Exploration

IIT, TGD, ZEO & Qualia

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Abstract

The integrated information theory (IIT) of Tononi and Koch that appeared around 2015 is materialistic and does not discuss problems like free will. The IIT approach does not mention quantum physics and the connections to physics are also otherwise rather meager. Deterministic information processing involving feedback is assumed to be an essential prerequisite of consciousness. The approach starts from panpsychism and deduces a quantitative criterion claimed to serve as a measure for the level of consciousness of the system considered. The somewhat surprising conclusion is that computers are probably not conscious. I have written about IIT around 2016 but at that time I was not mature to realize that the proposal of the review article for the identification of qualia allows to sharpen the TGD view of qualia in terms of zero energy ontology (ZEO). The improved understanding of ZEO and the emergence of holography = holomorphy vision leading to the interpretation of space-time surfaces as numbers motivates the reconsideration of the questions related to IIT,TGD,ZEO and qualia.

1 Introduction

Gary Ehlenberg sent a link to an article about Integrated Information Theory of consciousness (IIT) [J1] (see this). The article gives a nice summary of IIT as it was 2015. Gary wondered whether quantum theory is completely left out. The suspicion of Gary was correct: there is no mention of quantum theory. I have written about IIT around 2016 [9, 8] but at that time I was not mature not realize that the proposal of the review article for the identification of qualia allows to sharpen the TGD view of qualia in terms of zero energy ontology (ZEO).

The approach of Tononi and Koch is materialistic and does not discuss problems like free will. The approach does not mention quantum physics and the connections to physics are also otherwise rather meager. Deterministic information processing involving feedback is assumed to be an essential prerequisite of consciousness. The approach starts from panpsychism and deduces a quantitative measure claimed to serve as a measure for the level of consciousness of the system considered. The somewhat surprising conclusion is that computers are probably not conscious.

The notion of causal pair is essential. In particular, qualia are identified as causal pairs. When I wrote for the first time about IIT, I did not realize a connection with the holography and zero energy ontology (ZEO) of TGD in which essential role are played by almost deterministic time evolutions defined by space-time surfaces of $H = M^4 \times CP_2$ replacing the space-time of General Relativity. These 4-D Bohr orbit like entities replace 3-surfaces as basic entities and serve as analogs of behavioral patterns, biological functions or computer programs. Essential is that structure and function are almost equivalent notions. In this framework it is easy to grasp why DNA codes, not only for the phenotype of the organism, but also for its behavior.

The quantum superpositions of the Bohr orbits correspond to causal pairs in TGD. They correspond to space-time surfaces inside causal diamond ($CD = cd \times CP_2$) and their ends are fixed at the passive boundary but can change at the active boundary during a sequence of "small" state function reductions (SSFRs) defining self as a conscious entity. In SSFRs, the state at the passive boundary is not changed. Conscious experience [7] [14] is associated with the quantum jumps replacing the zero energy state with

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a new one, and one can say that the zero energy state as the counterpart of the causal pair determines the contents of consciousness, "qualia" in extremely general sense.

Of course, one can consider qualia in a much more restricted sense, for instance as quantum numbers measured in SSFR by the system representing self or by the large system having self as sub-self in BSFR. This has led to different quantum views about sensory receptors [7] [14] and the challenge is to understand how they relate.

The identification of TGD counterpart of the causal pair as zero energy state combined with the improved understanding of ZEO and of the holography = holomorphy vision leading to generalization of the geometric Langlands correspondence [22, 23, 19], has served as the motivation for writing this article.

2 IIT and TGD: 7 years later

It is good to attach here the abstract of the article "Consciousness: here, there and everywhere?" of Tononi and Koch published in the Philosophical Transactions of the Royal Society B in to give a general perspective.

The science of consciousness has made great strides by focusing on the behavioural and neuronal correlates of experience. However, while such correlates are important for progress to occur, they are not enough if we are to understand even basic facts, for example, why the cerebral cortex gives rise to consciousness but the cerebellum does not, though it has even more neurons and appears to be just as complicated. Moreover, correlates are of little help in many instances where we would like to know if consciousness is present: patients with a few remaining islands of functioning cortex, preterm infants, non-mammalian species and machines that are rapidly outperforming people at driving, recognizing faces and objects, and answering difficult questions.

To address these issues, we need not only more data but also a theory of consciousness one that says what experience is and what type of physical systems can have it. Integrated information theory (IIT) does so by starting from experience itself via five phenomenological axioms: intrinsic existence, composition, information, integration and exclusion. From these it derives five postulates about the properties required of physical mechanisms to support consciousness.

The theory provides a principled account of both the quantity and the quality of an individual experience (a quale), and a calculus to evaluate whether or not a particular physical system is conscious and of what. Moreover, IIT can explain a range of clinical and laboratory findings, makes a number of testable predictions and extrapolates to a number of problematic conditions.

The theory holds that consciousness is a fundamental property possessed by physical systems having specific causal properties. It predicts that consciousness is graded, is common among biological organisms and can occur in some very simple systems. Conversely, it predicts that feed-forward networks, even complex ones, are not conscious, nor are aggregates such as groups of individuals or heaps of sand. Also, in sharp contrast to widespread functionalist beliefs, IIT implies that digital computers, even if their behaviour were to be functionally equivalent to ours, and even if they were to run faithful simulations of the human brain, would experience next to nothing.

The article lists the 5 basic postulates of IIT leading to a numerical measure for the level of consciousness of a system. I wrote about IIT years ago and compared it with the TGD inspired theory of consciousness [9, 8]. It is interesting to take a fresh look at IIT since the mathematical and physical understanding of TGD has evolved dramatically during these 8 years.

1. The basic criticism is already raised by the idea that conscious experience means property of a system, consciousness. This reflects the materialistic view that conscious experience is a property of the system just as the mass and leads to the well-known philosophical problems. Materialism leads to problems with free will for instance.

2. The key problem is what subjective existence means and here materialism, idealism and dualism fail. Here quantum theory comes to the rescue and allows us to assign subjective existence as

experience to state function reduction (SFR), or rather the interval between two SFRs. The SFRs would be those which in standard wave mechanics correspond to repeated measurements of the same observables and in that context would have no effect on the system. In the zero energy ontology of TGD the state of system changes and "small" SSFRs give rise to the experienced flow of subjective time correlating with that of geometric time .

3. Also the assumption that the consciousness just exists or does not, is too simplistic. Already Freud realized Id-ego-super-ego triality and physics based picture strongly suggests that conscious entities form hierarchies just as physical systems do. There would exist very naturally a hierarchy of selves. They would have subselves, perhaps as mental images, etc.. and being subselves of higher levels selves. This would however be a dramatic deviation from the western world view. Although IIT assumes panpsychism, the lack of this realization reflects the brain centered view of neuroscience very analogous to the Earth centered world view before the emergence of astrophysics.

4. I saw no mention related to the problem of time: what is the relation between geometric time of physicists and the flow of subjective time which is the essential element of conscious experience.

5. About what death and sleep mean, IIT does not say anything at the philosophical level. Loss of consciousness can be explained as a reduction of the level of integration (more or less connectedness of the system) measured by the number Φ.

6. Metabolic energy feed is essential for life and consciousness and I saw no mention of this.

There are 5 postulates which are proposed to give rise to a criteria for when the system is conscious.

2.1 Intrinsic existence

Cause-effect power is taken as a key criterion. Cause effect power is understood classically since quantum theory is not involved. Cause effect power has several corresponds in TGD.

1. In TGD the classical correlate of cause-effect power at the space-time level is holography stating that 3-D data (3-surface dictates the space-time surface as analog of Bohr orbit. There is however a slight failure of determinism and this forces us to take these 4-D Bohr orbits as basic objects. They are classical correlates for almost deterministic behavioral patterns and SSFRs between different superpositions of Bohr orbits give rise to subjective time evolution.

2. In TGD "small" SFRs (SSFRs) are t quantum correlates of cause-effect power. "Big" SFRs (BSFRs) give rise to the death (sleep state) of the system and reincarnation with an opposite arrow of geometric time. Second BSFR means wake-up.

   BSFRs are essential for understanding biological processes like homeostasis. A pair of BSFRs means sleep period during which the entropy of the system is reduced and the system wakes up as a less entropic system. This is essential in the battle of the living systems against second law.

3. Causal diamond ($CD = cd \times CP_2$) is the correlate of the cause-effect power at the level of $H = M^4 \times CP_2$. cd has the geometry of causal diamond and the two light-like boundaries are in asymmetric relation. At the passive boundary the states do nt changes in SSFRs. It can be said to be the causal agent. At the active boundary they change. Also the size of CD increases in statistical sense and geometric time corresponds to the increasing temporal distance between the tips of CD. In BSFR the roles of active and passive boundaries of CD change.

   I must admit that I did not understand the illustrations of cause-effect structure involving Boolean algebra. Boolean functions are one way to see causality. In physics, classical deterministic time evolution defines a more general cause-effect structure.

2.2 Composition

Systems are structured. In standard physics, where space-time is infinite and without topological structure, there is no fundamental definition for what this means and only phenomenological models are possible. In TGD, many-sheeted 3-space decomposes to a union of 3-surfaces which can fuse and decay and these processes occur also in scales essential for life and consciousness and also we perceive the many-sheeted space-time and these processes directly but our education make it impossible to realize this.

2.3 Information

Cause-effect repertoire is taken as a basic concept behind the notion of information.

1. In TGD, a cause-effect repertoire corresponds to different 4-D Bohr orbits associated with the same 3-surfaces holographic data. These are the space-time correlates for the behaviours.

2. As the algebraic complexity of the space-time surface increases, the size of the repertoire increases. The dimension of extension of rationals assignable to the space-time regions measures this complexity and is assumed to define effective Planck constant which in turn gives a measure for the scale of quantum coherence serving as a measure for the evolutionary level of the system. This means deviation from the standard quantum theory with single Planck constant. Field bodies as carriers of dark phases of ordinary particles means a second deviation made possible by the new view of classical fields.

3. Number theoretic view of TGD is something completely new and allows to define the notion of conscious information. p-Adization and adelization in turn gives correlates of cognition and one can assign to the system an entanglement negentropy as the sum of its p-adic variants. Entanglement negentropy is positive and increases with the complexity of the system. It is larger than real entanglement entropy and its increase implies the increase of the latter: cognition produces unavoidably ordinary entropy.

4. The number theoretic entanglement negentropy could be seen as a counterpart of an integrated information and measures the cognitive level of the system and the level of cognitive consciousness.

   Number theoretic evolution as an unavoidable increase of complexity in the sequence of state function reductions forces the increase of this entanglement entropy so that the potentially conscious information of the system necessarily increases.

5. The ZEO based view of quantum jump [12, 18] [10] allows to understand how systems are able to have memories about their states before SSFRs: in standard quantum theory this is not possible. Therefore Universe making SSFRs and BSFRs learns more and more about itself and is able to remember what it has learned (see this).

   In IIT, the qualia space is identified as cause-effect space. In the TGD framework SSFR leads to a final state containing information about the previous quantum state since it is identified as a superposition of classical space-time surfaces leading from the fixed initial state at the passive boundary of the CD to the active boundary of CD. The original proposal that qualia are simply labelled by the quantum numbers measured in SSFR is not quite correct. The qualia also involve classical information about the SSFR via the superposition of space-time surfaces between initial (fixed) and final classical states: this would be the counterpart for the cause-effect.

2.4 Integration

The counterpart of integration in the TGD framework is entanglement.

1. Entanglement entropy to which one can assign adelic negentropy measures the degree of entanglement and integration. In SFR the entanglement is reduced: the system decomposes to two parts. This is the basic aspect of conscious experience. About this says IIT nothing.

2. Monopole flux tubes connecting parts of the system to a single coherent whole provide a classical correlate for the entanglement and in SFRs the flux tube connections between the two parts of the system could split. More precisely, pairs of flux tubes connecting the subsystems reconnect to U-shaped flux tubes associated with the systems: the connection is split, SFR has occurred.

3. In biology reconnection is fundamental, for instance for bio-catalysis and for the recognition of molecules by the immune system. Death of the system means splitting of these flux tubes. These flux tubes carry dark matter as large h_{eff} phases. There must be a metabolic energy feed to prevent the values of h_{eff} from decreasing. This leads to reduction of the cognitive level and geometrically to the shortening of the U-shaped flux tubes so that the system loses the control of its environment and receives information from a smaller volume.

2.5 Exclusion

Exclusion postulate states that cause effect structure must be definite. The notion is described in terms of a phenomenological set theoretic picture. I did not understand the Boolean illustrations of the cause effect structure. The notion of maximal irreducibility can be understood in TGD as maximal connectedness or at least connectedness of the 3-surface by connecting flux tubes (or in the weakest sense, the 4-surfaces as analog of Bohr orbit).

What precisely defined cause-effect structure could mean in ZEO? The state at the passive boundary of CD remains fixed during the sequences of SSFRs determining the life-cycle (wake-up period of self) so that one can can say that classically the almost deterministic evolution of the space-time surface is implied by the 3-surface at the passive boundary, it acts as a causal agent. The small failure of determinism means that there are also intermediate "agents" slightly affecting the time evolution. They also make possible memory and force ZEO solving the basic problem of the quantum measurement theory and allowing also free will.

2.6 What is missing from IIT?

The postulates of IIT are inspired by computationalism and materialistic neuroscience and have no connection to (quantum) physics or biology. The hierarchy of selves is a central notion missing completely in IIT and this hierarchy is essential for a real understanding of conscious entities. The levels of the hierarchy interact. For instance, the field body (magnetic body) carrying dark matter as large h_{eff} phases of dark matter serves as a boss of the biological body carrying ordinary matter. Cognitive hierarchies as hierarchies of extensions of rationals giving rise to directed entanglement hierarchies are also something not possible in the standard physics.

These hierarchies are also essential for understanding evolution. In particular, classical gravitational and electromagnetic fields give rise to field bodies with very long quantum coherence lengths, even of astrophysical size and these scales are predicted to be fundamental for understanding life and consciousness in ordinary living matter.

The somewhat surprising prediction of IIT is that ordinary computers need not be conscious. In TGD this is possible only if the quantum coherence time is longer than the clock period but the contents of consciousness need not correlate with the program. The change of the arrow of time in BSFRs makes possible the analogs of feedback loops at various layers of the self hierarchy and learning by trial and error and would be the basic aspect of living systems.

Whether ordinary computers could be conscious is an interesting question and in TGD one ends up with a quantitative criterion for this in terms of the clock frequency [15]. For the Earth's gravitational body, the lower bound for the clock frequency is 67 Hz. For the solar gravitational body, the clock

frequency should be above 50 Hz which is the average EEG frequency and satisfied for the ordinary computers. Does this mean that the users of computers can entangle with them? It has been claimed that when a chicken entangles with a robot whose motion is based on a random number generator, the robot seems to take the role of Mother.

3 Zero energy ontology, holography = holomorphy vision and TGD view of qualia

Zero energy ontology (ZEO) and holography = holomorphy vision providing an exact solution of classical field equations allow to solve some earlier problems of TGD inspired theory of consciousness and to sharpen earlier interpretations. Holography = holomorphy vision generalizes 2-D conformal invariance to 4-D situation and provides a universal solution of field equations in terms of minimal surfaces defined as roots for pairs of generalized analytic functions of the generalized complex coordinates of $H = M^4 \times CP_2$ (one of the coordinates is hypercomplex coordinate with light-like coordinate curves) [16, 19].

Consider first the implications of ZEO [12] [10].

1. ZEO predicts that in "big" state function reductions (BSFRs) as counterparts of ordinary SFRs the arrow of time changes. "Small" SFRs (SSFRs) are the counterpart for repeated measurements of the same observables, which in standard QM leave the system unaffected (Zeno effect). In SSFRs, the state of the system however changes but the arrow of time is preserved. This has profound implications for the understanding of basic facts about consciousness.

2. The sequence of SSFR corresponds to a sequence of delocalizations in the finite-dimensional space of causal diamonds $CD = cd \times CP_2$ [18] and consists of delocalizations (dispersion) followed by localizations as analogs of position measurements in the moduli parameterizing the CD. This sequence gives rise to subjective existence, self.

3. BSFR has interpretation is accompanied by reincarnation with an opposite arrow of geometric time. BSFR means the death of self as a sequence of "small" SFRs (SSFRs) and corresponds to falling asleep or even death. Death is therefore a completely universal phenomenon. The next BSFR means birth with the original arrow of time: it can be wake-up in the next morning or reincarnation taking place considerably later, life time is the first guess for the time scale. This follows from the fact that causal diamond $CD = cd \times CP_2$ increases in size during the sequence of SSFRs.

4. What forces the ZEO is holography which is slightly non-deterministic due to the classical non-determinism of an already 2-D minimal surface realized as a soap film for which the frame spanning it does not fix it uniquely. This means that the 4-D space-time surface located inside CD and identifiable as the analog of Bohr orbit determined by holography must be taken as a basic object instead of a 3-surface. In SSFRs, the state at the passive light-like boundary of CD is unaffected just as in Zeno effect but the state at the active boundary changes. Due to the dispersion in the space of CDs the size of CD increases in statistical sense and the geometric time identifiable as the distance between the tips of CD increases and correlates with the subjective time identifiable as sequence of SSFRs.

5. In standard quantum theory, the association of conscious experience with SFRs does not allow us to understand conscious memories since the final state of state function reduction does not contain any information about the earlier states and state function reductions. Zero energy ontology leads to a concrete view of how conscious memories can be realized in the TGD Universe [20]. The superposition of space-time surfaces between fixed initial state and changing final state of SSFR contains the classical information about previous states and state function reductions and makes memory possible. The slight non-determinism of the classical time evolution implies loci

of non-determinism as analogs of soap film frames and memory recall corresponds to a quantum measurement at these memory seats.

6. SSFRs correspond to repeated measurements of the same observable and the eigenvalues of the measured observables characterize the conscious experience, "qualia", partially. Also new commuting observables related to the non-determinism can appear and the set of observables can be also reduced in size. The superposition of the space-time surfaces as analogs of non-deterministic Bohr orbits however changes in the sequence of SSFRs and the associated classical information changes and can give rise to conscious experiences perhaps involving also the qualia remaining constant as long as self exists.

   The eigenvalues associated with the repeatedly measured observables do not change during the sequence of SSFRs and one can ask if they can give rise to a conscious experience, which should be assignable to change. Could these constant qualia be experienced by a higher level self experiencing self as sub-self defining a mental image? This higher level self would indeed experience the birth and death of subself and therefore its qualia.

   The observables at the passive boundary of CD correspond qualia of higher level self and the additional observables associated with SSFRs correspond to those of self. They would be associated with self measurements.

7. Note that self dies when the measured observables do not commute with those which are diagonalized at the passive boundary. It is quite possible that these kinds of temporary deaths take place all the time. This would allow learning by trial and error making possible conscious intelligence and problem solving since the algebraic complexity is bound to increase: this is formulated in terms of Negentropy Maximization Principle [17].

ZEO and holography = holomorphy vision allow us to understand some earlier problems of TGD inspired theory of consciousness and also to sharpen the existing views.

3.1 Negative group delay as support for ZEO

The time reversal taking place in BSFRs is absolutely crucial for quantum TGD and TGD inspired theory of consciousness and quantum biology. It should occur universally in all scales, also atomic scales. Paul Kirsch sent an interesting link to a finding to an article "Experimental evidence that a photon can spend a negative amount of time in an atom cloud" (see this). The finding is very interesting from from the point of view of zero energy ontology (ZEO) defining the ontology of classical and quantum TGD [10, 12, 13, 11]. Could the negative group delay be understood in terms of a time period with a reversed arrow of time spent by the photon around an atom?

1. Absorption and re-emission by atom would correspond to two types of "big" state function reductions (BSFRs) taking place. In the first BSFR photon would "die" by absorption by an atom. Photon would however reincarnate with an opposite arrow of time. The same would happen in the second BSFRs and photon would reincrane with the original arrow of time.

   According to the recent view of ZEO, after the second BSFR the photon would emerge geometrically later than it was absorbed in the first BSFR. The photon wave packet would come out as less entropic, that is younger. This effect would be like waking up as a less entropic, in this sense a younger person after a well slept night.

2. Does the group delay measure this effect? If the aging of the wave packet means widening then this might be the case. Free photon wave packet keeps its shape since it does not disperse. The widening must be of thermodynamic origin and would be due to SSFRs replacing the wave packet gradually with a wider one.

3. In TGD, the shape preserving wave packet has as a classical geometric correlates a "massless extremal" (ME) representing a pulse propagating in a precise direction. The shape of pulse does not change but "small" state function reductions (SSFRs) would replace ME with a new one representing in general a wider pulse. This would be dissipation: ME would age. The pair of BSFRs induced by atomic absorption would lead to a reincarnation as a younger ME. This would be the counterpart for the group delay.

What has negative group delay to do with consciousness? We sleep because we get tired. Sleep has beneficial effects. After a well-slept night, we feel like being reborn. Sleep increases our negentropic sources, with negentropy defined as a measure of conscious information as the sum of p-adic negentropies. Also the entropy of the body, defined in the standard way, seems to decrease during sleep: healing occurs. The findings about photons indeed suggest that the system travels back in the time defined by the entropy of the system: the entropy of the photons decreases as the arrow of time temporarily changes in absorption followed by re-emission.

3.2 Two models for how sensory qualia emerge

Concerning sensory qualia [7] I have considered two basic views.

1. The first view is that the sensory perception corresponds to quantum measurements of some observables. Qualia are labelled by the measured quantum numbers.

2. The second, physically motivated, view has been that qualia correspond to increments of quantum numbers in SFR [7]. This view can be criticized since the quantum numbers need not be well-defined for the initial state of the SFR. One can however modify this view: perhaps the redistribution of quantum numbers leaving the total quantum numbers unaffected, is what gives rise to the sensory qualia.

   The proposed physical realization is based on the sensory capacitor model of qualia. Sensory receptors would be analogous to capacitors and sensory perception would correspond to dielectric breakdown. Sensory qualia would correspond to the increments of quantum numbers assignable to either cell membrane in the generalized di-electric breakdown. The total charges of the sensory capacitor would vanish but they would be redistributed so that both membranes would have a vanishing charge. Membranes could be also replaced with cell exterior and interior or with cell membrane and its magnetic body. Essential would be emergence or disappearance of the charge separation.

   This picture conforms with the recent view about the role of electric and gravitational quantum coherence assignable to charged and massive systems. In particular, electric Planck constant would be very large for charged systems like cell, neuron, and DNA and in the dielectric breakdown and its time reversal its value would change dramatically. If this is the case the dynamic character of effective Planck constant involving phase transition of ordinary to dark matter and vice versa would be essential for understanding qualia.

3. As the above argument demonstrated, the qualia can be decomposed to internal and external qualia. The internal qualia correspond to self-measurements of sub-self occurring in SSFRs whereas the external qualia correspond to the qualia measured by self having sub-self as a mental image. They are not affected during the life-time of the mental image. Whether the self can experience the internal qualia of subself is far from clear. The sensory capacitor model would suggest that this is the case. Also the model for conscious memories suggests the same. The internal qualia would correlate with the classical dynamics for the space-time surfaces appearing in the superposition defining the zero energy state and make possible, not only conscious memory and memory recall based on the failure of precise classical determinism, but also sensory qualia as subselves experienced as sensory mental images.

3.3 Geometric and flag manifold qualia and the model for the honeybee dance

One can decompose qualia to the qualia corresponding to the measurement of discrete observables like spin and to what might be called geometric qualia corresponding to a measurement of continuous observables like position and momentum. Finite measurement resolution however makes these observables discrete and is realized in the TGD framework in terms of unique number theoretic discretization of the space-time surface.

Especially interesting qualia assignable to twistor spaces of M^4 and CP_2.

1. Since these twistor spaces are flag manifolds, I have talked about flag-manifold qualia. Their measurement corresponds to a position measurement in the space of quantization axes for certain quantum numbers. For angular momentum this space would be $S^2 = SO(3)/SO(2)$ and the localization S^2 would correspond to a selection of the quantization axis of spin. For $CP_2 = SU(3)U(2)$ the space of the quantization axis for color charges corresponds to 6-D $SU(3)(U(1) \times U(1)$, which is identifiable as a twistor space of CP_2.

2. The twistor space of M^4 can be identified locally as $M^4 \times S^2$, where S^2 is the space of light-like rays from a point of M^4. This space however has a non-trivial bundle structure since for two points of M^4 connected by a light-like ray, the fibers intersect.

What is the corresponding flag manifold for M^4?

1. The counterpart of the twistor sphere would be $SO(1,3)/ISO(2)$, where $ISO(2)$ is the isotropy group of massless momentum identifiable as a semidirect product of rotations and translations of 2-D plane. $SO(1,3)/ISO(2)$ corresponds to the 3-D light-cone boundary (other boundary of CD) rather than S^2 since it has one additional light-like degree of freedom. Is the twistor space as a flag manifold of the Poincare group locally $M^4 \times SO(1,3)/ISO(2)$. This is topologically 7-D but metrically 6-D. Since light rays are parametrized by S^2 one can also consider the possibility of replacing $M^4 \times SO(1,3)/ISO(2)$ with S^2 in which case the twistor space would be 6-D and represented a non-trivial bundle structure.

2. Could one restrict M^4 to E^3 or to hyperbolic 3-sphere H^3 for which light-cone proper time is constant? In these cases the bundle structure would trivialize. What about the restriction of M^4 to the light-like boundaries of CD? The restriction to a single boundary gives non-trivial bundle structure but seems otherwise trivial. What about the union of the future and past boundaries of CD? The bundle structure would be non-trivial at both boundaries and there would also be light-like rays connecting future and past light-like boundaries.

   The unions $\cup_i H^3_i(a_i)$ of hyperbolic 3-spaces corresponding different values $a = a_i$ of the light-cone propert time a emerge naturally in $M^8 - H$ duality and could contain the loci of the singularities of space-time surfaces as analogs of frames of soap filmas. Also these would give rise to a non-trivial bundle structure.

   These identifications differ from the usual identification of the M^4 twistor space as CP_3: note that this identification of the M^4 twistor space is problematic since it involves compactification of M^4 not consistent with the Minkowski metric. Holography = holomorphy vision in its recent form involves a general solution ansatz in terms of roots of two analytic functions f_1 and f_2 and $f_2 = 0$ [19], which identifies the twistor spheres of the twistor spaces of M^4 and CP_2 represented as metrically 6-D complex surfaces of H. M^4 twistor sphere corresponds to the light-cone boundary in this identification. This identification map also defines cosmological constant as a scale dependent dynamical parameter.

A basic application for the twistor space of CP_2 has been in the TGD based model [7, 6] for the findings of topologist Barbara Shipman [1, 2, 3, 4, 5], who made the surprising finding that the twistor

space of CP_2, naturally assignable to quarks and color interactions, emerges in the model for the dance of honeybee. This kind of proposal is nonsensical in the standard physics framework but the predicted hierarchy of Planck constants and p-adic length scales make possible scaled variants of both color and electroweak interactions and there is a lot of empirical hints for the existence of this hierarchy, in particular for the existence as a scaled up variants of hadron physics leading to a rather radical proposal for the physics of the Sun [21].

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Shipman found that the honeybee dance represents position in $SU(3)/U(1) \times U(1)$ coding for the direction and distance of the food source in 2-D plance! Why should this be the case? The explanation could be that the space-time surfaces as intersections of 6-D counterparts of the twistor spaces $ISO(2) \times \cup_i H^3(a = a_i)$ *resp.* $SU(3)/U(1) \times U(1)$ identified as a root of analytic function f_1 *resp.* f_2 [19] have space-time surface as 4-D intersection so that honeybee dance would map the point of the flag manifold $SU(3)/U(1) \times U(1)$ to a point of $M^4 \times S^2$ or $\cup_i H^3(a = a_i) \times ISO(2)$ (locally). The restriction to a 2-D subset of points could be due to the measurement of the distance of the food source represented by the point of H_i^3 (or M^4).

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