The Universe as a Cyclic Organized Information System: John Wheeler's World Revisited

Dirk K. F. Meijer

ABSTRACT

This essay highlights the scientific vision of John Archibald Wheeler, a giant of 20th century physics. His ideas provided the important insight that humanity may be in the very center of disclosure and manifestation of the evolution of our universe. This on the basis of scientific reasoning derived from quantum physics rather than simple anthropocentrism or scale chauvinism. Wheeler, the Joseph Henry Professor of Physics Emeritus at Princeton University, became 96. Over a long, productive scientific life, he was known for his drive to address big, overarching questions in physics, subjects which he liked to be merged with philosophical questions about the origin of matter, information and the universe. His interests ranged far and wide and were characterized by true fearlessness. Wheeler's work was not only in gravity and nuclear physics. In the 1950s Wheeler grew increasingly intrigued by the philosophical implications of quantum physics. According to Wheeler, there was no universe until the rise of consciousness to perceive it. In fact, Wheeler was one of the first prominent physicists seriously to propose that reality might not be a wholly physical phenomenon. In some sense, Wheeler suggested, reality grows out of the act of observation, and thus consciousness itself: it is "participatory." He also stated that information is the most fundamental building block of reality, and that the universe should be seen as a self-synthesized information system: a self-excited circuit that is developing through a (closed loop) cycle. His cosmic variant of the delayed choice experiment led to the idea that human observers may not only determine the present, but also may influence the past. According to Wheeler, ultimate mutability is the central feature of physics, and the meaning of reality can only be established if there is a universal knowledge field, that transcends physical past, present and future.

Key Words: John Wheeler, participatory universe, it from a bit, self-synthesized information system
DOI Number: 10.14704/nq.2015.13.1.798 **NeuroQuantology 2015; 1:57-78**

Introduction

In this essay an attempt is made to provide an interesting case study, as an example how scientific development in the 20th century led the famous physicist John Archibald Wheeler (1911-2008) to extend the classical ideal of rationality in which subject and object are entirely separated and the world is supposed to exist independent of human insight, towards a more phenomenological stance, postulating man in the center of disclosure and manifestation of the world. This seems to bring teleology into the heart of scientific explicability of the universe, related to the questions: can physics explain its own existence and why is physics possible at all?

John Archibald Wheeler

John Wheeler (Figure 1) made important contributions to theoretical physics. Wheeler was a pioneer in the theory of nuclear fission, along with Niels Bohr and Enrico Fermi. In 1939,

Corresponding author: D.K.F. Meijer
Address: Parklaan 17, 9724 AN, Groningen, The Netherlands.
Phone: + 0031-50-3180593
e-mail ✉ meij6076@planet.nl
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 24 November 2014; **Revised:** 12 December 2014;
Accepted: 12 January 2015
***e*ISSN** 1303-5150

Wheeler collaborated with Bohr on the liquid drop model of nuclear fission. Wheeler, among others, coined the expressions: black hole, black holes are "hairless"…, nuclear fission, geo-metro-dynamics, unified field theory, quantum foam and the famous "It from a Bit".

As a very influential physicist in the time of Einstein and Bohr, he formulated the Wheeler-De Witt equation, Wheeler–Feynman absorber theory and the Wheeler's delayed choice thought experiment. For this high standard and pioneering work, he received the Enrico Fermi Award (1968), Franklin Medal (1969), Oersted Medal (1983), Albert Einstein Medal (1988), Matteucci Medal (1993) as well as the Wolf Prize (1997). Famous students of Wheeler include Richard Feynman, Hugh Everett, Jacob Bekenstein, Kip Thorne, Charles Misner, Arthur Wightman, Benjamin Schumacher and many others.

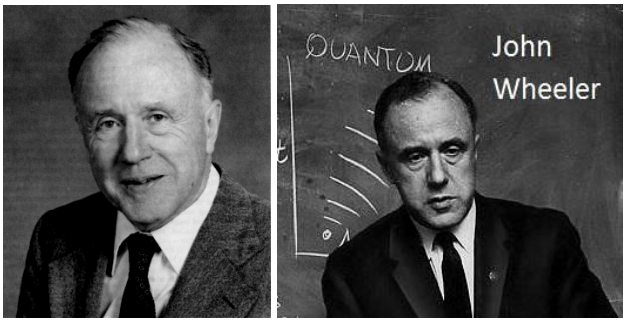

Figure 1. John Archibald Wheeler at different ages.

Wheeler realized the importance of a creative and challenging scientific atmosphere brought about by his students, saying that "The real reason universities have students is to educate professors…." And: "If you can involve young people in an atmosphere of hope and faith, then they will figure out how to get the answer". Yet, although being a modest person, he was a real team leader and mentor, he asked his students sharp questions, and he himself was not afraid to challenge the consensus trough his remarkable scientific visions that often shocked the scientific community. He encouraged his students to challenge well established paradigms, with ideas like: A particle goes from one point to another by following all possible paths, even if it goes faster than light, or even back in time!

He specially admired his Danish colleague Niels Bohr, and even told his excellent doctoral student Hugh Everett (known by the many world hypotheses in quantum physics) to rewrite a part of his doctoral thesis, since, in first version, it was to conflicting with Bohr's Copenhagen interpretation. Wheeler had a talent for summarizing complex ideas in simple phrases. The essence of Einstein's theory of gravity, he said, is that: *"Matter tells space how to warp, and warped space tells matter how to move."*

He also co-wrote the influential textbook on general relativity with his co-workers Misner and Thorne, called "Gravitation" (Misner *et al.,* 1973). In this framework, he described hypothetical 'tunnels" in space that he framed as "wormholes", that, according to some physicists (Morris *et al.,* 1988), in principle would allow time travel. Interestingly, Kip Thorne recently highlighted this aspect in his book "The Science of Interstellar" on the WBP movie "Interstellar", seen as a follow-up of the earlier film "Contact", with a similar astrophysical context. Wheeler's approach, challenging the natural scientific attitude, was often not appreciated by physicists who found his ideas "unpalatable in view of its rather mystical overtones". Such a skeptical reaction of physicists to Wheeler's ideas can perhaps be understood because his ideas represented a metaphysical extension of physics, which main stream physicists, regretfully, do not consider as a part of their vocation and duty. However, seen historically and in particular in conjunction with philosophical developments in the 20th century, this was not an isolated attempt, for it manifested a certain inevitability of shifting towards a transcendental or phenomenological appropriation of physics, with the aim to tackle the issue of its own foundation and its common assumptions (Nesturuk, 2009). An overview of recent history of Wheeler's scientific work is provided by Misner *et al.* (2009).

In 1979, Wheeler spoke to the American Association for the Advancement of Science (AAAS), asking it to expel parapsychology, which had been admitted ten years earlier at the request of Margaret Mead. He called it a pseudoscience, saying he did not oppose earnest research into the questions, but he thought the "air of legitimacy" of being an AAAS-affiliate should be reserved until convincing tests of at least a few so-called psi effects could be demonstrated. However, his request was turned down, and the Parapsychological Association remained a member of the AAAS.

Wheeler developed his career in three stages with the subjects 1) "Everything is Wave/Particles", 2) "Everything is Fields" and finally 3) "Everything is Information". With

regard to the latter he asked the intriguing question: are life, mind and intelligence byproducts of the fabric of reality *or are the rather central to it.* He based this consideration on the utterly strange aspect of quantum physics: by observation, quantum superpositions collapse to a single material position or, in other words: no phenomenon is real until it is an observed phenomenon. Wheeler thereby evidently became an early advocate of the "*Participatory Anthropic Principle*" as primarily put forward by Brandon Carter (1983) and later by Robert Dicke (1961), indicating that the laws of physics are fine-tuned to permit the existence of life (see for a review of anthropic factors, Ross, 1989). Later various variants of the anthropic principle were proposed, which have been refined and modified much over the years.

On the basis of the downward causation aspect of his "delayed choice thought experiment" in the double slit wave/particle set up, he even suggested that intelligent species not only participate in creating the here and now, but also the far away and long ago. Although some considered this at that time as pure speculation, later he obtained clear support for this idea from famous cosmologists such as Stephen Hawking, (1988), Fred Hoyle (1988) and Andrei Linde (2003) of Stanford University.

The latter stated that the universe and the observer seem to exist as a pair, and that he could not imagine a consistent theory of the universe that ignores intelligence and consciousness. However, in their book "The Cosmological Anthropic Principle", physicists John Barrow and Frank Tipler (1988) claim that the "must" is not just a fact based on observation in our universe, but rather a fundamental requirement for any universe to exist. They based this final argument largely on quantum physics and the *Participatory Anthropic Principle (PAP)* proposed by John Wheeler.

Nesturuk (2009) argued: "The alleged purposiveness of the universe brings us to the question of its subject: who is that intentional agent for whom the universe has a purpose? It is not difficult to see that the idea of the Divine subjectivity enters the scheme of things at a different level: the Participatory AP in this case becomes similar to that version of the Strong AP which postulates that the universe must have human agencies as its product at a certain stage of its development". This analysis thus unfolds the most important and metaphysical point to be made on Wheeler's ideas, namely the mystery and precarious status of human agents as observers-participants, in what concerns the origin of their purposive actions, in turn feeding back to the foundation of the universal knowledge of the universe.

John Wheeler indeed firmly believed that we live in a very interactive universe, implying that humans and probably other intelligence species function as observers. They thereby influence the universe at the most fundamental level and actively participate in the fabric of reality and evolution of the universe. He also proposed that the universe is a *self-synthesized information system* (Wheeler, 1990), dealing with the question how the universe was assembled and how it operates now and will operate in the future. The key to understanding the universe, according to John Wheeler was to simulate a role of an external observer, who is able to observe the universe as an integrated whole rather than a machine build out of parts. This implies the role of an observer who perceives a functional system, without exactly knowing its constituting parts, that is, as a thought experiment. Wheeler insisted that the overall connecting principle of the system should be information, being even more fundamental than matter and energy, as treated in the next section.

Information as Fundamental: *It from a Bit*

Wheeler considered information as a fundamental building block of reality, along with matter and energy (Figure 2).

In stating this, he implied *physical* information, which is different from the term information as we use it in daily practice: the word information, evidently, is rather a container term that represents many different modalities, ranging from information constituting a physical parameter, to the daily transmission of the news in human culture (Meijer, 2012, 2013a). Wheeler also was convinced that information is more fundamental than matter and energy: he postulated that matter and energy can not only be expressed in terms of information, but that digital information must precede the material world: framed in his famous thesis: "It from a Bit". With this aphorism, Wheeler argued that anything physical object, any it, ultimately derives its very existence entirely from discrete information-

theoretic answers to yes or no quantum binary choices: Bits. In this spirit, many theorists now give ontological primacy to information (Zeilinger, 2000; Vedral, 2010; Davies and Gregersen, 2010).

Physical information is particularly known from the description of nature at its micro-level and from computer science as binary units (bits and Qbits). Yet, it is also essential in understanding the evolution of macrostructures in the Universe (Davies and Gregersen, 2010). The interactions of subatomic waves/particles subsequent to the Big Bang created information on their relative position, momentum, spin and polarization that can be stored within these units (Seife, 2006). This creates a relational dynamic network of quantum information, also enabled intelligent search and selection processes in nature, aiming at a future path potentially through a process of backward causation (Davies, 2004).

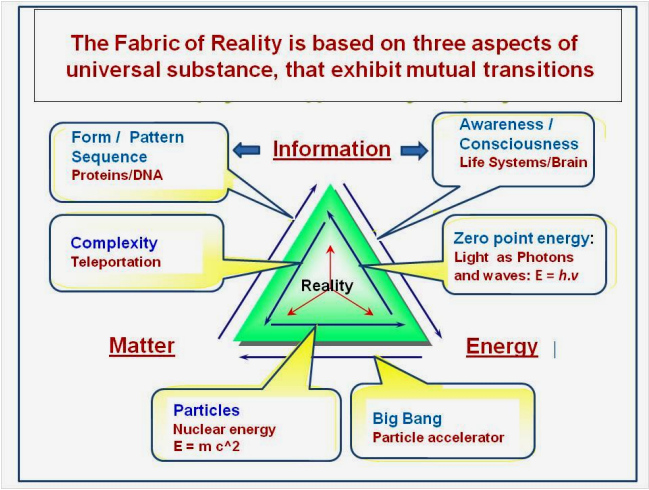

Figure 2. The fundamental building blocks of Nature: the triad of energy/matter/information and their mutual relation and transitions (from Meijer, 2013a).

In this respect, evolution can be conceptualized as a continuous measurement and creation of basic information that is subsequently compressed and stored within the system itself. It follows that a collective memory of nature (Figure 3) is a prerequisite for the creation of life and further evolution of intelligence (Meijer, 2014a). According to David Bohm, this universal consciousness takes the form of a general quantum field that stores information, penetrating all known structures, being continuously engaged in bidirectional communication with non-living and living material (Bohm, 1980; Levin, 2011; Meijer, 2012). A potential bidirectional flow of information in the scheme of Bohm was discussed by Holland (1994) and mathematically derived by Sutherland (2006).

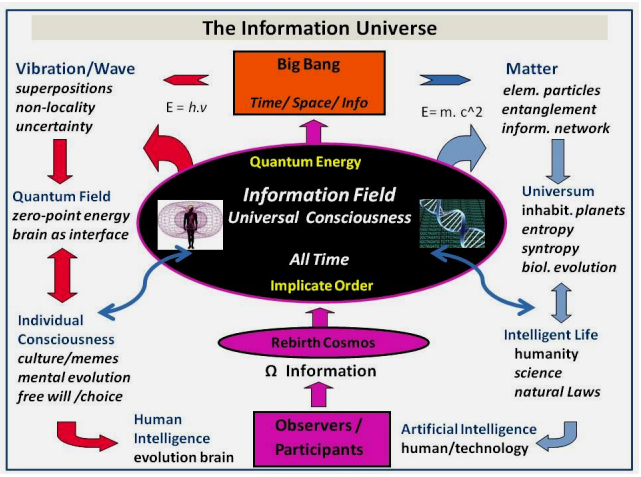

Figure 3. Schematic representation of the circular model of the history of our information universe, with its central knowledge field or universal consciousness (in black), leading to complementary evolution of the material and mental aspects of reality, finally producing human and machine intelligence that provide the final technology for rebirth of the universe (Figure taken from Meijer, 2012).

Current information theory implies that information can both be described as an entropic element in which the impact of information is inversely related to the probability that it will occur, versus the concept that information reflects the certainty of a message and is directly related to its probability and meaning. This dual aspect of information reflects the perspectives of sender and receiver in the transmission process (Meijer, 2013a, 2014a). It is shown that basic information is largely hidden from us, due to observation-induced perturbation of this intrinsic information. Information is transferred to the brain through specifically tailored sensory organs that accommodate complex patterns of wave activity, that subsequently are converted to neural activities in a cyclic workspace of the nervous system (Meijer and Korf, 2013; Meijer, 2014a) and recently reviewed in Meijer and Raggett, 2014b). It has been hypothesized indeed that a maximal *integration* of clearly differentiated, active information (information leading to action), produces consciousness (Tononi, 2008). Zeilinger (2005) explains:

> "It turns out that very naturally the referent of quantum physics is not reality per se but, as Niels Bohr said, it is 'what can be said about the world', or in modern words, it is information. Thus, if information is the most fundamental notion in quantum physics, a very natural understanding of phenomena like quantum de-

> coherence or quantum teleportation emerges. And quantum entanglement is then nothing else than the property of subsystems of a composed quantum systems to carry information jointly, independent of space and time; and the randomness of individual quantum events is a consequence of the finiteness of information. The quantum is then a reflection of the fact that all we can do is make statements about the world, expressed in a discrete number of bits. The universe is participatory at least in the sense that the experimentalist by choosing the measurement apparatus, defines out of a set of mutually complementary observables which possible property of a system can manifest itself as reality and the randomness of individual events stems from the finiteness of information".

Hans Christian von Bayer (2001) writes:

> "Zeilinger thinks that before we can truly understand quantum theory, it must be connected in some way to what we know and feel, and states "*an elementary system carries one bit of information"*. It therefore contains the fact that the world is quantized. To the question, "Why does the world appear to be quantized?" Zeilinger replied, "Because information about the world is quantized. Physicists call the building blocks of their planned quantum computers "Qbits". A Qbit is simply an elementary system such as an electron spin. Because a qubit can be in a superposition of 1 and 0, it must hold not only classical information, but some more elusive quantum kind of information too. Therefore, many practitioners feel that ordinary information theory must be contained in quantum information theory."

Is Wheeler's reasoning actually self-consistent? Wheeler argued that all reality arises from the posing of yes/no questions. Yet, his restriction to yes/no question ascribes only rational numbers to what he considered reality. This may indicate a sort of dichotomy. On the other hand, he needs the trichotomy (smaller, equal to, or larger than) of real numbers as to arrive at complete sets of vector spaces and in particular singularities. Yes/no as a binary choice should be extended to "yes or no as well as yes *and* no": the Qbit.

Barbour (2011) adds: A 'bit' is merely part of the huge interconnected phenomenological world that we call the universe and interpret by science; it has no meaning separated from that complex. Just because the overall conditions of the universe enable us to observe them in carefully prepared experiments, dots on screens are no proof that at root the world consists of immaterial single-digit information. For we have no evidence that the dots could exist in the absence of the world and its special properties: "*bit from it*".

In a similar vein, Foschini (2013) argued: there is a physical, engineering, material aspect of information, but it is only one part of a more complex problem. It is now clear that the knowledge of the material aspect only is not sufficient to understand the problem of information. It is the human being that, by assigning a meaning and creating a tongue with the signs so obtained, creates it from bit. How this happen has to do with the human mind and its conscious and unconscious structures instrumented with the gift of language. Of note, recently a new information paradigm has been proposed encompassing a new integral science of information on a physical and metaphysical basis: it seems easier to describe matter and energy in terms of information than vice versa. This implies that information could be used as a common language across scientific disciplines (Vedral, 2010; Davies and Gregersen, 2010).

David Bohm (1987) like Wheeler, put consciousness in a wide perspective, stating that consciousness in the form of a universal information/knowledge field can be seen as a creative force in the physical universe, which can influence the generation of complexity in all domains. This was related by him to a supposed implicate order functioning as a holographic steering system for all the material elements that form the Universe (t'Hooft, 2001). The concept of a holographic cosmic consciousness /intelligence was later on further elaborated by Germine (2007), Di Biase (2009), Kak (2009), Katafos (2011), Levin (2011), and Görnitz (2012), among many others. The information carried by a quantum hologram encodes the complete event history of the object with respect to its three dimensional environment. It evolves over time to provide an encoded non-local record of the 'experience' of the object in the four dimensional space/time of the object as to its journey in space/time and the quantum states visited. Bekenstein (2003) and later, Verlinde (2011) made clear that the information content of each object (from atoms to black holes), can be seen as projected in Bits on a virtual screen surrounding the particular object. The purpose of this huge information field in the universe is to provide

shaping information to its internal systems of parts: indeed elementary particles somehow "communicate" instantly over vast distances enabling an entangled web of information that registers data on a cosmic scale (Zizzi, 2006).

Wheeler postulated that if we are willing to keep our minds open to these different theories, a different way of thinking is required, and from this an entirely new picture of the cosmos, (a new scientific paradigm), may emerge. He proposed to define 'information' as a fundamental aspect of reality that even may have preceded matter and energy: information is "everything there is, including matter and energy". He evidently, perceived information as the universal substance from which everything else is made.

Wheeler's attempt to derive all of physical theory from a simple "atom of information", resembles that of his contemporary Friedrich Von Weizcäcker (Wheeler was mentored by Bohr and Weizcäcker by Heisenberg). Von Weizcäcker, (see the review in 2006), called this a quantized binary alternative "ur-alternative". Although Wheeler considered time as a derivative of information units, Weizcäcker, rather, considered time as fundamental. For both was information a primordial building substance and a quantitative measure of form in the sense that form represents the substance in the stream of events. The latter reminds us of the actual occasions and experiences of Whitehead (see Keeton, 2004). They both reached the perspective that information is the common basis underlying *both* matter and mind. Wolfgang Pauli called this concept earlier "neutral with respect to psycho-physical distinction. The relation between classical and quantum physics was more recently described as a dynamic layering process: the classical limit transforms a quantum theoretical description into a classical one and a process of quantization converts classical physics onto quantum physics. Quantum theory can be characterized as the "physics of relations": the whole is more than the sum of the parts (Görnitz, 2012).

Thus Wheeler's 'bit' may, instead of something that belongs to our perceptions as the result of yes/no questions, represents registered information in nature that can be seen as basic physical parameter that is created by the interaction of particles (Seife, 2006). An 'it' is something like a particle whose existence we produce from a set and pattern of bits that fully describes the particle, as in teleportation experiments (Zeilinger, 2000). Consideration of everything involved in the selection process, in which the *choice and organization* of bits plays an important role, raises the question whether Wheeler's contention that every 'it' derives its very existence from bits can be isolated from a guiding principle, such as have been proposed by David Bohm in his implicate order.

Scaling the Universe: Where are we Humans?

Wheeler developed his own transcendental argument basing himself in both Einstein's theory of relativity and quantum mechanics that, according to him, changed the vision of the human position in the universe by making human beings co-creators of physical reality in a very non trivial sense. *"The brain is small, the universe is large".* In brief, are life and mind irrelevant to the structure of the universe, or are they central to it?" (Wheeler, 1988; 1994). This question did not arise from a sort of anthropocentric scale chauvinism, nor out of radical reductionism, in the sense that large scale phenomena must be consistent with knowledge of smaller scales. It had much more to do with Wheelers interpretation of the observer effect in quantum physics: that consciousness seems to have a distinct action on the choice of wave/particle state, situated on the most fundamental level of nature, and thereby, in his idea on the whole manifestation of reality: although the human brain is small it provides an intellect that seems to serve as an interface for our brain to universal dimensions.

Indeed the size of the brain, which is responsible for mental articulation of the whole universe, is quite small compared with the spatial size of the visible universe: obviously, the actual infinity of the universe is attempted to be articulated from an infinitely small part of its formation. Still, the articulation of microscopic realities of particles and fields, as well as huge astronomical formations is possible by this organ through the powers of observation, conceptualization, and intuition. In fact through its insight humanity is co-present in all points of what it observes in the universe, or imagines: there exists no source of knowledge outside the human endeavor.

But, how come that we are here anyway?

How come all the extraordinary unlikely coincidences needed for the creation of life and intelligence have come together to create us? Wheeler argued that this perfect fit is unlikely to be a mere accident, and that mankind and the potential other modalities of intelligence in the universe played and will play an essential role in the evolution of the universe. And this, remarkably, even in retrospect with regard to the millions of years of evolution before human existence (Nesturuk, 2013).

The size of a human being seems to be in the center of all possible sizes of the universe (Figure 4) and this was in fact the position that the Wheeler proposed for humans as observers and participators in the becoming of the universe. The largest size that humans can observe is the cosmic horizon (10^{26} and the smallest size that was inferred is the Planck length (10^{-35}), about 60 orders of magnitude difference. Living creatures, in general, have to be large enough to contain that number of atoms that can provide the chemical and biological complexity to convert energy into materials, so that they can survive and replicate (Primack, 2006).

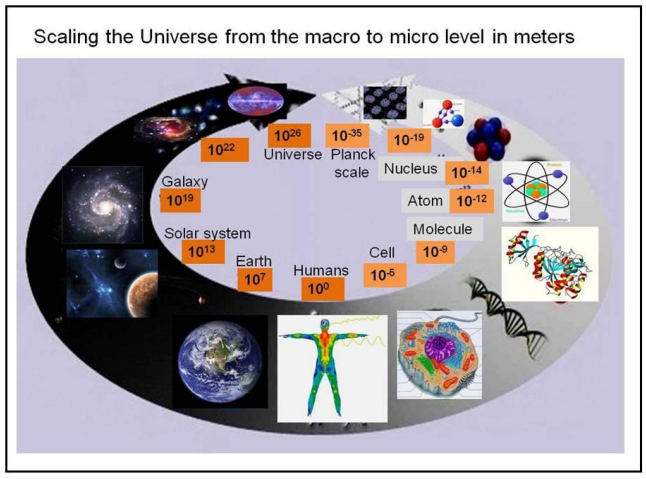

Figure 4. The dimensions of the Universe from extremely small (right part) to unthinkable large (left part), with humans seemingly in the middle.

It is important to realize that at each level of the scheme of Figure 4, the well-known forces of nature play a role, but that the extent of this can be very different. A special position in this respect takes gravity that on grand scale of galaxies controls the motion of matter. In the ongoing expansion of the universe it tends to pull matter together against the opposing effect of dark energy/matter and thereby provides local stability. It is gravity that that holds the solar system together and created the conditions that enabled the continuous evolvement of complexity and thereby of intelligent life forms (Hoyle, 1988). Gravity is a weak force at the level of atoms, but interestingly at very small scales it again becomes a major force due to the fact that distances between objects become extremely small. Consequently, gravity seems to links the largest and smallest sizes and it is no wonder that current physics tries to unify nature laws via the so called string theory that could in principle reconcile quantum theory and relativity,(see also Figure 11). Such a vibrating matrix, called quantum foam by Wheeler in 1985, may provide the force field that is the very basis of reality.

According to modern quantum physics the vacuum, which evolution has tempted us to regard as an empty background, is in reality a highly structured, responsive and dynamic medium. Because of the uncertainty principle the 'vacuum' contains virtual particles that can, like the molecules in an insulator, arrange themselves to partially screen an inserted charge. If that happens, the charge one measures at smaller distances, inside the screening cloud, or equivalently in higher energy processes, will effectively increase. The opposite behavior, anti-screening or asymptotic freedom, though less familiar, is also possible. In either case, the value of the charge, or coupling strength, is not an absolute concept, but depends on how it is measured (Wilczek, 1999).

It is suggestive that the Planck scale emerges here. To appreciate why, we must consider extending the notion of the relativity of charge to gravity. The sorts of charges, strong, weak or electromagnetic, to which the interactions of the *Standard Model* of particle physics respond, change only logarithmically with distance, owing to subtle quantum mechanical effects. But gravity responds to energy directly, so that it runs linearly with energy (or inverse distance) scale. From its much inferior strength at accessible energies, gravity ascends to equality with the other interactions at roughly the Planck scale. Thus we discover that all the coupling strengths become equal simultaneously: all of the basic forces arise from a common source, that we will converge on a unique set of basic equations for physics, and many physicists believe that such equations will emerge from investigations into superstrings.

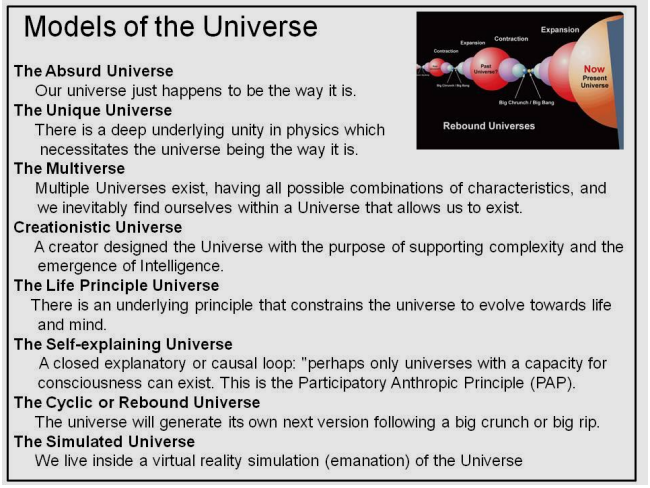

Figure 5. Various models of the universe that have been proposed (modified from Davies, 2007).

Wheeler was always very interested in why the universe exists anyway: how did the universe develop to its present state and why did it happen in this way? Would these unknown factors also determine the far fate of this "self-synthesized" system and are the underlying physical laws and their intrinsic numerical constants a given recipe, or are they somehow malleable through a giant feedback, fed by billions of observations that induce decisions at multiple scales? It is fair to say in this respect, that John Wheeler never found an answer to the question why the universe was created so, although he clearly contributed to find a solution how it was created. Paul Davies (2007) listed a number of potential models for comprehending the universe, at least as we know it. Albeit, this spectrum of very different modalities (Figure 5) demonstrate how far we are away from more definite answers.

As reviewed by Kuhn (2007), the universe seems self-creating, self-directing and self-explaining and the manifestation of conscious beings somehow animated a kind of backward causation in order to select from hidden laws and countless numerical values to actualize a world that was consistent with the evolution of life and mind. The latter may eventually become one, in order to engineer the universe own self-awareness. How is it that we humans have such farsighted understanding after only a few thousand years of self-consciousness, only a few hundred years of effective science and just a few decades of cosmological observation? This represented a major scientific quest for John Wheeler, as treated shortly in the next section.

A Self-synthesized Information System

Wheeler proposed to model the universe as a self-synthesized information system (Figure 6). A self-synthesized information system is defined as a system that creates, operates and maintains itself from within, through a dynamic kinetic equilibrium that requires energy. Yet, apart from the required raw materials it needs assembly instructions in order to, not only, create its parts but also to assemble those parts into a single system that maintains itself (Walker, 2013). In this framework, Wheeler added an essential element, by defining a so called participatory universe that requires human beings or other forms of intelligence as an essential and integral part in order to enable its evolution. Correspondingly, the diagram of the closed-circuit universe in Figure 6, is not just an accomplishment of physics, it is a *mental* accomplishment which is contingent upon intelligence, which is, through embodiment, a part of the diagram and, at the same time, something outside of it. In other words Wheeler's diagram presupposes for its own existence the presence of intelligence which creates this diagram: humanity appears in it as the centre of disclosure and manifestation. The physical genesis depicted in this diagram requires a reflecting consciousness which has propensities which do not simply follow from the chain of physical causations.

From a philosophical point of view there is a gap in Wheeler's reasoning on the universe as an emergent meaning circuit, for there is no explanation as to why the intelligent observers, who reveal the intelligibility of the entire universe, are possible at all. In other words, why the universe entails the transcendental conditions of its own explicability! (Nesturuk, 2013).

As put forward by Walker (2013), all information systems require hardware *and* software. A self- synthesizing system not only creates its own hardware, it must at the same time also create its own software as a steadily growing picture of the total construction (Figure 3 and 5). It goes without saying that for an optimal build-up the system would require an internal communication modality on the basis of a continuous supply of energy. The programming software would have to fully penetrate the hardware systems in order to enroll the basic blueprint. Communications in this universe would have to operate faster than its moving

parts including the updating of the programming software. In fact, the entire system could be conceived as a living system that is exposed to entropic and neg-entropic forces, continuously fed by free energy. Taking into account the huge dimension of the observable universe, it is clear that light as a communication instrument only can serve to connect the distant parts of the whole over very long stretches of time (billions of light years) and that a much more rapid communication means is required to fulfill this prerequisite.

How can we envision its internal structure on the basis of energy, matter and information and what properties are required for an integrative communication system that steers its evolution? Only if the system's hardware exhibits an intrinsic information modality such an operation can be realized. The wave/particle duality provides this condition: it enables the creation and updating of the supposed software by photons. Yet, going back to the unthinkable size of the universe, as stated above, apart from light as a local message system, another non-local communication modality must play a role: one that is not limited to the speed of light.

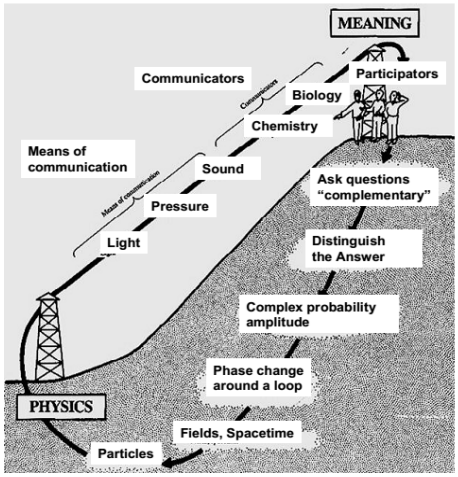

Figure 6. World seen as a self-synthesizing cycling system of existences. Physics provide light, sound and pressure as tools to probe and communicate. It also gives chemistry and biology, generating intelligent observers and participants that ask questions and select answers that in turn lead to knowledge, phase changes, perturbation of fields and thus new physics (modified from Wheeler, 1986).

Here we touch upon a central feature of our quantum physical universe: the feature of entanglement that allows instantaneous correlations of information, not restricted by the speed of light. This crucial attribute of all matter becomes even more powerful if it operates within a holographic geometric setting (Bekenstein, 2003; Linde, 2003), since this implies that every part of this entire holographic structure is reflected in its smaller parts. In-formation can, in this manner penetrate all parts of this giant structure on the basis of an ultra rapid connective system. Thus the living universe may not only contain a time-dependent internal light-mediated nervous system but also a supercausal time-independent (non-local) communication system that informs the whole of the changes induced in its parts.

In principle 6 different mechanisms, may provide ultra-rapid/ information transfer and/or enable instantaneous contacts at large distances, on the basis of current literature:

- Quantum entanglement, the spooky action at a distance of Einstein, with its apparent instantaneous character, cannot really transmit information, but may connect (correlate) elements of the universe at a speed of at least 4 orders of magnitude of the speed of light (Yin *et al.,* 2013).
- Propagation of gravity fields. Van Flanderen (1998), in an intensively debated paper, estimated the speed of gravity to be at least 10 billion times the maximal speed of light
- Flow of tachyon particles, also forming tachyon fields, is supposed in physics to occur at superluminal speed, far exceeding the speed of light and according to Einstein could be instrumental to communicate backwards in time (Benford *et al.,* 1970)
- Time reversed flow of antimatter (Vannini and DiCorpo, 2011), proposed, on the basis of the Klein-Gordon equation, that negative mass (antiparticles) travel at speeds much higher than the speed of light and in a reversed time modality.
- Casimir effects in the vacuum, within wormholes. This phenomenon may be analogous to quantum tunneling and may allow photons to travel at speeds far exceeding the speed of light (Visser *et al.,* 2002).
- The Holographic principle as applied to the whole universe, in which each part of the universe implicitly contains information of the whole (Bekenstein, 2003).

The underlying source of the hardware's

motion may have its basis in kinetic energy, entropic forces, gravity and dark energy/matter. Yet, the seemingly fine-tuned character of these phenomena point to the existence of a sort of program that could be seen as integrated software acting within the whole system. Descriptions of nature on the macro scale (relativity theories) and micro-scale (quantum mechanical) at first sight appear to be mutually incompatible. However, Wheeler (1988) suggested these two theories could also indicate evidence for a single, combined system: our universe to a self-synthesized information system on the basis of a connecting principle: information! (Walker, 2013).

As stated above, almost everything about our universe can be envisioned as an information system, just like the present internet is for mankind on our planet**.** Our seemingly material universe thus encompasses a *mental* (informational) element (Henry, 2005) and implicitly may require the two abovementioned physical theories to model its creation, evolution and death.

Information as the Universal Substance: the Water Metaphor

This *"Information Field of Intelligence",* in Wheeler's view has to be *aware* of everything that takes place in the universe and functions as an invisible mirror, acting as a medium that reflects back every experience, action, sensation, thought, feeling, emotion, and intentions to its source of origin (Walker, 2013). This quantum field was experimentally demonstrated and represents a large part of the entire energy of the universe. It is also called the zero-point energy field, since elementary particles and their anti-particle counterparts pop in and out of existence even at zero absolute temperature. Due to its potential to *interact* with all matter, it provides a dynamic self-reflecting field for storage and integration of knowledge. As mentioned above, it does so by entertaining a bidirectional *holographic* relation with all there is, meaning that, as in the hologram, each part reflect the information of the whole picture.

So how does the universe transform this single substance information into energy, matter, light, intelligence and consciousness? The cycling transport of water on our planet may provide an adequate analogy. This single substance can indeed be divided into five separate categories of glaciers, rivers, clouds, precipitation (rain/snow) and humidity (Figure 7).

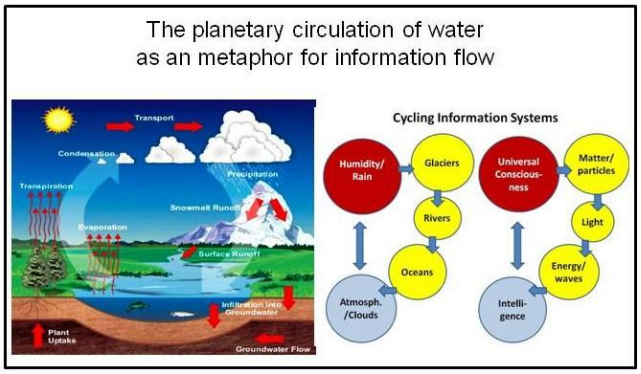

Figure 7. Left: The circular movement of water on our planet (left) as a life- conferring element. Right: The water cycling on our planet as a metaphor for information cycling in the universe. Yellow components indicate hardware parts, blue software part and red the connecting principle or source field (modified from Walker, 2013). The relation between universal consciousness and intelligence is bidirectional.

Wheeler conceived that the universe uses information in much the same way. Matter, Light, Energy, Intelligence, and Consciousness look and act differently, possess unique properties and characteristics, travel at different speeds, and yet are also made from the same underlying substance: information. Together they form an integral system in which water is transformed into these different categories by modalities of energy: heat, wind, and pressure as a metaphor for a circular flow of information.

Indeed, the metaphor "life is a river" have been used by many artists and scientists in relation to flow of information:

- one never stands in the same river: *the dynamic character of information flow*,
- increased rates of water flow in river rapids and cascades as a products of space constraints of the
- environment: *compression of information*,
- rivers can form spectacular waterfalls: *high impact of information through unique local conditions,*
- water as essential component of life organisms: *information is a fundamental element of life systems (so called neg-entropy)*.
- rivers finally end up in oceans*: information is collected as in a global internet*
- sea waves are formed by interaction of wind, soil and water*: information in*

complex wave form is

- *created by superposition, entanglement and fluctuation within quantum fields*
- water is evaporated to water vapor in expense of heat/energy, yet regardless of the extent of diffusion the total water amount remains constant: *information is distributed and handled by energy-using devices, but according to the supposed law of preservation of information, it remains constant in amount.*
- water vapor is condensed to drops of rain, *diffuse information is converted to messages, memes and news,*
- rain and precipitation is dropped through gravity: *information is collected and interpreted by*
- *integrating coherent information (thereby creating consciousness)*
- -rain water is stored in the form of ice in glaciers (neg-entropy): *information is stored as coherent*
- *quantum waves in a universal knowledge domain: the zero-point quantum field (see* Figure 3).

It follows that the required information matrix of the universe should have an ultra-rapid circulatory element to provide optimal information exchange and feed- back. Consciousness, that is required to collect, interprets and compresses the information to coherent messages, is created within this cycling integrating process. This may also explain why the universe is so incredibly fine-tuned to create life: to transform information into intelligence and conscious beings. This may guarantee that the Universe through us can increasingly observe and reflect on itself and in addition by scientific compression of information, for instance into natural laws, can ultimately create the technological expertise to create a next version of its mortal structure, (see also final sections). In this way the universe can be viewed upon as a life system: it maintains itself through the collection and creation of useful information (ecosystem) and finally may enable also its own reproduction (Vaas, 2004; Vidal, 2013).

In this respect the universe obviously requires life as a fundamental entity and inhabitable planets to function as a cradle for life. A recent analysis of the so called Keppler data, showed that at least 10 percent of *all stars* may have a planet of Earth-size or larger in a close orbit (see report of Harvard). If only 1 % of stars have just one Earth-size or larger planet at a proper distance from their sun, it means that there are at least one billion or more of them are manifest in our galaxy alone. It is entirely possible therefore that raw materials, values, and settings throughout the universe, are surprisingly similar and in entangled conditions. Our universe may be full of life and we need direct our attention to the manner in which living organisms transform information into *intelligence*.

A living organism is a unique self-supporting system that can only survive through its internal information set and collecting useful information from the environment. One distinction with non-living complex systems is that any self-generated behavior originating from within its system must be preceded by one or more *decisions* created within that system itself. A second distinction is that a living thing possesses an *internal sense of separation* between its physical and functional boundaries (Figure 10) and the environment (Walker, 2013). Each cell contains, apart from its plasma membrane, multiple functional organelles and at least 100.000 functional proteins, parts that operate in an amazing concerted action. How became all of this extreme complexity about? The particular guided assembly of the first replicating cells is unlikely to be a random process and it may rather be explained by an accelerated quantum search of a variety of life-sustaining structures in Nature (Davies, 2003; 2007, Meijer, 2013b). Taking into account that the human body has more than 50 *trillion* cells, that each embodies a wealth of information on its environment and internal functional structure, and realizing the number of humans on our planet, it follows that information transfer from and to the universal knowledge field, only of human intelligence, is beyond measure.

The Purpose of Human Existence: Observation and Participation

As mentioned above, John Wheeler hypothesized that we live in a participatory universe: the universe created human beings to help creating the universe. This implies that not only we depend upon the universe but that the universe also depends upon us: an enlightenment experience, that can be described as an individual's 'oneness' experience with the universe as a whole. Such a

perception of oneness can indeed be seen as a multi-layered experience. Two of the levels are always described as being unique to the individual: body/physical and mind/mental. The other two levels of existence are always described as being universal: a realm of intelligence and/or knowledge and a realm of consciousness and/or awareness ranging from the micro- to the macro-scale (Figure 6), that may directly correlate with the hardware and software systems of a self-synthesized information system.

This model of the universe as a self-synthesized information system also sheds new light on the part of the universe that somehow has gone "missing" to us human observers. The material world we know only represents 4% of the total mass/energy of the universe. The rest is unknown with regard to its composition: we call it Dark Energy and Dark Matter that appears to oppose the force of gravity and pushes our universe to even larger dimensions. Intelligence and consciousness are stored within the fabric of space itself (Seife, 2006).

Wheeler's Delayed Choice Experiment and its Cosmic Variant

Wheeler was intrigued by the famous double slit experiment. Rhodes (2003) elegantly explains the original double slit experiment: the results of Young's double slit experiment seemed to settle the question of the nature of light in a convincing fashion. The best explanation for the stripes of light, as shown on the back screen in Figure 8, was that they were the result of two symmetrical waves overlapping and interfering, which produced the stripes along the cross-section of the interference pattern at the back screen. However by detecting particles at the slits (observing it by a suitable detection instrument), we completely change the result at the back wall: the wave interference pattern immediately disappears and is replaced by the simple (clumped) particle pattern. This phenomenon is referred to as "the measurement effect." However what is crucial: the difference is whether we know. The difference is whether we choose to have the information available!

Wheeler asked himself what would happen if the decision to close one of the two slit interference system would be made *after* the particles had already passed through the two slits, at that time being on their way to the projection screen: would the interference pattern still disappear? To his surprise the time-symmetric equations clearly indicated that this should be the case. But how would these particles "know" that they would be exposed to a single slit earlier or in other words how could they look back in time? In other words: an event that we suppose has taken place in the past (impingement of the electron on the detector) will turn out to be correlated to a choice that we make in the present. It turns out indeed that the difference is whether the analysis of the results at the back wall is conducted when information about the electrons' positions at the slits is available, or not.

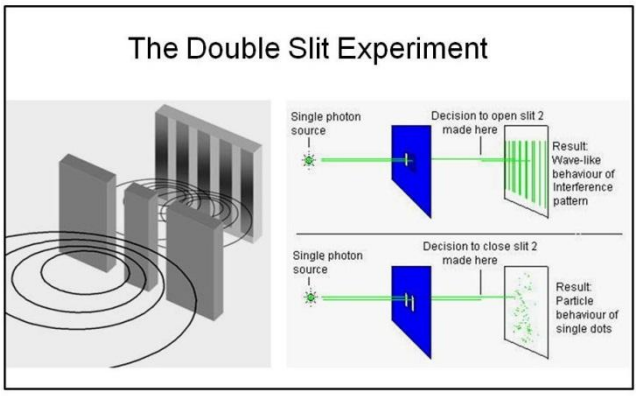

Figure 8. The two slit experiment, first carried out with multiple photons or electrons and later with the single particles, invariably showing a clear wave interference pattern on the screen (right) or, alternatively, a clumped particle pattern. The latter occurs if the particles are somehow detected at the two slits and these observations are analyzed/interpreted.

Recently, this wave form of particles was directly experimentally demonstrated, indicating that the wave function is physical and does not just indicate a probability distribution (Pusey, 2012) The wave world, that we humans cannot observe directly, is present in a reality domain that allows the presence of wave/particles at the *same time*, later on called wave particle duality! Note that waves propagate endlessly in time, so that waves, in contrast to the "frozen" particle state, have a future aspect!

Later laboratory experiments in various groups unequivocally demonstrated this delayed choice phenomenon (see for the many references**,** Gaasbeek, 2011 and Jacques *et al.*, 2006). Jacques *et al (*2006) stated: "Our realization of Wheeler's delayed choice *Gedankenexperiment* demonstrates beyond any doubt that the behavior of the photon in the interferometer depends on the choice of the observable which is measured, even when that choice is made at a position and a time such that it is separated from

the entrance of the photon in the interferometer by a space-like interval. In Wheeler's words, since no signal traveling at a velocity less than that of light can connect these two events, "we have a strange inversion of the normal order of time. We, now, by moving the mirror in or out have an unavoidable effect on what we have a right to say about the already past history of that photon". Once more, we find that Nature behaves in agreement with the predictions of quantum mechanics, even in surprising situations where a tension with Relativity seems to appear.

Yet, as discussed by Gaasbeek (2011), the delayed choice postulate may be debatable, since one should clearly distinguish between backward *causation* and backward *correlation.* This author rather prefers correlation since, as Wheeler made clear himself, "photons do not have a physical form until the moment they are measured", implying that a normal time ordering in a quantum domain does not apply. The citation above of Wheeler was also cited in the current Wikipedia text on "Wheelers delayed choice experiment", with the suggestion that Wheeler himself opposed the delayed choice concept perse.

However this seems close to a *rewriting* of scientific history (a rather peculiar form of backward causation!), since overseeing Wheeler's work, it is clear that he was utterly sure about the scientific value of his credo. Of note, it was recently stated that only if faster than light communication would be possible, photons can behave either definitely as a wave or definitely as a particle (Ma *et al*., 2013), again pointing to the inherent tension with the theory of Relativity. However, no one should be surprised by the different outcomes of Quantum mechanics and Relativity operations. Anyway, John Wheeler concluded that backward causation, in which a *future state* determines a present wave collapse, must operate here and that quantum information should be situated in a 4-dimensional domain in which past, present and future are manifest at the same time.

The Cosmic Variant of the Delayed Choice Experiment

John Wheeler even constructed a model of the delayed quantum choice on the cosmic scale: if conscious observers inspect the ultimate barriers of our universe by telescope, a site where we can still detect events of the big bang, being the supposed birth of our universe 13.5 million years ago, galaxies could function as "gravity lenses", bending the ancient light as photons into a giant two slit system (Figure 9).

Tim Folger (2002) writes about the cosmological model in Discover magazine: "Wheeler's hunch is that the universe is built like an enormous feedback loop, a loop in which we contribute to the ongoing creation of not just the present and the future but the past as well. Imagine, he says, a quasar — a very luminous and very remote young galaxy. Now imagine that there are two other large galaxies between Earth and the quasar. The gravity from massive objects like galaxies can bend light, just as conventional glass lenses do. In Wheeler's experiment the two huge galaxies substitute for the pair of slits; the quasar is the light source. Just as in the two-slit experiment, light — photons — from the quasar can follow two different paths, past one galaxy or the other. Suppose that on Earth, some astronomers decide to observe the quasars. In this case a telescope plays the role of the photon detector in the two-slit experiment."

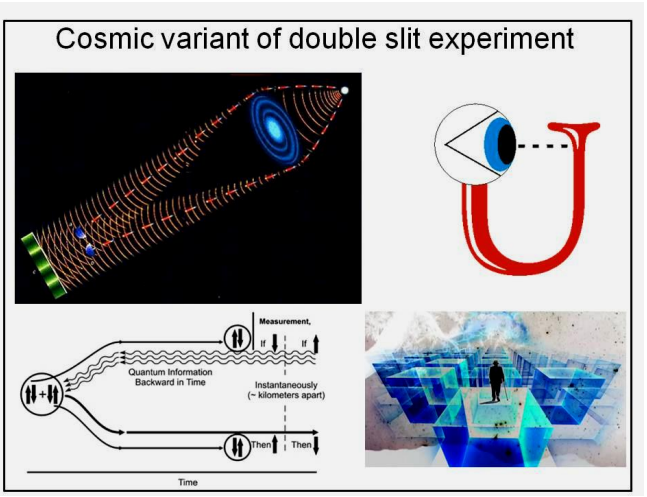

Figure 9. Cosmological variant with the principle of backward causation in which the universe observes itself in retrospect (above, left). The principle of backward causation is depicted below left and the universe observing its origin in a backward fashion through human observation (above, right) can also be pictured within a block universe context (below, right)

If the astronomers point a telescope in the direction of one of the two intervening galaxies, they will see photons from the quasar that was deflected by that galaxy; they would get the same result by looking at the other galaxy. But the astronomers could also mimic the second part of the two-slit experiment. By carefully arranging mirrors, they could make photons arriving from

the routes around both galaxies strike a piece of photographic film simultaneously. Alternating light and dark bands would appear on the film, identical to the pattern found when photons passed through the two slits. The quasar could be very distant from Earth, with light so faint that its photons hit the piece of film only one at a time. But the results of the experiment wouldn't change. The striped pattern would still show up, meaning that a lone photon not observed by the telescope traveled both paths toward Earth, even if those paths were separated by many light-years. By the time the astronomers decide which measurement to make, the photon could have already journeyed for billions of years, long before life appeared on Earth.

In 1984 physicists at the University of Maryland set up a tabletop version of the delayed-choice scenario. Using a light source and an arrangement of mirrors to provide a number of possible photon routes, the physicists were able to show that the paths the photons took were not fixed until the physicists made their measurements, even though those measurements were made after the photons had already left the light source and begun their circuit through the course of mirrors.

At every moment, in Wheeler's view, the entire universe is filled with such events, where the possible outcomes of countless interactions become real, where the infinite variety inherent in quantum mechanics manifests as a physical cosmos. And we see only a tiny portion of that cosmos. Wheeler suspects that most of the universe consists of huge clouds of uncertainty that have not yet interacted either with a conscious observer or even with some lump of inanimate matter. He sees the universe as a vast arena containing realms where the past is not yet fixed. The delayed choice of intelligent observers on earth or elsewhere in our galaxy and/or distant galaxies would than collapse primordial wave functions and thereby fix certain natural constants in the laws of nature into values that finally would enable the evolution of life in the universe and thus the creation of conscious and participatory observers.

Although the cosmic variant, rightfully, can be seen as speculative, the delayed choice and time symmetric (backward causation) aspects (Aharonov, 2010), may shed a light on the very evolution of first life: the blue print model for the first living and replicating cell, (and its irreducible complexity) may not be found in its past, but more likely was derived from its future! Such a quantum feed-back mechanism was earlier proposed by Paul Davies (2004) and Stuart Kauffman (2012) the latter is known from his work on self-aggregation processes in the evolution of life forms.

The Wheeler–Feynman Absorber Theory and Backward Causation

The Wheeler–Feynman absorber theory (also called the Wheeler–Feynman time-symmetric theory) is an interpretation of electrodynamics derived from the assumption that the solutions of the electromagnetic field equations must be invariant under time-reversal symmetry, as the field equations themselves. Indeed, Wheeler concluded there is no apparent reason for the time-reversal symmetry breaking which singles out a preferential time direction, that is which makes a distinction between past and future.

Feynman and Wheeler considered that all the charged particles (emitters) present in our universe, and assumed all of them to generate time-reversal symmetric waves. *It means that the radiation emitted by each particle is completely absorbed by all other particles present in the universe.* The resulting wave appears to have a preferred time direction, because it respects causality. However, this is only an illusion. Indeed it is always possible to reverse the time direction by simply exchanging the labels *emitter* and *absorber*. Thus, according to Wheeler, the apparently preferred time direction results from the arbitrary labeling. One of the major results of the absorber theory is the elegant and clear interpretation of the electromagnetic radiation process. A charged particle which experiences acceleration is known to emit electromagnetic waves, i.e., to lose energy.

Yet, the time-symmetric interpretation of the electromagnetic waves appears to be in contrast with the experimental evidence that time flows in a given direction and, thus, that the T-symmetry is broken in our world. It is commonly believed, however, that this symmetry breaking appears only in the thermo-dynamical limit (see, for example, the arrow of time). Wheeler himself accepted that the expansion of the universe is not time symmetric in the thermodynamic limit. This however does not imply that the T-symmetry must be broken also at the microscopic level. Later, this theory likely formed the basis for the so

called *"Transactional Interpretation of Quantum Mechanics"* by John Cramer. Cramer stated that: "Nature, in a very subtle way, may be engaging in backwards-in-time handshaking. The transaction between retarded waves, coming from the past and advanced waves, coming from the future, gives birth to a quantum entity with dual properties of the wave/particle. Thus the wave property is a consequence of the interference between retarded and advanced waves, and the particle property is a consequence of the point in space where the transaction takes place".

Consequently, the transactional interpretation requires that waves can really travel backwards in time. This assertion seems counterintuitive, as we are accustomed to the fact that causes precede effects. It is important to underline however that, unlike other interpretations of QM, the transactional interpretation takes into account special relativity theory which describes time as a dimension of space, as mentioned earlier. Of note, the completed transaction erases all advanced effects, so that no direct advanced wave signaling is possible: The future can affect the past only very indirectly, by offering possibilities for transactions" (Cramer, 1988).

Aharonov (2010) proposed a new framework called time-symmetric quantum mechanics. Generally the protocol included three steps: a "pre-selection" measurement carried out on a group of particles; an intermediate measurement; and a final, "post-selection" step, in which researchers picked out a subset of those particles on which to perform a third, related measurement. To find evidence of backward causality, (information flowing from the future to the past), the effects of, and so called, weak measurements were studied. Aharonov and Vaidman (1990) assigned to a quantum function at a given time *two* wave functions, one evolving from the past to the present and another evolving from the future toward the past. The so called weak value of a quantum variable is the physical property between preselected and post-selected measurements in which the time interval is symmetric under time reversal. Usual (strong) measurements would immediately collapse the wave functions in superposition to a definite state. Yet, repeated post-selection weak measurement of the weak type however clearly changed the pre-selection state, revealing a time-backward aspect of non-locality.

Thus, according to Aharonov, it appears that the universe might have a destiny that interacts with the past, in order to bring the present into view, clearly supporting the ideas of John Wheeler of potential backward causation. As mentioned above, according to Wheeler's and Feynman's electrodynamics, emitters coincide with retarded fields, which propagate into the future, while absorbers coincide with advanced fields, which propagate backward in time. This time-symmetric model leads to predictions identical with those of conventional electrodynamics. For this reason it is impossible to distinguish between time symmetric results and conventional results (Wheeler and Feynman, 1949).

Chris King (2014) strongly favors the transactional interpretation of EPR type non-local quantum correlations. As mentioned above, in the transactional interpretation of non-local events, when a measurement is made on an entangled particle, it sends a photon back in time to when it and the other entangled particle were emitted, and then forward in time to the second entangled particle. Thus the net time taken to send the quantum information about the measurement of the first particle is zero, and the effect of measurement on the second particle appears to be instantaneous, despite the spatial gap between them. Thus backward travel in time, which looks like a rather exotic feature, is allowed by the laws of physics as embodied in both the Maxwell and Schrodinger equations. King stated that "the transactional interpretation of non-locality can be combined with quantum computing to give a space-time anticipating system and that this may be even basic to the way the brain works. Since the photon is its own anti-particle, a negative energy photon traveling backwards in time, is precisely a positive energy one traveling forwards. Weak quantum measurement changes the wave function slightly mid-flight between emission and absorption, and hence before the particle meets, the future absorber involved in eventual detection. A small change is induced in the wave function, e.g. by slightly altering its polarization along a given axis (Kocsis *et al.*, 2011). This cannot be used to deduce the state of a given wave-particle at the time of measurement because the wave function is only slightly perturbed, and is not collapsed or absorbed, as in strong measurement, but one can build up a prediction statistically over many repeated quanta of the conditions at the point of weak

measurement, once post-selection data is assembled after absorption.

Within cells, quantum information may be transferred via vibratory proteins or through ions such as Ca2+ that can be in a coherent state in de-coherence shielded Ca-channel proteins (Meijer, 2014 a), see Figure 10.

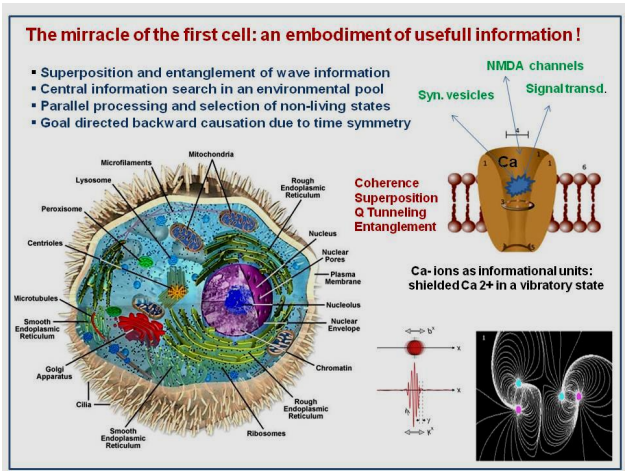

Figure 10. Fabric of the first cell through integration of information, as steered by basic quantum mechanisms (left above). De-coherence shielded Ca-ions in Ca- channel proteins may function as quantum information sensitive vibratory units (inset above right). Ca2+ ions influence a spectrum of intracellular regulatory processes (Meijer, 2014a).

Weak quantum measurements (WQM) have been used to elucidate the trajectories of the wave function during its passage through a two-slit interference apparatus (Kocsis *et al*., 2011), and to determine all aspects of the complex waveform of the wave function (Hosten, 2008; Lundeen *et al*., 2009). WQM provides a potential way that the brain might use its brain waves and phase coherence to evoke entangled (coherent) states that carry quantum encrypted information about immediate future states of experience as well as immediately past states, in an expanded envelope - the quantum present. It is this coordinated state that corresponds to subjective experience of the present moment, encoded through the parallel feature envelope of the cerebral cortex, including the areas associated with consciousness. Effectively the brain is a massively parallel ensemble of wave excitations reverberating with one another, through couplings of varying strength in which excitations are emitted, modulated and absorbed. Interpreted in terms of quantum excitations, the ongoing conscious brain state could be a reverberating system of massively parallel weak quantum measurements of its ongoing state. Intriguingly, continued weak quantum measurement, rather than provoking decoherence tends to preserve entanglement because the ordered nature of the weak quantum measurements reduces the disordered nature of the environment (Hosten, 2008; Lundeen *et al.,* 2009). Massively parallel weak quantum measurements in the brain might thus function to maintain the ongoing entanglement".

As mentioned above: a great puzzle in physics has been how to reconcile Einstein's theory of general relativity with quantum mechanics. General relativity remains the main theory for describing gravity, and is extremely accurate for with large objects (stars and planets, etc.). Quantum mechanics, on the other hand, is our main theory for dealing with microscopic objects, and the other three fundamental forces which act at the atomic scale. General relativity describes space as being a smooth surface, but quantum mechanics reveals a discontinuous microscopic world with constant fluctuations and activity. So, each of these theories is accurate in its own right but they describe the nature of space and matter so differently that it has proven highly problematic to combine the theories into a single unified theory.

The Concept of Time and the Wheeler-DeWitt Equation

There's something remarkable about the Wheeler-DeWitt equation: *the rate of change of the state of the universe with respect to time is zero*. The universe is not changing with time! As Andrei Linde explains: "The notion of evolution is not applicable to the universe as a whole since there is no external observer with respect to the universe, and there is no external clock that does not belong to the universe" (Linde, 2003). Therefore, the Wheeler-DeWitt equation agrees with the analysis of the nature of time of Einstein and Minkowski, because it suggests a block universe model in which all of time is laid-out (just as the space dimension is laid-out), and all times are equally real: there is no special "now", no distinction between past and future. In fact, in this framework "past" and "present" do not exist - the movement of time is considered to be just an illusion of human perception. Essentially, this means that the whole space-time "cone", exists as an unchanging structure. It is true that there is a time dimension defined within the universe. And for an observer within the universe, objects

appear to change with respect to this time axis. However, this apparent flow of time, according to Einstein, is just an illusion of human perception due to the asymmetry of the time dimension. As there is no clock outside the universe, there is no "external" time axis, and the external view of the entire universe structure can therefore never change with respect to that non-existent external time axis. This lack of temporal change in the entire universe structure has the following implications.

As stated by Thomas (2010) consequently, the "Big Bang" does not really represent the "start" of the universe. Remember, all times are equally real in the block universe - there is nothing special about time at the "Big Bang". As all times are equally real, the final state of the universe is just as real as the initial state. So the so-called "initial" Big Bang tells us nothing more about the existence of the universe than the "final" state does. While it is true that to an observer within the universe, the Big Bang might appear like the start of the universe, this is revealed to be an illusion of human perception caused by the psychological arrow of time.

Another striking conclusion is that the universe did not "emerge from nothing". It is meaningless to talk of the "start" of the universe, or the "emergence of the universe from nothing", or any other term which implies change of the entire block universe structure over time. The entire space-time block is laid out as one unchanging structure. Here's a quote from Stephen Hawking's book "*A Brief History of Time*": *"*If the universe is really completely self-contained, having no boundary or edge, it would have neither beginning nor end: it would simply *be"* (Hawking, 1988). This means that any theory which attempts to explain the existence of the universe, solely in terms of events which happened at the Big Bang, would appear to be clearly wrong. This also includes any theory which suggests the reason for the existence of the universe is because the universe "emerged from nothing" (so-called *ex nihilo* solutions)".

The Hidden Dimensions of Space-time

As treated above, Wheeler's model of the universe as a self-synthesized information system requires a deep layered communication system in order to enable a continuous exchange of information that is updating the integral state of the system. Yet, a universe that is somehow fine-tuned for the creation of life is not enough: rather the entire environment that houses intelligent life forms should be monitored. A universe containing only four dimensions does not provide the necessary conditions for this. For an adequate steering of this huge and complex process one needs an orchestrated knowledge system that can instantly receive and broadcast essential information in order to maintain the necessary conditions for survival and further elaboration of the living universe. Recent studies (Smythies, 2003; Carter, 2014) indicate that for this purpose more than four space-time dimensions are very likely required: at least two extra imaginary dimensions must be part of the total structure.

Wheeler devised the concept of quantum foam: a field of virtual particles popping in and out of existence in space, and considered it as the foundation of fabric of the universe (Wheeler, 1985). A larger set of dimensions provides a richer decision-making environment which benefits the universe by increasing the size and complexity of its information matrix more rapidly. Such perceivable dimensions must exist everywhere, and at all times and be perceivable by the decision-making (i.e. mental) apparatus of living and intelligent organisms. Thereby they become observers and at the same time participators in the evolution of the whole. This means that they must be composed of the smallest possible 'constituents' available to the universe, and can be linked together into three-dimensional 'sheet-like' screens upon which they can be displayed and perceived by the living thing. What we need is a theory that would require the necessity of these extra dimensions and would account for the five separate, but related information fields, composed of a single, underlying substance.

In fact, the challenges of string theory help confirm this model of our universe as a self-synthesized information system; conversely, this model represents the overarching theory that string theorists have been seeking: *M-Theory.* The five separate, but related string theories may match various information fields, including the manner in which they transmute into each other (Figure 11, inset right above). Theoretical physicists were troubled by the existence of five separate string theories. A possible solution for this dilemma was suggested at the beginning of what is called the second superstring revolution in the 1990s, which suggests that the five string theories might be different limits of a single

underlying theory, called M-theory (Figure 11).

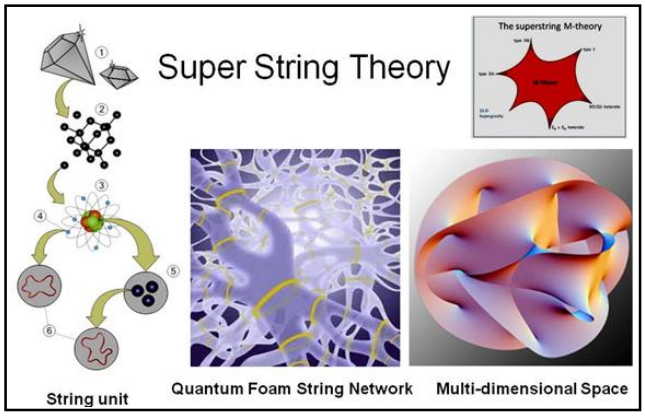

Figure 11. The String/M-theory: electrons and quarks, as parts of the atoms of a crystal, are vibration modalities of strings (A), three dimensional string membranes (B) and curled-up space dimensions (C).

Interactions between vibrating strings, involve the splitting apart and joining together of string loops. But the microscopic frenzy dictated by the uncertainty principle implies that string/anti-string pairs (two strings executing opposite vibrational patterns) can momentarily erupt into existence, borrowing energy from the universe, so long as they annihilate one another with sufficient haste, thereby repaying the energy loan. Such pairs of strings, which live on borrowed energy and hence must shortly recombine into a single loop, are known as virtual string pairs. And even though it is only momentary, the transient presence of these additional virtual string pairs affects the detailed properties of the interaction" (see also Green, 2000; 2004). An alternative for a string matrix is the hypothesis of spin networks as the connecting principle at the Planck level (Smolin, 2004; Rovelli, 2003)

The Ultimate Fate of our Universe: its Death and Rebirth

Wheeler sincerely believed that science will ultimately be able to provide an explanation of the origins of human intelligence in the future (Wheeler, 1994). This corresponds to his implicit desire to treat both intelligence as well as the intelligible image of the universe as emergent properties. He fully believed that finally physics would find an answer to how and why we are here. He envisioned this as genesis by observer ship.

Wheeler represented the universe as a self-excited circuit that is as developing through a cycle (closed loop) which excludes reference to any preexistent foundation outside this circuit. The sense of physical reality is not a pre-given compendium of laws and facts. It originates in the constitution of this reality, through formation of meaning of the universe by communication in the network of observers. Wheeler thought that the observer participates in choosing now the physical laws for the entire past and future history. He coined this vision "law without" law, (Wheeler, 1983). He wrote: "if the views that we are exploring here are correct, one principle, observer participancy, is able to build everything. The present expansion of the universe from the time of its inception up to a certain point is maintained until the system has had enough time to mature and create enough sentient beings that the conversion of information into software reaches a tipping point. It then may reverse from a state of deceleration to acceleration and in the shrinking phase, information will be condensed and compressed in order to create the conditions for rebirth of the entire Universe". The question is which role mankind and its successors as well as other intelligent species will play in the latter process. Wheeler developed a model, not only taking into account the particular future, but interestingly also the past of the Universe.

Yet, if Wheeler claims that the observers bring the universe into being, including its space, time, etc. (Wheeler, 1990), then one can reasonably ask: where do human observers do this from, if there is no preexistent space and time? One can conjecture that human beings belong to "something" which is beyond and prior to space and time and which, at the same time, contains in itself the potentiality of being explicated in terms of space and time. Then the process of constitution of the universe in Wheeler's participatory scheme reveals itself. That is: the universe itself becomes no more than an event related to the history of humanity, a flash of the universe's self-consciousness as depicted in Wheeler's writings by a diagram of the human eye emerging in the bold letter U (symbolizing the universe) which itself is the formation of this eye (see Figure 9, from Wheeler, 1994). Representations of such a unity: in an image of the so called Uroboros: symbolizing the interconnectedness of physical entities at different spatial scales of the universe (Primack, 2006). The way to perceive the university is to

constantly look from one perspective of scale to another. In the end, all scales may be unified in a Grand Unified Theory (Gut). The serpent swallowing its own tail represents the current hope that gravity can link the largest and smallest sizes in a final theory.

Both the becoming and future of the Universe can therefore be viewed as an unfolding of primordial information provided by a cycling universe (Linde, 2003; Steinhardt, 2007; Penrose, 2010), delivering a recipe from a previous version of the present Universe. Bekenstein, 2003, a former student of Wheeler, and more recently Verlinde (2011) confirmed his idea that atoms and their constituting elementary particles can intrinsically store basic and physical information in the form of spin, polarization and momentum and that this information can being seen as stored in bits or Qbits through holographic projection on a virtual screen**.** This model applies both to the micro- (elementary particles/atoms) and macro-(black holes) levels. The principle of the hologram was also employed by Mitchell and Staritz (2011) in relation to individual and universal consciousness.

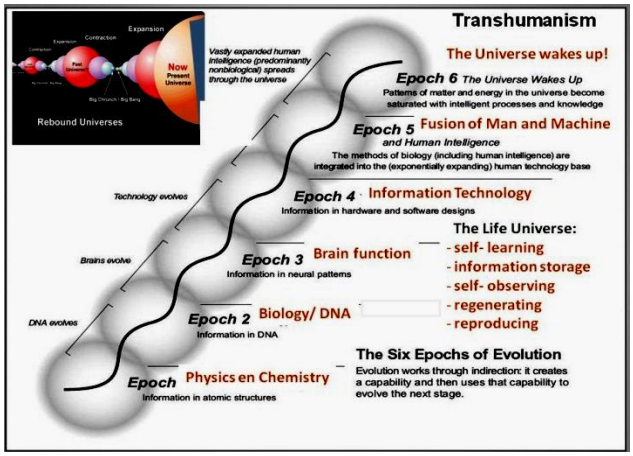

Figure 12. The sequential epochs in the evolution of our universe, also depicting the very far future of a "living" Universe (see text right in the middle), in a cyclic rebound universe model (top left) in which the universe takes care of its own reproduction (after Kurzweil , 2005).

Barrow and Tipler (1988) developed a dynamic model of the universe which will guarantee the possibility of indefinite information processing, which, according to Tipler must imply the persistence of life in the universe. This led Wheeler to an intuition that such a representation of the universe can be seen a mental accomplishment. This may even reach to the far future of the universe and even to its potential rebirth. Trans-humanists project that our "mind children", as very advanced, hybrid, (cyborg) machines, will ultimately travel to the boundaries of the universe, not restricted by the current limitations of the human body, and will eventually collect all the information about the universe and its total past history. As long as the universe does not die in a heating process, the universe will be gradually populated, and will finally become saturated with information (see Tipler, 1995; Kurzweil, 2005; and epoch 6, depicted in Figure 12).

However physics foretells that our world will not be everlasting…This is because our Universe is finally doomed to a heat death (by final contraction of the Universe) or, alternatively, destined for a cold death (by a further rapid expansion of the Universe). Vidal (2012) and Vaas (2006) postulate a programmed transfer of the total, condensed, information of the dying universe into an adjacent new "baby universe" may enable such a recreation process. It is assumed in this theory that our descendents and/or other advanced forms of intelligence will master the physics of black holes or wormholes, seen as giant portals to other universes. These giant cosmological structures could be manipulated to pass the required information as a recipe for the birth of a new version of our universe (an engineered Big Bang)! Thus our successors, in the far future, may give a new start to our universe in a kind of circular evolutionary process (see for circular universe models also Gott, 1997; Steinhardt, 2008; Penrose, 2012; Vidal, 2012).

The universe seems to be isomorphic to a mathematical structure (Stoica, 2013), as was also proposed by Lloyd (2006) and Tegmark (2008). It seems based on natural law with their empirical constants that may not have a real constant value in the evolution of the Universe. But Wheeler's philosophy law without law goes far beyond the idea of a mechanism of random mutations of the constants. He viewed the law as being created, or perhaps chosen from infinity of alternatives, by the very observation process. The bit not only determines the (past) it of the universe, but also the laws. Anyway, it seems very plausible that there may be a (possibly infinite) collection of propositions which contains all the truths about the universe. In this case, we have a theory (of everything).

In this sense the Universe at micro- and macroscales can be viewed upon as a dynamic

flow of information at each level of organization. The projections of Gott (1997), Penrose (2010), Steinhart and Turok (2007), and many other scientist that have theorized on cyclic models of the Universe, can also be interpreted to mean that our own reconstructed Big Bang, that is often seen as the real start of the present cosmos, is rather a reflection of information transfer from a *previous version* of our Universe. However, will each cosmic cycle encompass identical information, so that all of us will be reproduced, or will each rebirth also contain novel information and innovations, leading to ever growing complexity and intelligence of cosmic life?

Final Conclusions

According to nature-for physicists, as constituted through questions and answers, which it itself is a mental accomplishment, one should treat Wheeler's genesis of meaning as an ever-going mental completion of the concept of nature, (Nesturuk, 2013). The meaning of reality can only be established if there is a field with some trans-empirical features, which transcend physical past, present and future (Wheeler, 1983), an aspect later on highlighted by Laszlo (2007). The more radical, metaphysically oriented conclusion of Wheeler is that the overall reality, that is the totality of the world, is constituted through the interaction between the inarticulate "out there" with humans and perhaps other intelligent agencies who create the network of questions and answers directed to and received from what they intend to call "reality". Wheeler indeed represented the universe as a self-excited circuit that is as developing through a cycle (closed loop) which excludes reference to any preexistent foundation outside this circuit (Wheeler, 1988). In fact, he stressed the point that this so called "evolution" cannot be seriously treated as related to the objective pole in the universe, that is as a physical or biological evolution, devoid of the human insight.

Wheeler could never stop teaching nor stop learning. During one of his visits, he ran into a young physicist who briefed him his "new cosmological theory", postulating that the universe is riddled with knot-like spatial "defects." I can't believe space is that crummy, Wheeler declared! Noting the young physicist's somewhat perplexed expression, Wheeler touches his arm and says: "To hate is to study, to study is to understand, to understand is to appreciate, to appreciate is to love. So maybe I'll end up loving your theory….

It stands to reason: John Wheeler's vision that the fabric of reality may *finally* be understood and mankind even may ultimately perceive the ground of its own existence, was probably correct. This final perception may even turn out to be surprisingly transparent, beautiful, and compelling. At that time, albeit in the far future, we may also uncover the purpose of human existence, and fully see personal responsibility for our planet and the entire cosmos in a different light (Figure 12). To know that all of us have a role to play in the universe, should matter to each and every one of us and motivate us to take our personal responsibility. When we become real participants, we may truly make our world, and the universe as a whole, a better place for ourselves and all that is living. Ultimately we may even understand our own position in this grand design, as Wheeler formulated splendidly:

> "*Someday we'll understand the whole thing as one single marvelous vision that will seem so overwhelmingly simple and beautiful that we may say to each other: 'Oh, how could we have been so stupid for so long? How could it have been otherwise!"* Wheeler (2002).

References

Aharonov Y, Popescu S, Tollaksen J. A time-symmetric formulation of quantum mechanics. Physics Today 2010; November: pp.27-32

Aharonov Y, Vaidman. Properties of a quantum system during the time interval between two measurements. Physical Review 1990; 41: 11.

Barbour J. Bit from it. 2011; http://fqxi.org/data/essay-contest-files/Barbour_Wheeler.pdf

Barrow JD, Tipler FJ. The Anthropic Cosmological Principle. Oxford University Press, 1988.

Bekenstein J. Information in the holographic universe. Sci Am 2003; 289: 58-65.

Benford G, Book D, Newcomb W. The Tachyonic Antitelephone. Physical Review D 1970; 2: 263. doi:10.1103/PhysRevD.2.263

Bohm D. Wholeness and the implicate order, London: Routledge & Kegan Paul, 1980.

Bostrom N. Are You Living In a Computer Simulation? Philosophical Quarterly 2003; 53, No. 211: 243-255.

Carter B. The Anthropic Principle and Its Implications for Biological Evolution. Philosophical Transactions of the Royal Society of London Series A 1983; 310: pp 352-363.

Carter PJ . Consciousness and perception of higher-dimensional quantum space-time. NeuroQuantology 2014; 12(1): 46-75. DOI: 10.14704/nq.2014.12.1.724

Cho A. Furtive Approach Rolls Back the Limits of Quantum Uncertainty. Science 2011; 333: 690-693

Cramer J. An Overview of the Transactional Interpretation. International Journal of Theoretical Physics 1988; 27: 227

Davies P and Gregersen NH. Information and the Nature of Reality: From Physics to Metaphysics. Cambridge: Cambridge University Press, 2010.

Davies PCW. The Origin of Life. London, Penguin, 2003.

Davies P. Cosmic Jackpot. Why Our Universe Is Just Right for Life. Houghton Mifflin Company, 7:139-150, 2007.

Davies PCW. Quantum fluctuations and life. 2004; Available at: arXiv: quant-ph/0403017

Di Biase FA. Holoinformational Model of Consciousness. Quantum Biosystems 2009; 3: 207-220.

Dicke RH. Dirac's Cosmology and Mach's Principle. Nature 1961; 192: 440–441.

Folger T. Does the Universe Exist if We're Not Looking? Discover Magazine 2002.

Foschini L. Where the it from bit come from? 2013; Essay for the 2013, FQXi Contest arXiv:1306.0545 [physics.hist-ph]

Gaasbeek B. Demystifying the delayed choice experiments. 2011; arXiv:1007.3977v1 [quant-ph], http://arxiv.org/abs/1007.3977

Germine M. The Holographic Principle Theory of Mind. 2007. http://goertzel.org/dynapsyc/2007/holomind.htm

Görnitz T. Quantum Theory as Universal Theory of Structures – Essentially from Cosmos to Consciousness, in: Cotaescu I (Ed.), Advances in Quantum Theory. InTech, 2012.

Gott JR, Li X-Li. Can the Universe create itself? Phys Rev D58 1997; 58 (2): 023501-1 http://arxiv.org/abs/astro-ph/9712344v1

Greene B. The Elegant Universe. Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory. Vintage Books, 12:313, 2000.

Greene B. The Fabric of the Cosmos. About the Search for the Theory of Everything, Utrecht. The Spectrum, 2004.

Harvard-Smithsonian Center for Astrophysics, Press Release No.: 2013-01, At Least One in Six Stars Has an Earth-sized Planet, January 07, 2013.

Hawking SW. A Brief History of Time. New York: Bantam Books. p.174, 1988.

Henry RC. The Mental Universe. Nature 2005; 436(7): 29

Holland P. Quantum back-reaction and the particle law of motion. 1996.

Hosten O, Kwiat P. Observation of the Spin Hall Effect of Light via Weak Measurements. Science 2008; 319: 787-790.

Hoyle F. Intelligent Universe. A new view of creation and evolution. Publisher: Book Sales, 1988.

Jacques V, Wu E, Grosshans F, Treussart F, Grangier P, Aspect A and Roch J-F. Experimental realization of Wheeler's delayed-choice GedankenExperiment, 2006. http://arxiv.org/abs/quant-ph/0610241v1

Kafatos M, Tanzi R E, and Chopra D. How Consciousness Becomes the Physical Universe. J Cosmol 2011; 14: 1-11.

Kak S. The Universe, Quantum Physics and Consciousness. J Cosmol 2009; 3: 500-510

Kauffman S. Answering Descartes: Beyond Turing. MIT Press, 2012.

Keeton H. Physics and Whitehead: quantum, process, and experience. SUNY Press, 2004; p.181.

King CC. Space, Time and Consciousness. http://www.dhushara.com/stc/ct.htm, 2014.

Kocsis S, Braverman B, Ravets S, Stevens MJ, Mirin RP, Shalm LK & Steinberg AM. Observing the average trajectories of single photons in a two-slit interferometer. Science 2011; 332: 1170-1173.

Kuhn RL. Why this universe? Toward a taxonomy of possible explanations. Skeptic 2007; 13(2): 28-39

Kurzweil R. The Singularity is Near. When Humans Transcend Biology. Viking, 2005.

László E. The Akashic field. New York, Dutton, 2007.

Levin T. Holographic Trans-disciplinary Framework of Consciousness: An Integrative Perspective Journal of Consciousness Exploration & Research 2011; 2(9): 1385-1416.

Linde A. Inflation, Quantum Cosmology, and the Anthropic Principle, in: Barrow JD, Davies PCW and Harper CL eds. Science and Ultimate Reality: From Quantum to Cosmos, honoring John Wheeler's 90th birthday. Cambridge University Press, 2003.

Loyd S. Programming the Universe: A Quantum Computer Scientist Takes On the Cosmos, Knopf Doubleday Publishing Group, (Random House), 2006.

Lundeen JS, Steinberg AM. Experimental Joint Weak Measurement on a Photon Pair as a Probe of Hardy's Paradox. Phys Rev Letters 2009; 102: 204.

Ma X-S, Kofler J, Qarry A, Tetik N, Scheidl T, Ursin R, Ramelow S, Herbst T, Ratschbacher L, Fedrizzi A, Jennewein T, and Zeilinger A. Quantum erasure with causally disconnected choice. PNAS 2013; 110(4): 1221–1226.

Meijer DKF. The Information Universe. On the missing link in concepts on the architecture of reality. Syntropy Journal 2012; 1: 1- 64.

Meijer DKF and Korf J. Quantum modeling of the mental state: the concept of a cyclic mental workspace. Syntropy Journal 2013; 1: 1-41.

Meijer DKF. Information: what do you mean? Syntropy Journal 2013a; 3: 1-49

Meijer DKF. Immortality: Myth or becoming Reality? Syntropy Journal 2013b; 3: 166-203.

Meijer DKF. The Extended Bran: Cyclic Information Flow in a Quantum Physical Realm. NeuroQuantologgy 2014a; 12: 180-200.

Meijer DKF and Raggett S. Quantum Physics in Consciousness Studies. The Quantum Mind Extended. 2014b.

Misner CW, Thorne KS, Zurek WH. John Wheeler, relativity and quantum information. Physics Today 2009; April, pp.40-46.

Misner CW, Thorne KS, Wheeler J A. Gravitation, Physics Series, 1973

Mitchell E D and Staretz R. The quantum hologram and the nature of consciousness. J Cosmol 2011; 14: 1-35.

Morris M, Thorne K, Yurtsever U. Wormholes, Time Machines,

and the Weak Energy Condition. Physical Review Letters 1988; 61(13): 1446–1449.
Nesturuk AV. From the Unknowbility of the Universe to the Teleology of Reason: A Phenomenological Insight into Apophatic Cosmology". In J. Bowker (Ed.) Knowing the Unknowable: Science and Religion on God and the Universe, I. B. Tauris & Co Ltd, pp. 63-86, 2009.
Nesturuk AV. A Participatory Universe of JA Wheeler as an intentional correlate of embodied subjects and example of purposiveness in physics. J Siberian Fed Univ 2013; 6:415-437
Penrose R. Cycles of Time. An Extraordinary New View of the Universe. London: Bodley Head, 2010.
Primack J, Abrams N E. The View from the Centre of the Universe. Discovering our Extraordinary Place in the Cosmos. London: Fourth Estate, 2006.
Pusey MF, Barret J and Rudolph T. On the reality of the quantum state. Nature Physics 2012; 8: 475-478. http://lanl.arxiv.org/abs/1111.3328
Rhodes R. The Reality program. Chapter 2: The double slit experiments, 2000.
Rovelli C. Loop Quantum Gravity. Physics World 2003; November, pp. 1-5
Ross H. Design and the Anthropic Principle. http://www.reasons.org/articles/design-and-the-anthropic-principle Accessed Date: March 10, 2015.
Seife C. Decoding the Universe. How the new science of information is explaining everything in the cosmos, from our brains to black holes. Penquin books, New York. 2006.
Smolin L. Atoms of space and Time. Scientific American, 2004; February, pp.43-52
Smythies J. Space, time & consciousness. Journal of Consciousness Studies 2003; 10(3): pp. 47-56.
Steinhardt PJ and Turok N. Endless Universe: Beyond the Big Bang, (Doubleday), London: Weidenfeld & Nicolson, 2007.
Stoica C. The Tao Of It and Bit. FQXI essay 2013; http://arxiv.org/pdf/1311.0765.pdf
Sutherland R J. Causally symmetric Bohm model, 2006.
t'Hooft G. The Holographic Principle. Basics and Highlights. In: Fundamental Physics The Subnuclear Series, Vol. 37, Zuchichi, A, Ed.; Singapore, World Scientific, 2001; pp 72–100.
Tegmark M. The mathematical universe. Found Phys 2008; 38:101-150, arXiv:0704.0646 [gr-qc]
Thomas A. What is Reality. 2010. http://www.ipod.org.uk/reality/
Thorne K. The Science of Interstellar, Norton, 2014.
Tipler F. The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead. New York: Anchor Ultimate Reality, Cambridge: Cambridge University Press, 1995.
Tononi G. Consciousness as Integrated Information: a Provisional Manifesto. Biol Bull 2008; 215(3): 216-242.
Vaas R. Time before Time. Classifications of universes in contemporary cosmology, and how to avoid the antinomy of the beginning and eternity of the world. 2004. arXiv:physics/0408111
Vaas R. Dark energy and Life's ultimate fate. in: Burdyuzha, Vladimir (Ed.): The Future of Life and the Future of our Civilization. Dordrecht, Springer, 2006; pp. 231-247. http://philsci-archive.pitt.edu/3271/1/Vaas-DE.pdf
Van Flanderen. The speed of gravity- What the experiments say, 1998.
Vannini A and Di Corpo U. Quantum Physics, Advanced Waves and Consciousness. J Cosmol 2011; vol 14. http://journalofcosmology.com/Consciousness101.html
Vedral V. Decoding Reality, Oxford, U.K, University Oxford Press, 2010.
Verlinde EP. On the Origin of Gravity and the Laws of Newton. J. High Energy Physics;2011; 04: 1-29.
Vidal C. The Beginning and the End: The Meaning of Life in a Cosmological Perspective, 2013. arXiv:1301.1648
Visser M, Liberati S and Sonego S. Faster-than-c signals, special relativity, and causality. Annals of Physics 2002; 298: 167–185. doi:10.1006/aphy.2002.6233.
Von Baeyer HC. In the beginning was the bit. New Scientist 2001, febr. 17: 26-30 http://www.quantum.at/fileadmin/links/newscientist/bit.html
Von Weizäcker CF, Gornitz T and Lyre H. The Structure of Physics. Dordtecht, Springer, 2006.
Walker III R W. This is it, 2013.
Wheeler JA. On recognizing 'law without law'. Oersted Medal response at the joint APSAAPT meeting, New York, 25 January, 1983. American Journal of Physics 1983; 51:398.
Wheeler JA. Information, Physics, Quantum: The Search for Links. In: W H Zureck (ed.), Complexity, Entropy, and the Physics of Information, Redwood City, CA: Addison Wesley, 1990.
Wheeler JA, Feynman RP. Classical Electrodynamics in Terms of Direct Inter-particle Action. Reviews of Modern Physics 1949; 21: 425-433
Wheeler JA. World as system self-synthesized by quantum working. J Res Develop 1988; 12: 4-18.
Wheeler JA, Geons FK. Black Holes and Quantum foam. A life in physics. 1985.
Wheeler JA. Foreword, in: The Anthropic Cosmological Principle. John D. Barrow and Frank J. Tipler, Oxford, U. K.: Clarendon Press, 1986.
Wheeler JA. At Home in the Universe, New York Institute of Physics, 1994.
Wilczek F. Getting its from bits. Nature 1999; 397: 303-306.
Wikipedia.org. Observable universe. Wikipedia, the free encyclopedia; 2013 [online] Available at: http://www.wikipedia.org/wiki/Observable_universe. Accessed date: 15-3-2015
Yin J, Cao Y et al. Lower Bound on the Speed of Nonlocal Correlations without Locality and Measurement Choice Loopholes. Phys Rev Lett 2013; 110 (26): 260407. DOI: http://dx.doi.org/10.1103/PhysRevLett.110.260407
Zeilinger A. Quantum Teleportation. Sci Am 2000; April: 8-16.
Zeilinger A . Why the Quantum? It from Bit? A Participatory Universe? Three Far Reaching, Visionary Questions from John Archibald Wheeler and How They Inspired a Quantum Experimentalist; 2005. http://www.metanexus.net/archive/ultimate_reality/zeilinger.pdf
Zizzi P. Consciousness and Logic in a Quantum-Computing Universe. In: The Emerging Physics of Consciousness. The Frontiers Collection, Chapter 14, pp.457-481. DOI: 10.1007/3-540-36723-3_14, Berlin, Springer, 2006