

# Some considerations relating to the dynamics of quasicrystals

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November 12, 2012

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## 1 The dynamics of quasicrystals, the dynamics of Kähler action, symbolic dynamics, and the dynamics of self-organization

The dynamics of quasicrystals looks to me very interesting because it shares several features of the dynamics of Kähler action defining the basic variational principle of classical TGD and defining the dynamics of space-time surfaces. In the following I will compare the basic features of the dynamics of quasicrystals to the dynamics of preferred extremals of Kähler action [K1].

Magnetic body carrying dark matter is the fundamental intentional agent in TGD inspired quantum biology and the cautious proposal is that magnetic flux sheets could define the grid of 3-planes (or more general 3-surfaces) defining quasi-periodic background fields favoring 4-D quasicrystals or more general structures in TGD Universe. Also 3-D quasicrystal like structures defined by grids of planes can be considered and 4-D quasicrystal structure could represent their time evolution.

Quite recently it has been reported that grids consisting of 2-D curved orthogonal surfaces characterize the architecture of neural wiring so that this hypothesis might make sense. This structure would be analogous to 2-D quasicrystal and its time evolution to 3-D quasicrystal.

### 1.1 The non-determinism for the dynamics of quasicrystals contra non-determinism of Kähler action

The dynamics of quasicrystals is non-deterministic in the sense that one cannot construct a unique quasicrystal by starting from a finite portion or even D-1-dimensional section of D-dimension quasicrystal thickened to a slice. Four-dimensional quasicrystals would therefore define a non-deterministic dynamics. This dynamics could serve as a geometric correlate for a full non-deterministic quantum dynamics involving also state function reductions. This requires that quantum classical correspondence is generalized so that also non-deterministic aspects of quantum dynamics are required to have

geometric space-time correlates. The global empires of the 4-D quasicrystal could be interpreted as self-organization patterns whereas global empires would represent long range correlations.

This is very much analogous to 4-D spin glass degeneracy in TGD framework.

1. In TGD framework the preferred extremals of so called Kähler action define the dynamics of space-time surfaces. Kähler action [K3] is Maxwell action for the gauge field induced from the Kähler form of  $CP_2$ . Symplectic transformations of  $CP_2$  act as abelian gauge transformations and therefore leave the induced Kähler form invariant. They do not however leave the induced metric invariant so that the action changes by a contribution assignable to classical gravitation. For vacuum extremals however the symplectic transformations act as symmetries.
2. This implies huge vacuum degeneracy. Every space-time surface for which  $CP_2$  projection is Lagrangian manifold and thus having at most 2-D  $CP_2$  projection has vanishing induced Kähler form and is therefore vacuum extremal: there is infinite number of 6-D vacuum sectors labelled by Lagrangian sub-manifolds of  $CP_2$  transformed to each other by symplectic transformations. These vacuum extremals behave non-deterministically which means an analogy with quasicrystal dynamics and suggests that quasicrystals might define a simplified model for quantal self-organization.
3. Small deformations of these define non-vacuum extremals and It is very conceivable that part of the vacuum degeneracy remains and is manifested as multi-furcations. The number  $n$  of branches for a multi-furcation has interpretation in terms of effective Planck constant  $\hbar_{eff} = n\hbar$  to which dark matter is assigned in TGD framework. This degeneracy is very much analogous to a 4-dimensional spin glass degeneracy meaning that space-time decomposes to deterministically behaving regions just like spin glass decomposes to magnetized regions with varying direction of magnetization.
4. The interpretation for the situation in TGD framework is in terms of quantum classical correspondence: not only quantum states correspond to space-time geometries as analogs of Bohr orbits but also quantum jump sequences - which according to TGD inspired theory of consciousness define the contents of consciousness - have non-deterministic space-time geometries as geometric correlates. Space-time geometry and topology are like written text providing information about contents of consciousness.
5. Also p-adic topology as effective topology of space-time surfaces and natural topology for the landscape of extrema of Kähler function of WCW definings its Kähler geometry emerges naturally from this degeneracy. In physics obeying effective p-adic topology the counterpart would be short range chaos with long range correlations in the sense that one would have periodicity in the sense that physical states at time  $t$  and  $t + kp^n$ ,  $k = 0, 1, \dots, p - 1$ ,  $n \geq 1$ , would be very near to each other. The interpretation in terms of intentional action would be natural. One could also imagine of defining the analogs of empires as connected deterministic regions of space-time surface and the analogs of empires would be unions of disconnected components perhaps understandable in terms of p-adicity. Self-organization patterns would naturally correspond to these regions. Many-sheeted space-time would imply fractal hierarchy of self-organization patterns within self-organization patterns.

## 1.2 The dynamics of quasicrystals as a model for fundamental dynamics or high level symbolic dynamics?

Stephen Wolfram has suggested that cellular automaton could define the fundamental dynamics. It is not difficult to invent grave objections against this view. One of the objections is that this kind of dynamics is based on simple and rather ad hoc rules and applies to a society rather than to elementary particles. It is difficult to circumvent this counter argument.

One can however ask in what scale the symbolic dynamics does emerge? For few years ago my answer would have been "in biological length scales" (genetic code as symbolic dynamics). TGD Universe is however fractal, and this forces to ask whether this symbolic dynamics emerges already above  $CP_2$  scale in some rudimentary form. In any case, even in this case the dynamics of self-organization would not be identifiable as the fundamental dynamics but as analogous to the rules of behavior in society.

The dynamics of quasicrystals brings indeed strongly in mind the dynamics of self-organization patterns prevailing at relatively high level of dynamical hierarchy. Symbolic dynamics prevailing at the level of biomolecules (genetic code) and at higher levels could be in question. This dynamics is dynamics for a society of conscious entities, which can decide whether to follow the rules or not. Rules as such do not matter too much: what is important that they make possible to predict the behavior of individuals and therefore make possible co-operation and formation of coherent and synchronous large scale structures making possible collective consciousness. In human society moral rules, laws, traffic rules, grammatical rules of language, etc... are examples about symbolic dynamics having very little to do with the laws of physics at fundamental level.

A natural question is whether the rules for building quasicrystals could provide a simplified model for this "social" dynamics - or perhaps even semi-realistic description - at the molecular level? Either quasicrystals or their building bricks - the arguments to be discussed later suggest that finite-sized quasicrystals - could be seen as a kind of society. The refusal to obey the rules guaranteeing the formation of larger quasicrystals would stop the quasicrystal growth and isolate the individual quasicrystal from the society. It could also lead to metabolic starvation: metabolic energy feed is indeed crucial element in living systems.

Quasicrystals could be seen as idealized structures having maximal complexity and therefore ability to represent information. Critical systems - also quantum critical ones - have a universal dynamics so that there is a large number of models making the same predictions for a given system. In practice this can be used to find the simplest possible model to simplify the mathematical description (say by finding the simplest conformal field theory to describe a 2-D critical system). From this point of view quasicrystals could be seen as an especially simple model possibly able to catch the universal properties of a real world system.

Does this self-organization dynamics then emerge only at and above bio-molecular scales or in all scales?

1. In TGD framework the classical dynamics at the fundamental level would be the geometrodynamics of space-time surfaces [K6]. Quantum Dynamics would be dictated by Dirac equation for WCW ("world of classical worlds") spinor fields and reduce to the modified Dirac equation for second quantized induced spinor fields at space-time surfaces.

The fractality of the TGD Universe suggests that self-organization occurs in all length scales above  $CP_2$  scale, which is about  $10^4$  times Planck scale. If so, structures analogous to finite pieces quasicrystals could appear in all scales down to  $CP_2$  scale.

2. I have proposed a method for constructing preferred extremals of Kähler action [K7] and this recipe leads to an iteration procedure. Quite generally, iteration is known to lead to fractals as fixed sets of iteration. Therefore space-time surfaces could be seen as space-time correlates of self-organization patterns and fractals.
3. Fractality would mean that even inanimate matter should share some aspects assigned to living matter and that also systems like species and biosphere could behave like living organisms in some respects. Sheldrake has proposed is famous for his notion of memory at the level of entire species. He has also proposed that even inanimate systems could have "habits". For instance, minerals would have adopted the habit to crystallize to a particular crystal form. In this framework living matter would differ from mineral kingdom in that its habits would be much more flexible. I have discussed the implementation of Sheldrake's ideas in TGD framework [L1].

### 1.3 Could ordered water layers around biomolecules be modelled as quasicrystal like structure?

Water forms multilayered quasi-lattices (to be distinguished from quasicrystals!). These quasi-lattices around molecules are like ice coverings. These quasilattices have water molecule as a basic tetrahedral building blocks giving rise to icosahedral blocks (as suggested in discussions): the 4 electron pairs of water molecule are indeed located at the vertices of tetrahedron and for lattice like structures a regular tetrahedron is in question. Perhaps these quasi-lattices could be modelled as deformed quasicrystals.

This molecular ice would form a quasicrystal, which could somehow store information about environment via its structural degeneracy. If the information is conscious, it should be stored in the

negentropic entanglement between the states of finite-sized quasi-lattices surrounding two separate molecules, and would have magnetic flux sheets connecting them as a space-time correlate. For 3-D quasicrystal like structure the lattice points would be in the intersections of 3 2-planes (or thin locally planar flux sheets) and define points of a lattice at which the analogs of coordinate planes meet.

Making these structures dynamical one would obtain 4-D quasicrystal like structures. In this case the intersections of 2 3-planes (or thin locally planar 3-D flux sheets) would give rise to 1-dimensional word lines of 3-D quasicrystal points whereas the intersections of 3 3-planes would correspond to points of 4-D lattice. What special could happens at these dynamically special points of space-time?

Zero energy ontology and TGD inspired theory of consciousness allows to consider a possible answer: the points of 4-D lattice correspond to CDs (causal diamonds) serving as space-time correlates for sub-selves identifiable as mental images. Quite generally quasi-periodically appearing mental images might be assigned to the points of quasi-lattice like structure.

Note that also cubic crystals can be constructed using grid consisting now of 3 orthogonal planes and the distances between grid planes serve as geometrical parameters which magnetic body could vary. The constant deformation of the magnetic body would now however force rather large deformations of crystal structure probably impossible energetically. One can however ask whether phonons could be induced by the local deformations of the flux sheets of the grid inducing small oscillations of the lattice points. If the magnetic body indeed serves as the intentional agent using biological body, this connection might allow to understand the very special role of acoustic oscillations in hearing, speech, internal speech, and thought. For instance, could the reaction of magnetic flux sheets to sound give rise to hearing? And could the reaction of the quasilattice units to the oscillations of the flux sheets give rise to internal speech or induce even speech in sound organs? It has been argued that the structure of the intronic portion of DNA resembles that of language and this has led to proposal that acoustic waves propagating along DNA could code for language. If DNA is indeed accompanied by flux tubes and flux sheets, this idea would look rather natural in the recent context.

One of the basic findings of biology is that protein molecules are most of the time in a resting state in a folded configuration with globular form and surrounded by ordered water defining kind of ice covering. This state could represent conscious information realized as a negentropic entanglement between different molecules: kind of a molecular meditative state would be in question. In the presence of energy feed inducing "molecular summer" the molecular ice would melt, globular proteins would open and self-organize to form molecular aggregates as a reaction to the energy feed. After the energy feed stops, molecules would fold back to the globular form but the memory from the "molecular summer" would be stored to the negentropic entanglement between molecules.

The Indra's net formed by the magnetic flux tubes and sheets has become a standard part of TGD based view about living matter. The model for DNA as quantum computer [K2] involves flux sheets traversing through DNA strand and flux tubes connecting nucleotides to lipids of the cell membrane as well as flux sheets with the shape of cell membrane. This suggests that one actually has also in the case of DNA-cell membrane system three orthogonal grids of flux sheets at some scale and flux tubes condensed at the sheets of grids. These structure would organized the living matter to a well-organized geometric structure.

One of the first really crazy ideas related to the magnetic was the proposal that the magnetic bodies associated with living organisms could have shape reflecting the shape of the organism and its parts - even in the length scale of Earth [K4]. If one takes the flux sheets grids seriously, and replaces planes with closed surfaces obtained by scaling outer surfaces for parts of the organism, something like this is indeed expected.

## 2 What could be the variational principle behind self-organization?

Quasicrystals (say Penrose tilings) have a huge ground state degeneracy: given region of quasicrystal can be completed to infinite number of quasicrystals. For crystals the situation is different: local empire is the entire infinite crystal. Quasicrystals are clearly analogous to spin glass systems also possessing also large ground state degeneracy.

TGD Universe is a 4-D spin glass, and this degeneracy would imply non-determinism analogous to the non-determinism of quasi-crystal dynamics in 4-D 4-D Minkowski space) with local empires interpreted as self-organization patterns and global empires reflecting the long range correlations due to intentional action and obedience for social rules. In human society the ability to predict what

person probably does next year in given day only by knowing his profession, would represent example about this kind of long range correlation caused basically by social forces.

## 2.1 Why Negentropy Maximization Principle should favor quasicrystals?

In TGD inspired theory of consciousness Negentropy Maximization Principle (NMP) [K5] is the basic variational principle. NMP states that the information contents of conscious experience is maximal. Therefore entanglement negentropy is expected to be the fundamental quantity.

1. Since conscious entities forming larger coherent structures (societies) are in question, it seems that one should characterize the quasi-lattice by a negentropy, which should be maximized (purely mathematically negentropy is very similar to entropy which is maximized for a closed system). This negentropy would *not* correspond to the negative of the ordinary thermodynamical entropy, which characterizes ensemble of particles rather than single coherent unit.
2. In TGD Universe this negentropy would naturally be the number theoretic negentropy characterizing negentropic entanglement identified as a measure for conscious information. This information measure is assigned with the magnetic flux tubes connecting biomolecules and other units of living organism and even living organisms to larger coherent structures. In the case of quasicrystals flux tubes or flux sheets give rise to the long range constraints binding the units of quasi-crystal to each other.
3. The maximization of negentropy characterizing information content of conscious experience should be equivalent with the maximization of complexity as the number of almost degenerate ground states of quasicrystal. It is intuitively clear why quasicrystals would be favored over crystals. But how quasicrystals could maximize entanglement negentropy? Why the entanglement negentropy would be large for quasicrystals? Why the large number of quasicrystals configurations would favor large entanglement negentropy.

If the entanglement is between two different quasicrystals, it means formation of quantum superposition of pairs of quasicrystal configurations and the higher the quasicrystal degeneracy, the larger the maximal entanglement negentropy. This conforms with the fact that quasicrystals are necessary of finite size. Most naturally the negentropic entanglement would be between the degenerate ground states of two finite-sized quasicrystals.

4. If degrees of freedom associated with the space-time geometry are entangled, the quantum dynamics at the level of "world of classical worlds" would be involved and by definition would not be describable by QFT in a fixed background space-time. One could speak about genuine quantum gravity: The Orch-OR proposal of Penrose and Hameroff is also a conjecture of similar character. One can also consider entanglement between states of some particle and quasicrystal but the negentropy content would be now much smaller due to the small number of particle states.

## 2.2 Maximal capacity to represent information with minimal metabolic energy costs as a basic variational principle?

The interpretation as a symbolic dynamics assignable to conscious entities would suggest that the maximization of the capacity to represent information (perhaps with minimal metabolic costs) could be the variational principle behind this dynamics. The number of different quasicrystals formed using the given rules should be maximal. This would give rise to very large number of states with nearly same energy allowing to represent the states of the external world (primitive sensory system). The larger the size of quasicrystal, the larger the number of degenerate configurations. Here of course physical constraints would pose an upper limit of the size.

But can one really assume rigid rules of construction giving rise to only quasicrystals? If the basic dynamical units are conscious entities they refuse to obey strict rules although they can decide to do so under "social pressures" (absence of metabolic energy feed can transform a sinner a saint!). Should these rules be an outcome of the variational principle alone? Or are they forced by some minimization principle - say minimization of metabolic energy feed - in presence of quasi-periodic background field configuration regarded as an external field favoring quasicrystals?

It seems that all configurations of the basic units must be accepted a priori: in principle even random spatial configurations of the basic units. For random configurations complexity would be maximal but co-operation minimal, long range correlations would be absent, and the ability to represent information would be minimal. For crystals long range correlations and co-operation would be maximal but crystal would have minimal capacity to represent and mimic. The natural manner to achieve long range correlations is to assume slowly varying quasi-periodic fields configurations representing the "social forces". In TGD framework these fields would naturally correspond to magnetic flux quanta serving as basic building bricks of magnetic bodies controlling biological body.

Note that by previous argument, the capacity to store conscious information is equivalent with ability to generate negentropic entanglement.

### 2.3 A possible realization for 4-D dynamics favoring quasicrystal like structures

Can one imagine a physical realization of 4-D quasicrystal dynamics in TGD framework? The basic problem is to understand how the rules for the formation of quasicrystals are forced. Certainly the hyper-plane grids associated with the basic polytope defining the quasicrystal force the long range correlations. But how to realize these grids physically?

1. In TGD Universe magnetic body acts as an intentional agent using biological body as a motor organ and sensory receptor. This suggests that the plane grids parallel to the faces of - say - icosahedron in the case of 3-D quasicrystal could in TGD Universe be realized as thin (and thus effectively 2-D) magnetic flux sheets forming the magnetic body around which the ordinary matter would self-organize to form a quasicrystal as a configuration sustainable by using minimum metabolic energy feed. These grids would be part of the magnetic body responsible for the "social forces".

Rather remarkably, quite recent findings strongly suggest that brain involves an orthogonal grid of curved planes. Maybe this grid correspond to a quasi-lattice associated with a cubic basic unit serving as a basic information processing unit. Exact cubic crystal does not guarantee the needed ground state degeneracy and the deviation from it could be crucial in guaranteeing large degeneracy of the basic structures.

2. Maybe the basic variational principle could be minimization of the metabolic energy feed in presence of fixed grid structure formed by flux sheets representing the slow dynamics to which the molecular dynamics would rapidly adapt. The intersections of the grid hyper-planes are good candidates for the equilibrium points and going outside them would require metabolic energy. The minimum of the magnetic energy  $\mu \cdot B$  of magnetic dipole is reduced in the intersections of flux sheets if the effects of the magnetic fields sum up at the intersection. For the crossing of  $n$  orthogonal sheets there is an enhancement by  $\sqrt{n}$  factor. The motor activities of the magnetic body itself would deform the quasicrystals: the flux sheets could be deformed and the distances between the flux sheets could also vary. This would lead to new quasicrystal configurations with high negentropic content.

From the point of view of individual quasicrystal regarded as conscious entity fight for survival would be fighting for metabolic resources and fusion with a bigger quasicrystal could be one manner to guarantee the availability of metabolic energy.

3. Phason dynamics seems to allow both short range description in terms of permutations of basic units and long range hydrodynamical description. Two dynamics seem to be present: slow *resp.* fast dynamics in short *resp.* long scales. Maybe these paradoxical properties of phasons could be understood in this framework if the microscopic fast dynamics forced by the slow long length scale dynamics of flux sheets.
4. Also other than quasicrystal configurations would be possible but would require higher metabolic energy feed to preserve entanglement negentropy (amount of conscious information). In 4-D case one would have similar grids of thin and effectively 3-D magnetic flux sheets associated with the 3-D faces (maybe icosahedrons) of 4-D building brick of quasicrystals. Magnetic flux sheets would carry dark matter and give rise to negentropic entanglement between the units of the quasicrystal.

5. The negentropic entanglement between two different quasi-crystal like structures means quantum superposition of different space-time surfaces since the grids formed by the flux sheets would have different geometric parameters such as the distance between the flux sheets of the grid. Hence genuine quantum gravitational effects would be in question having no description in QFT framework and requiring description at the level of WCW.

## 2.4 Summary

The essential element of picture would be spin glass degeneracy giving a large number of ground states making possible highly negentropic entanglement between separate spin glasses. Quasicrystals are not the only manner to satisfy this condition and 4-D quasi-lattices for which grid could contain also more general 3-surfaces than hyperplanes, can be considered. Grids of thin 3-surfaces would represent the rules forcing the quasi-lattice like configurations through localization to the worldlines defined by intersections of two 3-surfaces. TGD inspired quantum model for biology suggests concrete models for the grids of flux sheets involving also flux tubes topologically condensed on them as a manner to generate negentropic entanglement. Also fractal structures consisting of flux quanta inside flux quanta are highly suggestive.

The basic variational principle of quasicrystal dynamics (and its generalization to quasi-lattices) could be minimization of metabolic energy feed in presence of fixed configuration of the magnetic body obeying a relatively slow dynamics. The time scale of EEG is in the range .01-.1 seconds gives a first guess for the time scale of the dynamics of the magnetic body in scale of Earth. This time scale is to be compared to the time scale of  $10^{-10}$  seconds of conformational dynamics bio-molecules. Quasi-crystallization - or more generally, formation quasi-lattices - would be due to the existence of grids of thin 3-sheets parallel to the basic units of the 3-faces of 4-D basic unit of quasicrystal.

To show that this picture makes or does not make sense, one should be able to estimate reliably the metabolic energy feed needed to preserve a given negentropic entanglement entropy for a given configuration of the basic units (say clusters of water molecules) and to show that it is minimized for quasicrystal configurations in presence of the grid structure formed by flux sheets. This is probably relatively easy since the first guess for the equilibrium configurations corresponds to the highly symmetric crossing lines of for two 3-planes. One might also try to demonstrate the presence of negentropic entanglement between molecules, which are in resting state. This would be a direct demonstration for the notion of WCW and for non-trivial quantum gravity effects in living matter.

**Acknowledgements:** I want to thank the quantum gravity research group of Topanga, CA, for a generous support Klee Irwin, Fang Fang, Julio Kovacs, Carlos Castro, Tony Smith for highly interesting discussions concerning quasicrystals.

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