



**The GDI Revisiting Programme**

**Part I: The Progressive Perspective: Top-Down**

# Emergence and Evolution of Meaning

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One longer version to be published in:

- *Information* 2011, (in press)
- Draft version available in: <http://bitrum.unileon.es>

# 1st result

- Information is always meaningful, but not necessarily truthful. (Modified GDI)
- Starting point: The Universe (at the Big Bang) begins with a generalized process of computation
- Energy (-matter) and information are different aspects of the same underlying substratum: matter = energy that acquired mass.

# The Big Bang is also a Bit Bang

- Lloyd (2006, 2010)
- “... [b]its, Boolean variables, and classical computation are all emergent or approximate properties of qubits, manifested mainly when they undergo decoherence.” (Deutsch 2004b, 93)

# It from Qubit

- Bit Bang Thesis consequence of „It-from-Bit“ thesis of Wheeler’s (1977): „... the universe be fundamentally an information processing system from which the appearance of matter appears at a higher level of reality.“
- Zizzi, Lloyd: It from Qubit (1999)

# Deutsch contd.

- : “The world is made of qubits ... What we perceive to some degree of approximation as a world of single-valued variables is actually part of a larger reality in which the full answer to a yes-no question is not just yes or no, nor even both yes and no in parallel, but a quantum-observable – something that can be represented as a large Hermitian matrix.”  
(Ibid., 100)

# Loop Quantum Gravity

- „... just as a polymer ... the fundamental 1-dimensional excitation of geometry can be packed appropriately to provide a geometry which, when coarse-grained on scales much larger than the Planck length, resembles continuous geometries.“ (Ashtekar, 1998)

# Loops

- Named after Wilson-type loops = closed curves carrying quantized electric flux and being organized into hexagonal networks called spin networks.
- Essentially holonomies: representing a generalized kind of parallel transport described in terms of a suitable Lie group element.



# Loops

- The result of evaluating a Wilson loop about a very small planar circle around a point  $x$  is proportional to the area enclosed by this circle times the corresponding value of the curvature tensor of the gauge field evaluated at  $x$ . (L. Kauffman, 1994)
- A spin network then, is a linear combination of products of holonomies of closed curves that wrap along the graph.

# Evolution = Organization

- If a theory of cosmology must, in order to be self-consistent, be a theory of the self-organization of the universe, the very aspect of organization entails a concept of information on an equal footing with the concept of energy. (Smolin, 1997)

# Loops & Spin Networks

- With a *loop* (cf. e.g. Loll 1994, Rovelli 1997) we mean here a closed curve  $\alpha$  such that
- $T[\alpha] = -\text{Tr} [U_\alpha]$ , where

$$U_\alpha(s_1, s_2) \sim P \exp \left\{ \int_{s_1}^{s_2} A_\alpha(\alpha(s)) ds \right\}$$

- is the parallel propagator of the vector field  $A_\alpha$  along  $\alpha$  defined by (the  $s_i$  being points of  $\alpha$ )

$$\frac{d}{ds} U_\alpha(1, s) = \frac{d\alpha_i(s)}{ds} A_i(\alpha(s)) U_\alpha(1, s)$$

# Loops & Spin Networks

- The  $SO(3)$ -field  $A$  is here essentially the difference of the  $SU(2)$ -spin connection and the extrinsic 3-curvature called *real Ashtekar connection*:

$$A_i^j(x) = \Gamma_i^j(x) - k_i^j(x)$$

- The important result (cf. Rovelli) is that each spin network state can be decomposed into a finite linear combination of products of loop states.

# Loops & Spin Networks

- So „[w]hat we [a]re really doing, ... , is writing down ,quantum logic gates‘ which manipulate *qubits* in an  $SU(2)$ -invariant [in fact,  $SL(2,C)$ -invariant] way. We [a]re seeing how to build little Lorentz-invariant quantum computers. From this viewpoint, what the Barrett-Crane model does is to build a theory of quantum gravity out of these little Planck-scale quantum computers.“ (Baez, Christensen, 2000, 42)

# Loops & Spin Networks

- von Neumann entropy of the form  
 $S(\rho) = - \text{tr } \rho \ln \rho$ , where  $\rho$  is a suitable density matrix.
- $S_E(\Omega)$  with  $\rho_\Omega = \text{tr } H_\Omega^c |\psi\rangle\langle\psi|$ . For cyclic functions of an  $SU(2)$  connection  $A$ :  $\{\psi | \psi(A) = f(U(A, \gamma_1) \dots U(A, \gamma_L))\}$ .
- Then,  $\oint_\gamma dS_E(\Omega) \geq 0$  fulfils Stuart Kauffman's condition for an **autonomous agent**.

# Spin Network

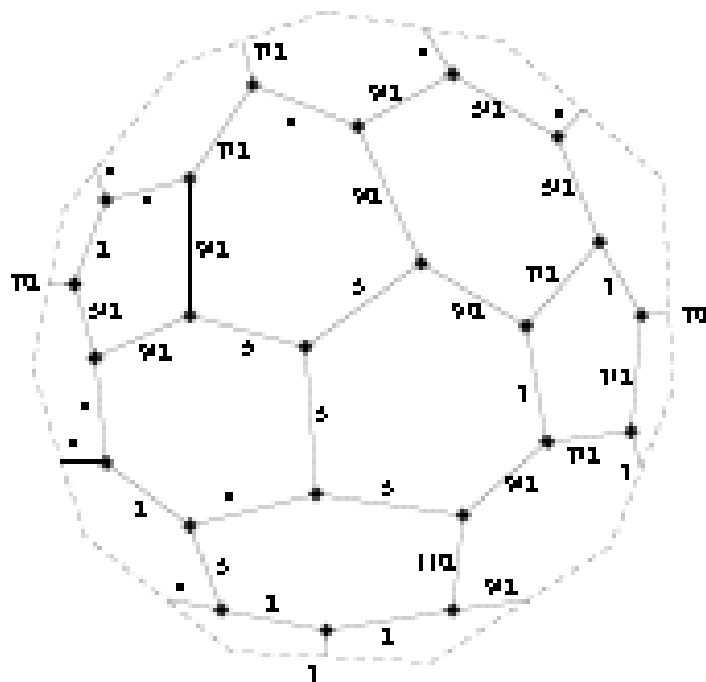


Figure 6: A spin network

# Space Triangulation

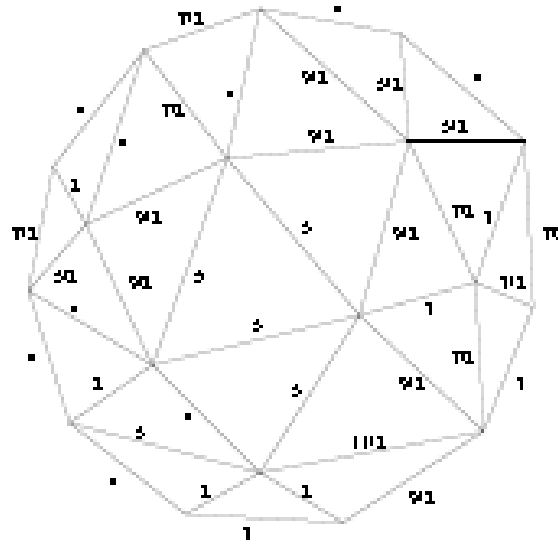


Figure 4: A state in the preliminary Hilbert space for 3-dimensional quantum gravity



# Cobordisms

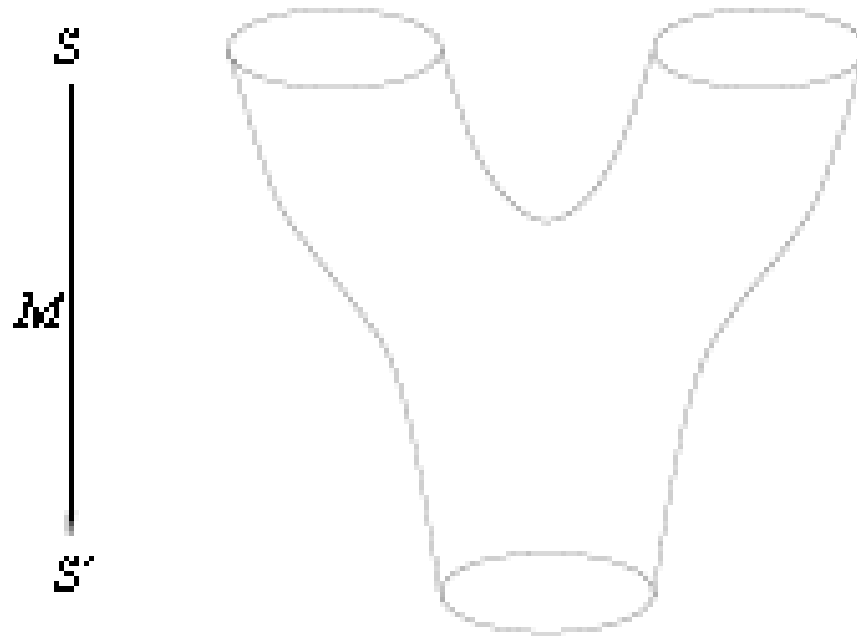


Figure 1: A cobordism

# Cobordims

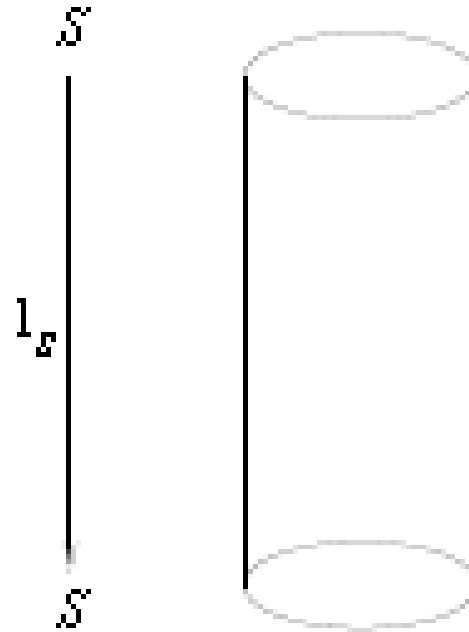


Figure 3: An identity cobordism

# Cobordisms

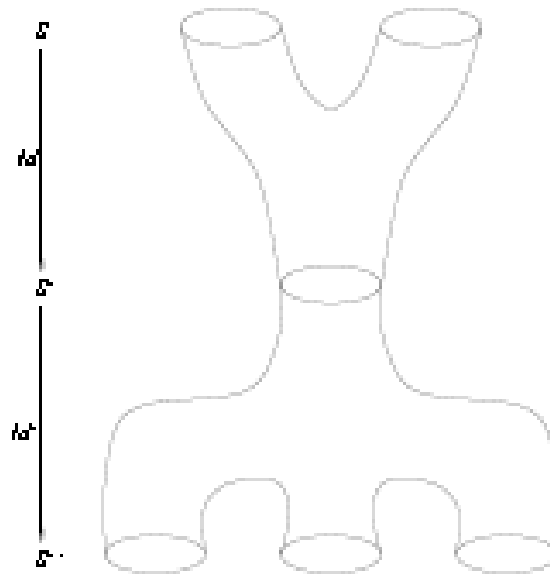


Figure 2: Composition of cobordisms

# Meaning

- (Lloyd, 2006): If you adopt Wittgenstein's perspective that the meaning of a piece of information is to be found in the action this information provokes ...
- Action from the beginning on: spin networks as the fundamental fabric of space processing information by organizing co-operating loops to constitute these very networks.

# Consequences

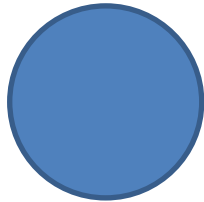
- A loop in the above sense fulfils what Stuart Kauffman calls the criteria for autonomous agents.
- Hence: We stay with Floridi's formulations ON1 through 4, but dispute that false information is no information.
- We differ between pre-reflexive and reflexive (human) types of meaning.

# 2nd result

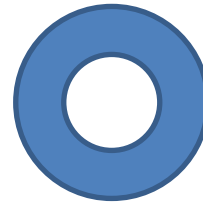
- In analogy to the concept of energy, there is no trilemma in the sense of Capurro: because evolutionary levels are organized according to their degree of complexity (superposition principle).
- According to evolution in the sense of S. Kauffman's 4th law of thermodynamics, the multiperspectivity of univocity, analogy, and equivocity unfolds the relevant local viewpoint.

# complexity as distinction

- Spencer-Brown: no indication without distinction (= difference)



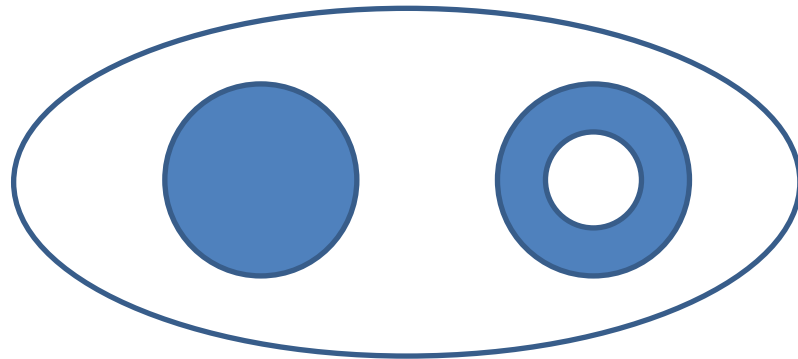
empty set 0 = P



Set whose member is the empty set 1

# complexity as distinction

- Complexity vs. Information
- Distinction = transformation from the state called inside to the state called outside



set whose members are 0 and 1



# complexity as distinction

- arithmetic of forms = patterns of distinction
- arithmetics have algebras the first of which is the Boolean algebra associated with classical Aristotelian logic
- recursion implies self-reference
- negation relevant:
- $O = C \Leftrightarrow \textcircled{C} = \text{Not } C$  (complementarity)

# difference that makes the difference

- distinguishing distinctions = differentiating differences (in terms of self-referential recursions) = dialectics of systems
- Laws of Form and the Logic of Non-Duality:  
Louis Kauffman,
- [www.math.uic.edu/~kauffman](http://www.math.uic.edu/~kauffman)

# Table 1

<b>energy</b>	<b>information</b>
<b>potential for a state vs. actual states (matter)</b>	potential information vs. actual information (structure)
<b>capacity to perform work</b>	capacity to organize by utilizing work
<b>local balance vs. global conservation</b>	local balance vs. global entropy balance
<b>total energy = 0 incl. matter</b>	total information = ? incl. structure
<b>varies by complexity</b>	varies by complexity

# Table 2: Rosetta (Baez/Stay, 2008)

categories	physics	topology	logic	computation	games
objects	Hilbert spaces	manifold	proposition	data type	(ground) state
morphism	operator	cobordism	proof	program	strategy
tensor product	of Hilbert spaces	disjoint union	conjunction	products	move products
tensor product of morphisms	parallel processes	of cobordisms	parallel proofs	parallelly executed programs	algorithm
Internal homomorphism	dual Hilbert space products	orientation reversal	conditional proposition	function type	isomorphic algorithms