming a unique winding throughout each universe. This of course assumes that the laws and constants of physics depend on the flux windings.

It is unconventional to think that the windings might vary within a single universe. Yet that is precisely what the astronomical measurements of Sommerfeld's fine-structure-constant (~1/137) seem to suggest: "Observations of quasar spectra from the Keck telescope suggesting a smaller value of the fine structure constant, alpha, at high redshift. A new sample of 153 measurements from the ESO Very Large Telescope (VLT), probing a different direction in the universe, also depends on redshift, but in the opposite sense, that is, alpha appears on average to be larger in the past" [Webb (2010)].

Now if the fine-structure-constant alpha were smaller (or larger) in every direction one could claim the alpha was aging. But alpha varies from minus to plus about its average value across the universe. So the physics of inner space is most likely variable in space rather than time. But then we only see a very small slice of the whole universe and the generalization that physics varies monotonically across the whole universe may be unfounded.

The Consciousness of Inner Space

We argue that each discrete CYCM unit throughout the entire universe may be distinct and numerable such that they may be described by Peano Arithmetic. Here we are assuming that what makes Peano arithmetic collectively so powerful and creative- able to represent phenomena of extreme complexity- is that each of its elements, the natural integer numbers, are distinct. If so the Compact subspace may manifest a form of consciousness based on emergent, non-computational and non-deterministic natural processes. The argument is based on extensions of Gödel's Incompleteness Theorem that consistent-system processes with Peano properties must admit strong emergent phenomena that cannot be derived from fundamental axioms or principles of the system.

The development of this argument occurred in stages. To begin with "In 1931, Gödel had taken it [system requirements for incompleteness] to be a version of simple-type theory over a number-theoretical base [as in the book *Principia Mathematica*], but he soon weakened that to a form of the first-order system of Peano Arithmetic" [Feferman(1996)]. (Others have suggested that even Robinson Arithmetic may be incomplete, but that is controversial). Gödel extended such thinking to the human mind in 1951 as mentioned above.

Next in 1961 in an essay *Minds, Machines and Gödel*, Oxford philosopher John Lucas suggested a Gödelian basis for free will and mathematical insight. In 1977 Douglas Hofstadter in his book *Gödel,Escher,Bach* related Gödel Incompleteness to the unpredictability and complexity of strong

emergent behavior. However, he offered a reductionist explanation of human consciousness and human intelligence. He regarded those processes as self-referential but only weakly emergent.

From Wiki-Emergence: "Weak emergence describes new properties arising in systems as a result of the interactions at an elemental level… [whereas regarding] strong emergence, Mark A. Bedau observes: "Although strong emergence is logically possible, it is uncomfortably like magic. How does an irreducible but supervenient downward causal power arise, since by definition it cannot be due to the aggregation of the micro-level potentialities? Such causal powers would be quite unlike anything within our scientific ken. This not only indicates how they will discomfort reasonable forms of materialism. Their mysteriousness will only heighten the traditional worry that emergence entails illegitimately getting something from nothing."[Bedeau(1997)]"

Then in 1989 in *The Emperor's New Mind* Sir Roger Penrose argued that consciousness must be a non-computational process, but emphasized collapse of the quantum wavefunction. In *Shadows of the Mind*(1994) Penrose elaborated his biological wave collapse concept and also presented a mathematical Gödelian argument for human consciousness that brought criticism [Penrose(1996)] from mathematicians and philosophers, and considerable discussion of the validity of the argument as it applies to human consciousness. But he and David Chalmers seem to have agreed on a correct 7 step Gödelian argument based on human reasoning and contradiction. I am skeptical that argument because neurology seems to lack "Peanicity". For completeness, here is a concise rendition of that 7 step argument [Chalmers(1995)]:

(1) Assume my reasoning powers are captured by some formal system F (to put this more briefly, "I am F"). Consider the class of statements I can know to be true, *given* this assumption.
(2) Given that I know that I am F, I know that F is sound (as I know that I am sound). Indeed, I know that the larger system F' is sound, where F' is F supplemented by the further assumption "I am F". (Supplementing a sound system with a true statement yields a sound system.)
(3) So I know that G(F') is true, where this is the Gödel sentence of the system F'.
(4) But F' could not see that G(F') is true (by Gödel's theorem).
(5) By assumption, however, I am now effectively equivalent to F'. After all, I am F supplemented by the knowledge that I am F.
(6) This is a contradiction, so the initial assumption must be false, and F must not have captured my powers of reasoning after all.
(7) The conclusion generalizes: my reasoning powers cannot be captured by any formal system.

David Chalmers, Hofstadter's student, introduced the concept of the "hard problem of consciousness" in his book *The Conscious Mind: In Search of a Fundamental Theory*(1996) and discussed emergence. However, Chalmers explicit statement that the only 'strong emergent process' is 'consciousness' is found in a chapter "Strong and Weak Emergence" in the book *The Re-emergence of Emergence*(2006): "Strong emergence has much more radical consequences than weak emergence. If there are phenomena that are strongly emergent with respect to the domain of physics, then our conception of nature needs to be expanded to accommodate them. That is, if there are phenomena whose existence is not deducible from the facts about the exact distribution of particles and fields throughout space and time (along with the laws of physics), then this suggests that new fundamental laws of nature are needed to explain these phenomena." He is essentially saying the physics is incomplete and that a new

ingredient is required. For example, quantum gravity is a new ingredient that Penrose introduced in *Shadows*.

In this paper I propose that string theory may also qualify as a new ingredient and that it possesses sufficient richness to support the Gödelian argement. To recapitulate, I postulate that the requirements for the Compact Manifold to manifest Peano Consciousness is that each discrete (10^{-30} cm. dia.) CYCM unit must be distinct and numerable. Small variations of neighboring units would make them numerable in agreement with astronomical observations.[Webb(2006)] The 10^{500} or more ways that flux in 10 quantum states can weave through the 500 topological holes in each CYCM unit provides more than ample numbers for every unit in the space of the universe to be distinct.

Since the visible universe is 3×10^{80} cubic meters, the number of Planck volumes in it is about 10^{185} [Ruquist(2008)] or the number of CYCM units is 10^{175}. The human brain contains over 10^{90} CYCM units. The number 10^{500} is so large number that if every CYCM element were distinct in every universe, about 10^{325} of our visible universes could be filled with distinct elements. On the other hand, if the flux had only 2 quantum states, the $2^{500} = 10^{150}$ possible windings are not even enough to fill our visible universe with distinct units. The actual size of the whole universe is of course orders of magnitude larger. Even so it would appear that the flux cannot be binary. That the array of these CYCM units, being in 3 space dimensions rather than a 1 dimensional arithmetic, may also contribute to their collective consciousness- an interesting problem.

For what it's worth, it seems to me that emergence and consciousness are not exactly the same. Rather the realm of emergence borders the realm of pure consciousness and separates it from the realm of mathematics and physics, and that downward causation may connect all three. In philosophy 'downward causation' is the opposite of reductionism in the sense of self-organization at the highest levels is independent of the elements of the system. According to Hofstadter(2007) Gödel had to work through 46 stages or levels to prove his Incompleteness Theorems..

In addition 'strong emergence' is a more inclusive category than a whole number theory such as Peano arithmetic because there may be many systems that can represent phenomena of such complexity that it may be self-referential. In fact Peano arithmetic may be the weakest math system that is powerful enough to be self-referential. Nevertheless, Peano arithmetic is sufficient to mimic any pattern however complex including the laws of physics and the weakly emergent laws of thermodynamics and fluids, chemistry and biology, and perhaps even psychology. But can number patterns mimic the patterns of reasoning? Is self-referentiality the basis of consciousness or is this all just circumstantial evidence for a connection between math and consciousness?

The Power of Inner Space

At this point one could claim omnipotence for the CYCM since it apparently contains the laws of physics and may consciously control all particle interactions. On the other hand all physical particles could have

some degree of cosmic consciousness and the ability to select quantum superpositions. The CYCM units are so infinitesimal that about 10^{52} of them would fill an electron volume at the Lorentz radius $(3/10^{13}$ cm)- ample numbers to provide for a Peano Arithmetic. Therefore in agreement with at least one aspect of Bohm Quantum Mechanics, particles may be conscious.

However, Bohm contends that consciousness is exhibited when groups of particles are in the same quantum state which is particularly true for a Bose-Einstein Condensate BEC. This means that bulk matter in a non-coherent state may be effectively unconscious[Alfred(2007)]. Bohm contends that Standard Model particles "easily lose their property of consciousness when they become entangled with other particles and decoherence sets-in".

I have read that quantum waves exist on strings. However in my limited exposure to quantum theory, quantum waves appear to be a volume effect. Therefore I suggest that quantum waves exist on the CYCM subspace and that in the Bohm sense quantum waves may be conscious. But I expect that the CYCM consciousness controls the waves and therefore controls the selection of which waves become reality. Particle consciousness may not be significant.

Bose-Einstein Condensates (BECs) are a different story. They may be separately conscious from the CYCM. The particles in a BEC are discrete, coherent and all identical; so they are not numerable and would not manifest Peano consciousness. Yet it is thought by Bohm and others[Alfred(2007)] that BECs exhibit consciousness on their own. I suspect that this belief comes from the fact that all entangled particles in a BEC or across separated BECs (even of differing kinds of particles) share the same quantum waves and therefore exhibit collective behavior. But I think that purely collective behavior is insufficient for consciousness.

Perhaps the CYCM, also having BEC properties, might be conscious even if its units were not numerable. After all the CYCM is a precipitate from space and presumably its units are motionless which is what manifests a BEC. On the other hand, if the units of CYCM are numerable, then they are mathematical and programmable, just what a higher power in a higher space might desire. My suspicion is that the CYCM is a BEC only in the sense of being frictionless and capable of instantaneous communication.

Discussion

The background of these ideas came from an effort to find an argument for reality where our universe would contain just one world rather than "many parallel worlds". The Many Worlds Interpretation MWI of quantum theory, seemingly believed by all big name physicists except Penrose, is deterministic and lacks free will and the need for conscious choices. A cosmic consciousness could select which quantum superposition becomes real and therefore result in a single world within each universe. But a source for such a cosmic consciousness was needed.

Sir Roger Penrose following Kurt Gödel's lead provided a source for such consciousness. In fact he provided two: one mathematical based on Peano Arithmetic, suitable for cosmic consciousness; and with Hameroff a physics method, based on quantum-gravity effects in cell microtubules, suitable for neurology-based physical consciousness. N.B., the two methods reinforce the concept of mind-brain duality. My contribution to all this is to suggest that the units of Calabi-Yau Compact Manifold might be amenable to Peano arithmetic whereas human and animal neurology seems to lack "Peanicity"..

This hypothesis differs only slightly from Hameroff's suggestion that a BEC proto-consciousness exists at the Planck scale rather than that the Compact scale. How the Compact scale physics correlates or interacts with Planck-scale virtual-particle physics is of interest, but beyond the scope of this paper, except to note that the string scale is 12 orders larger than the Compact scale and 15 orders larger than the Planck scale. Then if virtual particles are string sized, which seems necessary, the controlling consciousness is likely at the Compact scale.

Even so it is not clear that Peano arithmetic is conscious. A key remark in Hofstadter's latest book, *I Am a Strange Loop* (2007), is instructive: "Just as the richness of whole numbers gave PM [*Principia Mathematic*(1927)] the power to represent phenomena of unlimited complexity and thus to twist back and engulf itself via Godel's construction, so our extensible repertoires of symbols give our brains the power to represent phenomena of unlimited complexity and thus to twist back and to engulf themselves via a strange loop". This is an argument by way of analogy that I do not find acceptable. Whole numbers are not analogous to symbols. If anything, whole numbers are a downward causation from symbols. In addition, human and animal neurology does not seem to have the discrete, distinct and numerable properties of whole numbers.

Many have hypothesized that the brain contains one kind of BEC or another. But physical BECs are too simple to be capable of representing complex phenomena. So where do these symbols come from that are integral to our physical consciousness? I speculate that the symbols are a property of the human mind in a mind-brain duality and that the function of BEC entanglement is communication between mind and brain. Perhaps when Gödel said in the 1951 Gibbs lecture at Brown that "the human mind (even within the realm of pure mathematics) infinitely surpasses the powers of any finite machine" he intuited that the mind part of the mind-brain duality was based in whole number metamathematics.

Conclusion

The import of this paper is the conjecture that a cosmic consciousness may exist on the basis of the Calabi-Yau Compact Manifold of 10 dimensional supersymmetric string theory having discrete, distinct and numerable elements. This of course assumes that string theory is a valid theory of nature including the existence of supersymmetry and extra dimensions that compactify. Moreover this paper assumes that these elements collectively are a mathematical system as strong or stronger than first-order Peano arithmetic. Finally that such a system by way of Gödelian analysis is an adequate model for the selection of quantum superpositions as well as the symbols and ideas of the human mind.

My intuition is that Gödelian emergence separates physical creation from pure consciousness and that physical creation is the downward causation from consciousness. I regard emergence as the shadow of consciousness. So I do not claim that the realization of a whole number system in nature is consciousness. Consciousness is more fundamental than emergence. But rather that Gödelian emergence provides some understanding of where the symbols and ideas that we all experience in the conscious brain come from.

I also conjecture that the invisible human quantum mind and the visible physical classical consciousness of the brain communicate by way of BEC entanglement. Therefore a physical BEC that pervades the brain is required. If so, the symbols and ideas that are developed in the mind (using the rich representational capability of whole number theory to categorize sense data) and the sense data itself are therefore equally available to both the conscious brain and the quantum mind. Such a mind/brain model is consistent with Hofstradter's reductionistic and weakly emergent brain consciousness. However, I attribute Gödel's human mind, which "infinitely surpasses the powers of any finite machine", to the strongly emergent power and creativity of the 10^{90} discrete, distinct and numerable elements of the Calabi-Yau Compact Manifold within the human brain.

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