How to set goals in a timeless quantum Universe

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Abstract. Aims and intentions as pertaining to conscious agents are defined in a temporal, classical perspective onto the Universe. In this essay we contrast this temporal, classical perspective with a timeless and fundamental quantum reality and argue that these points of view correspond to philosophical notions of "becoming" and "being". These realms can be identified both within physics as well as within psychology. We speculate that the relations between the corresponding realms in both fields are non-trivial and raise some of the most fascinating fundamental questions that could link the understanding of consciousness with fundamental physics.

1. Introduction

How can mindless mathematical laws give rise to aims and intentions?

It often seems to be that the things most intimate to us are the most difficult to explain. The Australian philosopher David Chalmers has made this point about consciousness – and has consistently dubbed the problem how to explain consciousness "The hard Problem" [1]. Aims and intentions are definitely bound to intelligent agents having conscious awareness of their environment. Similarly, the notions of time and a definite, classical (as opposed to quantum) world are necessary prerequisites for purpose and intention. There is no dynamics without time and the setting of goals makes no sense in a Universe of mere potentialities.

In the following we discuss a concept that arises in both modern physics and psychology: the notion that time, mind and classical reality are emergent properties that arise as a consequence of the factorization of the Universe into an observing self, an observed object and an unknown environment. This view has fascinating consequences: both in physics as well as in psychology.

Already at the dawn of Greek philosophy, where Heraclitus was arguing that "No man ever steps in the same river twice", his contemporary Parmenides asserted "Change is an illusion". In spite of these seemingly oppositional world views, both philosophers agreed that the Universe is an all-encompassing unity, that on the most fundamental level "All is One".

This suggests that the world views of Heraclitus and Parmenides correspond to complementary perspectives rather than ontologies[1] : While Heraclitus focussed on the temporal, "dionysian" "realms of becoming" (Friedrich Nietzsche understood "dionysian" as "eternal lust of becoming"), Parmenides focussed on the transcendental, atemporal or "apollonian" aspect (the

[1] Compare this idea to Lee Smolins opposing suggestion of a fundamental role for time in Nature, a fact which would have to be taken up in a future theory of physics [3].

greek god Apollon was understood as a personification of unity – "A-pollon" means "not-Many" – in Pythagoreanism and Platonism). Frank Wilczek has coined these different perspectives as "God's eye" (the outside view onto the entire spacetime) versus "ant's eye" (the individual experience along a spacetime trajectory or "worldline") view in the context of Relativity. These notions resemble intriguingly the "bird" and "frog" perspectives Max Tegmark and H.D. Zeh speak about in the context of unitary quantum mechanics which raises the idea of a deep connection.

To understand how things such as aims and intentions can arise from mindless fundamental physics we first have to understand what the fundamental reality is. This is no easy task, since nobody knows yet how physics on the fundamental level really looks like. Is it described by string theory? Or by loop quantum gravity? Is it something totally different? In this essay we take a pragmatic stance and argue that fundamental physics is described by a microstate in the sense of statistical mechanics. Or in other words: the concepts of fundamental physics will have vanishing entropy.

2. Properties of the Quantum Universe

Ironically, the view that the Universe is a single, all-encompassing unity carries the misleading name "Many-Worlds-Interpretation" in physics. To understand this point, one has to realize that there are two different parts to quantum mechanics:

First, the unitary and deterministic evolution of the quantum state, described by a Schrödinger-type equation, which is generally accepted. And second, the quantum measurement process, which is still the topic of heated debates. While the quantum state describes the complete knowledge about the system under consideration, it does not, in general, unambiguously determine the outcomes of measurements. The reason for the indeterministic outcome of measurements is that the system under consideration is usually not in one specific eigenstate – a state corresponding to a specific measurement outcome – but in a "superposition" of various eigenstates. A popular example is the infamous Schrödinger cat existing in a superposition between being alive and dead. In other words, classical reality emerges when a state vector corresponding to a superposition of various eigenvectors gets reduced to (or projected onto) a single eigenvector of the measurement observable.

While there still exists no consensus about the entire process of how this state vector reduction occurs, at least some aspects of the measurement process, which are based on the phenomenon of entanglement, are unchallenged.

In general, when two subsystems interact and constitute a composite quantum system, the properties of the subsystems will be strongly correlated albeit each individual property being completely unknown. As an example, a composite system of two states can have total spin zero, meaning that if one constituent systems spins clockwise the other sub-system has to spin counter-clockwise and vice versa, while the spin direction of each individual subsystem is absolutely unspecified in a maximally entangled state.

In the measurement process, the object system gets entangled with the measurement apparatus or observer. If the object system was in a superposition before the measurement, after the measurement has been performed the combined system of object and apparatus/observer will be in a superposition as well, superposing the various possible eigenstates of the object system (dead cat versus live cat, for example) with corresponding observers experiencing this particular state as a measurement result. This phenomenon allows one to interpret the measurement process as follows: the original quantum state of the combined system (object system + measurement apparatus) has split into various different, mutually excluding branches or realities. If the apparatus is understood as observer the experimentalist will find herself within one of the branches and will not experience any alternative realities. These alternative realities correspond to the "infamous" Everett branches, "Many Worlds" or "Many Minds" and have been the subject of heated debates: Many physicists and philosophers consider these "alternative classical realities" uneconomic and argue for a quantum collapse which removes all but one of the Everett branches. It should be stressed, though, that such complements to the unitary quantum description are not necessary to understand the observed phenomena. Moreover, supplementing quantum physics with a "physical collapse" usually leads to problems with the notion of locality in special relativity.

Unitary evolution governed by a Schrödinger-type equation, on the other hand, is attractive as it does not introduce any new elements into the formalism of quantum mechanics, and can in this sense be understood as "minimal" or "conservative". Thus, among the various interpretations of the quantum measurement process the "Many Worlds" or "Many Minds" interpretations (MWI) are recently becoming increasingly popular.

The understanding of the measurement process as a coupling of object system, measurement apparatus and observer is known as the von-Neumann chain [7], and it leads immediately to a new problem: where in this chain is the quantum-to-classical transition, also known as "Heisenberg cut", happening? In principle there could always be an outside observer ("Wigner's friend") who would experience her experimentalist buddy in a quantum superposition or "Schrödinger cat state". All that seemed to be known for sure at that time was that the mind of the observer is in a well-defined state ("psycho-physical parallelism" [7]). In this situation Wigner advocated a quantum collapse triggered in the experimentalist's consciousness ("consciousness as the last observer") and this understanding is known as the Wigner-von-Neumann interpretation [8].

Wigner later on changed his mind, however, when H.D. Zeh discovered decoherence ([5], see also [9]): the phenomenon that entanglement with an incompletely known environment leads to an extremely fast suppression of interference terms/quantum superpositions.

While this process provides an elegant and minimal explanation of the quantum measurement process, it also has two disturbing consequences:

- "Many Minds": the observer "splits" into multiple copies observing each possible outcome.
- Classical reality is a consequence of perspective. It results from our ignorance about the exact state of the environment. It is "emergent", not fundamental.

While heated debates have been fought out over the first of these two points, upon a closer look the second consequence appears to be the more interesting one: Classical reality is a consequence not only of a measurement system being coupled to an environment but also of the incomplete knowledge about this environment, which is of course a consequence of the local observer who simply cannot have all possible information about the exact state of the entire Universe. This local perspective has been dubbed "frog perspective" (local, classical) by Tegmark and Zeh in contrast to the "bird perspective" (non-local, quantum) in which the entire quantum system would be observed and no quantum-to-classical transition takes place: The quantum-to-classical transition is perspectival!

Thus in principle there are two possible kinds of quantum systems:

- Isolated (typically microscopic) systems with no interaction with the environment. While all quantum systems we have experience with are of this type, this is naturally always an approximation.
- The entire quantum Universe: global, encompassing, with no external environment and thus not subject to decoherence. It is this latter system which constitutes the only true fundamental quantum state which can be experienced only in the non-local bird perspective.

3. Do classical time and reality emerge together with consciousness?

But how are the two different perspectives (”frog” versus ”bird”) related to the temporal or atemporal realms of ”becoming” versus ”being” or ”ant” versus ”God”? This can be understood by realizing that what is usually perceived as the directionality of time is characterized by the increase of entropy. The state function Entropy describes how many fundamental microstates (being characterized for example by momenta and positions of constituent particles) correspond to a macrostate (being characterized by averaged properties such as temperature). This way it specifies the probability to observe the macrostate (the more corresponding microstates the more probable). What we usually experience as passage of time is the evolution of less probable towards more probable macrostates, which typically amounts to destruction and equilibration.

Now, the quantum Universe as a pure, fundamental quantum state has vanishing von-Neumann entropy (the quantity describing the missing information in a statistical mixture of quantum states). It thus seems likely that the quantum Universe as a whole is timeless, as described by the Wheeler-DeWitt equation [10]. It has been argued by Zeh [11] and Kiefer [12] that time itself then could be an emergent property of classical spacetime as a consequence of decoherence related to averaging out irrelevant gravitational degrees of freedom such as gravitational waves or tiny density fluctuations. In this case, not only the classical world but even time would be perspectival.[2]

We thus have retrieved our two perspectives introduced above:

- Parmenides’ perspective: the Universe as a whole - a fundamental, static quantum state.
- Heraclitus’ perspective: The Universe as perceived by a conscious observer – individual, localized objects in an unknown environment, a classical reality with emergent time.

The main open question of this approach seems to be what defines the ”frog perspective” or - in Tegmark’s words - the ”factorization” [14] into subject, object and environment. Obviously this perspective is a consequence of the observer’s consciousness being confined to her nervous system including her cerebral cortex. But what defines the boundaries of this ”cognitive self” without assuming a classical description and preferred basis beforehand? In the following we argue that the ”frog perspective” may be a crucial requisite of consciousness itself and therefore of the propensity to have aims and intentions.

Of course the phenomenon of consciousness is far from being understood. In the recent years however an interesting approach called ”Integrated Information Theory” [15] has been developed by neuroscientist Giulio Tononi which pursues a mathematical framework for evaluating the quality and quantity of consciousness based on properties of the corresponding information processing such as the irreducibility into subsets or ”integration of information”. While such a property resembles the properties of entangled quantum systems, Max Tegmark has provided two important results which suggest that consciousness at least in the IIT framework can most probably not be a quantum process:

- In [16] Tegmark estimated decoherence times of neurons and microtubules within the human brain and found that quantum superpositions decay on extremely fast time scales of the order of $10^{-13} - 10^{-19}$ seconds.
- More recently Tegmark applied IIT to quantum systems and found that due to the free choice of the Hilbert space basis only an insufficient maximum integrated information of 0.25 bits can be obtained [14].

While these results are not unchallenged, we nevertheless thus adopt as a working hypothesis that consciousness should be understood as a phenomenon linked to a classical algorithm operating in the brain and defining the factorization into subject/conscious self, object and

[2] Compare the recent work by Carlo Rovelli [13] which argues along these lines.

environment. In fact, taking Tononi and Tegmark seriously, consciousness seems to be emergent itself and only possible within the classical Heraclitus perspective. Consciousness may actually be a by-product or even the trigger of the quantum-to-classical transition.

4. What is a conscious self?

Turning to psychology, it should be stressed that there is not only one possible definition of "self". Several aspects of a self are indeed discussed such as minimal embodied, minimal experiential, affective, intersubjective, psychological, and narrative, etc. [17]. For physics, it is of crucial importance to understand which self or selves define(s) the local perspective giving rise to decoherence and classical reality.

Here we focus on the minimal self, defined as being consciousness of oneself as an immediate subject of experience or as the experience of a self as the perspectival origin of perceptions, thoughts, emotions, and a sense of agency. In other words, conscious states have a first-person mode of givenness, phenomenal experience is mine [18]. This quality of "mine-ness" in experience thus includes a minimal sense of self [19].

What is important in our context is that the self is not a passively experiencing entity but has a strong active future orientation. In fact, perception in recent conceptualizations is defined as a predictive, goal-oriented inference process [20]. Perception as 'predictive coding' means that based on prior experience the brain constantly makes predictions about what might happen. The goal thereby is to minimize surprise defined as the discrepancy between prediction and actual sensory input. This discrepancy essentially amounts to more or less 'prediction error', which the organism aims to minimize in order to reduce energy consumption. Normal waking consciousness thereafter can be associated with constant short-term and long-term predictions [21].[3]

The emergence of an experiencing self has also been discussed in the context of a predictive coding model related to interoceptive (bodily) processes, where subjective feeling states arise from actively-inferred generative (future-oriented) processes related to the causes of the incoming body signals [23]. This fits to another recent conceptualization where the experience of time is created by the integration of successive moments of self-realization which are based on bodily feelings, i.e. the successive integration of incoming bodily signals in the brain, most notably in the insular cortex [24, 25]. The relationship between an experienced self and the time domain has also been elaborated in phenomenological analyses, i.e. based on Edmund Husserl's work. The sense of time and the sense of self thereafter are manifestations of the same underlying process [19, 26]: I become aware of what I am through memory of what has just happened to me and expectations/predictions of what might happen to me in future. Only through this temporal structure of consciousness, the self-relatedness of the time perspective which contains "me", the realization of a self can emerge. Also more generally speaking, self-consciousness and time consciousness are strongly interlinked as everyday examples clearly show [28]. In waiting situations, especially when we are bored, time is in the focus of awareness and self-consciousness is most pronounced. Impulsive individuals more strongly attend to time in waiting situations as they anticipate the very near future when the waiting period is over [27]. That is, impulsive persons feel the "pull" to the future very strongly in situations where they cannot act as they wish. In contrast, when we are absorbed in pleasant activities, we are less aware of ourselves and subjective time contracts. Thus, both in the information-theory based IIT approach to consciousness as well as in the 'predictive coding' and 'integration of successive moments' concepts, a classical, temporal reality seems to be a requisite for conscious experience.

[3] The more radical idea that the superior predictive power of reconstructing the present from the past as compared to the future could be responsible for an evolutionary origin of the psychological arrow of time (the fact that we remember the past but not the future) has been discussed in [22].

Time consciousness and self-consciousness are more prominently modulated in altered states of consciousness. Altered states of consciousness are most strikingly induced through psychoactive substances such as LSD, ayahuasca, and psilocybin. During hallucinogen intoxication individuals sometimes report a dissolution of the mental self and subjective time.

In such states of consciousness – which can also occur during peak states of meditation[4] [29] – the notion of a conscious 'self' and of 'time' can jointly disappear, culminating in the feeling of 'selflessness' and 'timelessness' [28]. That is, in such reports the experienced self becomes one with the surrounding and the conception of past, present and future collapses into a single frame of non-temporal reference. In a certain way, one could speak about such peak states as constituting a non-local experience as opposed to a strictly local perspective in normal waking consciousness. The passage of time ceases and the self becomes one with the surrounding world, a feeling of unity of the self with the universe or an overall ego dissolution is reported [30, 31]. Obviously, also time and intentions fade away in those situations as any notion of a future dissolves.

Potentially, these experiences result from attenuated information filtering in the thalamus. As a result of the drugs' influence on the thalamus sensory input from the environment is less inhibited. Consequently, more activation is registered in mainly frontal areas of the cortex [32]. Alternatively, it has been proposed that during psilocybin intoxication transient functional connections build up between distributed brain networks, this stronger connectivity being measured albeit globally reduced cortical activation [33]. That is, the few existing systematic studies on the underlying neural changes in the brain during hallucinogen intoxication do not show a consistent picture, the results being strongly dependent upon the measurement and analyses techniques. However, one might tentatively sum up the available findings that the degree of separateness and segregation between brain networks, which themselves are functioning less stable and with less integrity, is reduced [31]. In more colloquial terms one could state that the changes in neural activation during hallucinogen intoxication are consistent with the notion that everything dissolves into one. In terms of the "integrated information theory" psychedelic drugs lead to an increase in entropy, thereby reducing cause-effect information, i.e. time-related knowledge about past and future states [34].

Strikingly, in psychology we find the same two perspectives as in physics: A non-local experience related to being one with the environment and feeling no passage of time corresponding to Parmenides' timeless unity in altered states of consciousness and Heraclitus' realm of becoming when we pursue aims and intentions in normal waking conditions: The aspects of hallucinogen experience thus exhibit interesting (anti-)parallels to the adoption of the local "frog perspective" triggering the quantum-to-classical transition: Conversely, here a classical, local self and possibly even time itself emerges, as a consequence of the neglect of information about the environment. Given these parallels one even may speculate whether the local algorithm constituting the conscious self gets so strongly coupled with the environment as a consequence of the hallucinogen intoxication that it is lifted to a less local perspective and in this way is able to experience some kind of "quantum holism". A first experiment to study such phenomena has been proposed in [36].

We are aware that this is a strong claim/hypothesis. The mainstream interpretation from cognitive neuroscience concerning empirical findings of distortions induced by hallucinogens

[4] From a psychological perspective a radical change from a local to a non-local perspective can also be induced through meditative practice. A typical induction in mindfulness meditation is the attentional focus on the own body states while breathing in and out, which in turn leads to an especially intensive awareness of time and the self, a state which is modulated through increased insular cortex activation [35]. However, highly practiced meditators can reach a peak experience where they later report a sense of loss of time and of self. Essentially, this resembles again a non-local state of being, the subjective alterations of time correlating with fluctuations in self-related brain areas such as the insula [29].

would be as follows: It is the construction of a phenomenal self that is distorted, with no correspondence to non-local physical states. The phenomenal self thereafter is constantly created by ongoing neural processes which results in the emergence of a self-model [18]. Psychoactive substances merely distort this process which nevertheless happens to the frog perspective of an altered self. Even in this case, it will be important to clarify and discriminate the different meanings of 'self' and 'perspective' in physics and psychology.

What we would like to encourage is a careful exploration of what happens in mental states where consciousness fades away and is experienced as "dissolving". As Tegmark has argued in [16], classical systems exist in some kind of intermediate or critical regime between too little interaction (no decoherence) and too much interaction with the environment, where in the latter case it is not meaningful to consider the system as an independent entity anymore. If the "conscious self" defines the local perspective that leads to the perception of a classical world, it is the local and classical property of this "self" which is crucial for the quantum-to-classical transition. What is proposed here is to study the conditions where consciousness looses its independence by increasing the information flux into the algorithm assumed to be its physical correlate.

5. From aims to meaning

If unitary quantum mechanics provides a truthful description of Nature, then the emergence of time and classical reality depend on our local perspective onto the Universe. Conversely, time and classical reality are requisites of our aims and intentions and of conscious experience - according to both Tegmark's analysis of IIT and the 'predictive coding' or 'integration of successive moments' concepts. Our frog or ant perspective onto the world seems to be linked intimately to our conscious experience, and any 'ascending' towards a bird or God perspective [2] seems to include a dissolving local perspective and self.

While "aims" and "intentions" thus rely on a temporal, classical reality, "meaning", on the other hand, emerges from the interconnectedness of things, of seeing Nature – as Alexander von Humboldt insisted – as a "net-like intricate fabric".

Now, at the dawn of the quantum age, the relations between the inner and the outer world, between self and Universe and between "becoming" and "being" will have to be negotiated again.

Once we understand better how the realms of "being" and "becoming" are connected in physics and psychology, and once we understand how these relations in the two research fields are linked, maybe a "net-like intricate fabric" emerges that relates our dionysian and unsteady temporal existence to the atemporal, apollonian and transcendental realm of Parmenides and may bestow our life with meaning. Until this happens, "wandering towards a goal" will always be accompanied by "wondering about the meaning".

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