BIT, IT, BOTH OR NEITHER

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1 INTRODUCTION. INFORMATION

Since antiquity, human beings have always had an intuition that what there is – existence – has emerged from something else. The implied question of "why is there anything at all?" has never been satisfactorily answered. Science has not provided an adequate meaning for these concepts or the implications of "from" which remain the purview of religion and tradition. Another question, as to whether geometry (position, form) or matter (energy) is more fundamental in the universe – the "ground of being" - is also still debated today, in the terms of information and quantum physics.

Quantum physics has enabled insight into the properties of what *is*, in three domains: the quantum vacuum and its apparent content of zero-point energy and virtual particles; the quantum particle-fields that are the energetic ground of "ordinary existence"; and the thermodynamic world of matter, energy and change we inhabit. The nature and properties of these domains nevertheless remain subjects of debate.

Information is somehow associated with or constitutive of what *is* but has proven difficult to characterize, due to its multiple duality: it has both physical and apparently non-physical components. Information is both meaningful and a carrier of meaning. Information can be viewed as well-defined data [1], processes [2], referring to what is not or not yet "there" [3] and in many other ways. As noted by the philosopher of information Wu Kun, to approach correctly a concept considered part of standard science—information—we must reexamine the entire philosophical structure of transmitted human knowledge!

2 THE THEME OF THE CONTEST

The theme of the Contest, "It-from-Bit or Bit-from-It?" is also stated in the Contest document as whether *information* or "material" objects is more fundamental in the universe. Wheeler's position, following Wiener, can be summarized by two statements: 1) information is not energy; and 2) information and not energy is fundamental. A related view is that the universe operates like a digital computer, and the emergence of Its as things from Bits as immaterial digital information is the only acceptable cosmogony. The further key issue is that of continuity: even if energy as objects – Its - is primitive, is the universe at bottom discontinuous and digital?

Any answer thus requires, as a minimum, a more complete statement of at least two opposing positions and of the definitions of information corresponding to them. The following reflects my initial views:

A. **It-from-Bit**

1. Bits are fundamental and constitute information.
2. They have the properties of binary arithmetic digits
3. They support the concept of a digital, computational universe that processes this information to produce Its (things).

B. **Bit-from-It**

1. Its are fundamental.
2. They have the properties of energy, better energetic processes, including information and point toward analog, natural computation.

3. Bits as information accompany and/or are an integral part of Its and emergent phenomena. They enter into *a posteriori* descriptions of digital computation.

In this essay, I will support the position of Barbour [4] in his 2011 essay "Bit-from-It". As Collier put it [5], each interaction (1) in quantum mechanics involves a sort of choice (2), and the choice can be represented in terms of bits (3). But this does not prove that the interaction (1) is constituted by bits (3), still less that non-quantum interactions and all forms of information are so constituted. *Contra* Wheeler, Barbour made a convincing argument for the primacy of things, but left open the possibility that nature is fundamentally digital and continuity an illusion. My theory, outlined below, strongly supports his first position, with the proviso that 'things' are primarily understood as dynamic (energetic) processes. However, it offers a significant alternative to the second, based on the self-dualities and dualities of quantum physics and the functional role of the relational properties derived from them at higher levels of reality[1].

C. It-and-Bit

Thus, going beyond the simple dichotomy, I will discuss some additional positions, which I refer to as It-*and*-Bit:

(1) Energy and information are the most fundamental entities in the universe, but neither is ontologically prior to the other.

(2) Information and energy emerge together from, or are different aspects of, an as yet undefined primordial substrate more fundamental than either.

In my synthesis of these positions, at some level of reality, I suggest that energy is more fundamental than information, and information emerges from but is always functionally associated with it. In the macroscopic world, energy and information, as well as continuity and discontinuity, are non-separable partners.

3 THE LIMITED SCOPE OF IT-FROM-BIT

Positions A. and B. above both refer to information but mean something quite different by it. As stated by Gordana Dodig-Crnkovic [7]: "Info‐computationalism is a view according to which the physical universe on a fundamental level can be understood as an informational structure whose dynamics is a computational process. Matter/energy in this model is replaced by information/computation; matter (structure) corresponds to information while the dynamics ‐ constant changes in the informational structure – are computational processes."

Floridi, in the Chapter on It-from-Bit in his *Philosophy of Information* [8] argues that *digital ontology*, according to which the ultimate nature of reality is digital, should be carefully distinguished from *informational ontology*, according to which the ultimate nature of reality is structural. Floridi avoids the Boolean digital *vs*. analogue dichotomy in favor of an Informational Structural Realism, according to which knowledge of the world is knowledge of its structures. The most reasonable ontological commitment favors an interpretation of reality as the totality of structures, energetic entities, dynamically interacting with each other.

The It-from-Bit position reflects the view of information incorporated into Wheeler's doctrine. This doctrine includes five significant, mutually dependent statements:

1. Every It derives its existence, even if in some contexts indirectly, from apparatus-elicited answers to yes-or-no questions, binary choices.

[1] As discussed by McGinn [6], taking *any* realist position or ontological option about such "things" as fields and particles involves difficulties which I will not attempt to address here.

2. It-from-Bit symbolizes the idea that every item of the physical world has at bottom an immaterial source and explanation.
3. That what we call reality arises from the posing of yes-no questions and the registering of equipment evoked responses.
4. All things physical are information –theoretic in origin, and
5. ours is a participatory universe.

The results of electron-beam splitting experiments by a magnetic field, which constitutes the energetic It in this case, are adduced in support of Point 3. As Barbour points out, however, the presence of a dot on a computer screen, here the Bit, is not a simple Boolean (yes-no) answer to the appearance of interference, but implies differences in the experimental results with and without the field that cannot be understood in isolation. "Wheeler's thesis mistakes abstraction for reality. … Just because the overall conditions of the universe enable us to observe them in carefully prepared experiments, dots on screens are no proof that the world consists of immaterial single-digit information".

We thus have already reason to question Points 1 and 3. Point 2, on closer inspection, is not even a claim for a "digital physics": It-from-Bit only *symbolizes an idea.* If the idea is wrong or incomplete, then the possibility that material sources and explanations may be fundamental cannot be excluded *a priori.* Point 4 is a restatement of Point 2 and adds no new information or proof, but its completion by Point 5 is extraordinary! It implies that only a fundamentally *immaterial* universe, describable by standard notions of digital information, could be "participatory". As I suggest below in support of the concepts of Bit-from-It and It-and-Bit, the tendency to favor immaterial information over matter-energy (Its) may be due to the apparent absence of a basis for meaning in the latter. Information would appear to more easily enable the ascent from quantum Its to the complex macroscopic world.

These five It-from-Bit positions are contradicted by general relativity; which requires an inertial frame of reference; relational quantum mechanics (see below); and current cosmology which supports a configurational view of the universe in which there is neither a containing space nor a standard background time [9]. Let us now look at the versions of It-from-Bit adduced in connection with computational models of the universe.

4 COMPUTATIONAL MODELS OF THE UNIVERSE

Much discussion of whether information or matter-energy is more fundamental relies on the concept of the universe as a computational system equivalent to a Turing Machine[2]. It has been suggested that information may be an artifact of human thought imposed on nature to describe some of its aspects, or in some computational models, the same as nature. Tamari's answer to the question [10] is neither It-from-Bit nor Bit-from-It but rather It = Qbit at the Planck-scale of the universe. We will look at one model in which the reader can find references to earlier work.

4.1 The Computational Universe of Lloyd

Since Church and Turing, it has become common to describe thermodynamic processes as equivalent to performing a computation (though, importantly, it is equivalence under an *interpretation*). But Lloyd [12] makes the more radical claim that "here is where life shows up.

[2] See for example the Mathematical/Computational Universe Hypothesis of Tegmark [11].

Because the universe is already computing from the very beginning when it starts, starting from the Big Bang, as soon as elementary particles show up."

On the assumption that organisms and brains are also merely computers, it seems that Lloyd views teleological processes as mere complications of the general digital information processing of the universe. Here Lloyd walks a tightrope between pan-psychism and its opposite, the eliminative view that computation is only physics—a physics that has no room for intentional properties [13], those unique to some animals and humans. The fact that the universe expresses, eventually, intentional information is not a proof that information is primitive and neither the universe nor information necessarily have the characteristics which Lloyd reasons they have (my summary):

- The universe can be regarded as a machine; the universe is *technically* a giant computer. *Therefore*, the universe *is* (emphasis mine) a machine that processes information.
- Elementary particles can be programmed to perform arbitrary digital computations. *Therefore*, the computing universe is not a metaphor, but a mathematical fact; the universe is a physical system that can be programmed to perform universal digital computation.
- The universe is continually creating random bits of information. *Therefore*, because of its computational nature the universe processes and interprets those bits, naturally giving rise to all sorts of complex order and structure.

Lloyd claims that the physics of the computing universe is the basis for its metaphysics, as Aristotle's physics was for his *Metaphysics*.[3] For me, however, the above arguments are not physics and are all open to question: what if the universe is not a machine? What about processes which are not computable? What if there are other sources of order and structure? In the same compendium [14], Davies suggests that the ground of being is somehow vested in a quantum wave function rather than the informational bits that emerge from (its) measurement and observation. Let us now proceed, then, to a first alternative view.

5 BIT-FROM-IT

I have given above Barbour's main argument *against* It-from-Bit. His main argument *for* Bit-from-It is that the properties of all kinds of information, either as digital bits or the differences or distinguishing attributes refer to things.

Their structured variety is the "ground of being", the content of science and life in a low entropy universe. This reality creates information and is separate from it. My own non-propositional Logic in Reality [15] (cf. Appendix A) supports several of Barbour's key insights:

- Nature may be both continuous and discontinuous, instantiating both continuity and discontinuity (see Section 9);
- There is neither a containing space nor an unfolding of time, and, one cannot ask when or where things happen; things are or produce their own time and space[4].
- There is still causality but of a "different kind", that is the reflection of a dialectic interaction between cause and effect.

[3] I note that in Book IX of *Metaphyiscs*, Aristotle frequently indicates that energy is primary as opposed to potentiality or other principles.

[4] This echoes a statement made by Stéphane Lupasco in 1951.

However, even if Bit-from-It is accepted in the sense of Barbour, full application to the understanding of information cannot be made if the "special properties of the world" are 1) discussed only in terms of "its" as described by quantum mechanics, but no extension is made to processes at macroscopic levels of reality: and 2) we are required to make a (classical) *binary* choice between continuity and discontinuity as the more fundamental in the universe.

One should, therefore, construct a basis for the emergence of information and meaning from the "underlying invisible world of quantum fields and particles". Barbour does not discuss the evolution of the configurations of the fields in which quantum events are embedded. To do so, I will have to go beyond the It-Bit dichotomy.

6 RELATIONAL PROPERTIES. QUASI-INDIVIDUALS

The existence of relational properties in the universe might help resolve the debate regarding the fundamentality of energy or information (Penrose [16]). Relational Quantum Mechanics [17] discards the notions of the absolute state of a system, value of its physical quantities, or an event and describes only the way systems affect one another in the course of physical interactions. Elements and events are not the 'material' terms of a relation, but are themselves always relations. Can the It-from-Bit theory provide a basis for relational properties? I think it cannot. The standard definition of Bits types them as classic individuals, with a total *absence* of relations between them as such.

Following Krause, I consider Bits [18] as quasi-individuals. Relational properties, if they are present in Its, must somehow arise during the transition from Its to Bits or subsequent to it. The world then involves fundamental aspects that absent in Bits, contradicting the idea that Bits are the sole source of everything real. In the latter case, we must ascribe to Bits the capacity or potential for the emergence of relational properties. In both cases, the result would be a radical change in the concept of a Bit as a classic individual.

Collier's It-from-Bit position [6] retains the idea that information (Bits) is fundamental but that Its emerge from distinctions or differences between the Bits. To me, this requires a concept of *non-digital* "Bits" that can reflect qualitative differences other than that between a 0 and a 1. Now, such source Bits look like Its themselves, that is, like energy or energetic systems, no longer primitive and structureless. One thus comes to a Bit-from-It position where all bits emerge from some more fundamental substrate such as matter-energy.

6.1 The Meaning of "From"

Relational properties pose no problem for the Bit-from-It position, as digital Bits are not required to have them and can be defined as entities lacking them. However, one should show what "from" means, that is, how non-relational Bits emerge from Its or are related to them. Barbour's view is that a digital Bit is simply part of a large interconnected phenomenal world. Another approach is to say that all change, all real processes including cognitive processes involve transfers of energy. However, as Priest has shown [19], non-real or abstract entities do exist. Bits can be seen as the imaginary entities that the mind can 'abstract' from the reality of the energy that they are (in ones computer), they can be counted, *etc.* The cognitive process involved is then no different from that in thinking about any abstract entity or logical proposition: the process involves energy that the ideal object does not possess.

7 IT-AND-BIT (1)

A version of It-from-Bit is due to Chalmers in which information, as Bits, is truly fundamental but has two aspects or components corresponding to the physical and the

phenomenal features of the world. This formulation begs the question of which aspect is primary one and whether they can be totally separated. However, it does suggest that there is an irreducible interactive relation between energy and information such that the designation It-*and*-Bit corresponds better to reality, the "existential field".

This case is perhaps implied by Barbour's statement, echoing Leibniz, that reality consists in configurations, and these configurations are reality, everything that *is*, which we separate into the categories of information and energy. However, as Collier has pointed out, at the lowest level we can imagine, that of the quantum vacuum, all processes are totally random, structureless and timeless, and neither information nor energy in the standard senses is possible. There are no "records" in the quantum vacuum, and attempts to find direct links between the quantum vacuum and biological macromolecules, as in the "fluctuon" theory of Conrad, have failed. Therefore, whether information or energy is *more* fundamental, neither can be the *most* fundamental entity.

8 IT-AND-BIT (2) ENERGY AND MEANING

The position, developed recently by Diaz Nafria and Zimmermann [20], suggests that both matter-energy and information are two different, associated aspects of the same underlying and still unknown primordial structure of the world. The best picture is that they emerge together from this substrate: the concepts of energy and information are always present in fundamental physics. The authors refer to Smolin's view that a theory of cosmology must, in order to be self-consistent, be a theory of the self-organization of the universe and "the very aspect of organization entails a concept of information on an equal footing with the concept of energy". Within a Theory of Everything, both concepts would be unified.

8.1 Energy as the Ground of Information and Meaning

Diaz Nafria and Zimmermann correctly state both 1) that the major problem is how information acquires meaning and that 2) attempts to solve the problem, for example by Floridi, have been limited by focus on the epistemological features of information. A major objection to the concept, expressed in the Bit-from-It position, that energy is primitive is that it appears meaningless and its ability to function as a source of meaning difficult to establish. In a computational universe digital information as Bits is fundamental and the "presence" of information would appear to provide a ground of meaning, but no mechanism for its emergence is stated, for example in Lloyd [12] .

Diaz Nafria and Zimmermann therefore opt for an "onto-epistemic" stance. As I discuss below and also in [2], data are relational entities, and information, given its relational qualities, always entails meaning. The ontological ground of information and thus of the meaning that emerges from it, both ontologically and epistemologically, is energy, an energy that is in some sense the prime expression for (or of) the *potentiality of the system.* They quote McMullin to the effect that it "is to the potential, rather than to the actual, that reality should be attributed at its most fundamental level". The approach I have adopted elsewhere [15] is to provide a demonstration of how actuality and potentiality can evolve together, alternately and reciprocally, to have the "best of both worlds", so to speak.

My critique of the Diaz Nafria – Zimmermann program is that it retains a separation of energy and information as standard categories of irreducibly different phenomena. They consider with Burgin that the underlying structure of the world and the general aspects of emergence can be well modeled by category theory. Thus they extend the distinction between potentiality and actuality of information by ascribing potentiality to *energy* and *information*, with respect to the *realization* of changes in processes or the *selection* of changes respectively; on the other hand,

and actuality to *matter* and *structure* with respect to the actualized and selected changes respectively. In my view, such formal categorial separations are neither necessary nor desirable for several reasons. They appear to return to outdated dual substance positions despite the authors' stated preference for a Heraclitean monism. In my view, no real complex process is totally actual or potential, and the movement from actuality to potentiality must be provided for as well as the reverse. In the next Section, I will attempt a synthesis of the best features of the alternatives summarized above.

9 IT-AND-BIT (3)

Because, as noted, a domain of energy exists in which information does not, I am driven to my final variant, It-and-Bit (3). It-and-Bit (2) does not take into account that the information of processes and thermodynamic change does not inhere in isolated quantum particles. These must, in my view, be considered as energy, with a structure, but, as in the case of the timeless, pre-thermodynamic quantum vacuum, there is no information associated with their interactions other than the interactions themselves, no *meaningful* data. Some data from, for example, nuclear accelerators are said to approximate early high-entropy states of the universe.

I agree with Diaz Nafria and Zimmermann that their "substrate" (systems) is constituted by energy and not an abstraction from energy as in the computational case of It-from-Bit. In my preferred picture, information and energy are the components of all higher level processes, but in contrast to the Diaz-Zimmermann view, information and energy are not and do not have to be absolutely the same or different, nor emerge in tandem. Because energy is primitive, (Bit-from-It), it is the dualistic, oppositional properties of energy that determine the properties of information. In the logic to which I have referred that describes such a state of affairs, they are the same *and* different, ontologically and also epistemologically, as the mind moves between focus on one or the other aspect to the partial, temporary exclusion of the other.

Recent work by Kaufmann [21] and his colleagues in the area of biosemiotics have also pointed to qualitative, second-level instructional or "biotic" information-with-meaning. Unlike the quantitative aspects of information, higher-level information in my view has not been, and in my view, cannot be captured by any categorial theory involving separate exclusive and exhaustive categories, in view of the dynamic relation between energy and information.

A further appropriate description of information is provided for this alternative (It-and-Bit(3)) by Hofkirchner [22]. In his concept of an "emergent creative universe", inhabited by us as real subjects, he places the concept of self-organization as central to the production of novel information by systems where the "deterministic connection between cause and effect is severed" … and *information generation goes beyond a mechanical process that can be formalized, expressed by a mathematical function or carried out by a computer* (italics mine). I agree with this stance, but note that it also requires understanding the origin of the *capacity* for certain systems to self-organize and propagate information. For me, this capacity exists in the same antagonistic properties, referred to above, of the energy which constitutes any real system.

10 CONTINUITY *vs.* DISCONTINUITY. THE CONTINUUM HYPOTHESIS

Let us complete our discussion by showing how the above considerations apply to the question of the fundamentality of discontinuity *vs.* continuity. Barbour, following proponents of a digital ontology, seems to retain the view that the universe might be digital and that continuity is an illusion. I outline an opposing view and suggest a resolution of the two.

The continuum hypothesis refers to a conception of the universe founded on geometry, the Cantor-Dedekind view, as discussed by Longo [23], which sees not only in mathematics, but

everywhere, continuity as ontologically preceding the discrete: "The latter is merely an accident coming out of the continuum background." Points are derived concepts, even if 'non-dimensional'. In this view, geometry (statism) is in some deep sense more fundamental than dynamics, that is, energy. This hypothesis has the advantage of corresponding to our intuition and experience, integrated into and confirmed by mathematics, of continuity in our perception of 'time' and linear movement. Penrose, on the other hand, had the strong intuition that physics and the space-time structure should be based on *discreteness*. This discreteness is evidenced in quantum number and spin, combined with a fundamental notion of phenomena as a relation between objects, rather than only between an object and some background space [24].

In principle, differential calculus captures the apparently simultaneously continuous and discrete nature of changing phenomena. However, this position only displaces the philosophical and metaphysical problem. Change at an instant is what differential calculus presents in formal terms, but this begs the question of whether reality is composed of 'points' and 'instants' in the sense used in the theory. If it is not, then differential calculus, like classical logic, may *not* capture the essential properties of real processes and systems.

In [25], Bell quotes Weyl to the effect that "we are employing the principle of gaining knowledge of the external world from the behavior of its infinitesimal parts." However, I feel that Weyl made an error regarding these parts which I see as equivalent to Wheeler's Bits. Nothing proves that Bell's infinitesimals (or any others in standard calculus) and those of the physical world, (if such exist), are the same. I thus conclude that there is a fatal error in any description of the universe that embodies either absolute continuity or absolutely discrete Bits as constituting its fundamental parts.

Davies [14] agrees that the status of infinitesimals is crucial, but he remains agnostic about whether space-time is or is not continuous and differentiable and what the ultimate impact of insights from digital computation might be. The way is therefore open for a restatement of the view, available since the advent of quantum mechanics, that the answer is both.

11 SUMMARY AND CONCLUSIONS

My response to the question of this Contest is that energy-matter is ontologically prior to, that is, more fundamental than information as digital bits. I have considered the alternative that matter-energy and information emerge together from some more fundamental underlying but at this time unknown substrate – the ground of being. This picture (It-and-Bit (2)) is plausible, but it is less parsimonious than my preferred position. It requires a categorial separability between energy and information justified essentially on formal rather than physical grounds.

Whether the ground of being can be equated with the quantum vacuum can not yet be decided. My position is that the quantum vacuum does embody energy, but as it does not undergo thermodynamic change, information is absent and only evolves from energy at the particle-field level. In the thermodynamic world, energetic processes are always accompanied by or have the aspect of meaningful information which evolves further with those processes. Information can be defined as an operator, constituted by vector differences in energy levels, which changes the distribution of probabilities in a given set of energetic processes, constituted by both their potential as well as actual properties. The former provide the basis for the emergence of new, more complex informational entities. Such "Bits" thus emerge from energy and remain in a dynamic relation with it, a position that I have called It-*and*-Bit.

I have contrasted my views of Bit-from-It and It-and-Bit with computational models of the universe that are based on the assumption that since information is *present* throughout nature it is *more primitive* than energy in nature. But computationalism is not the world; it is a modeling

framework that is acceptable within certain domains and does not exhaust our possibilities to relate to the world [7]. Finally, a picture of the universe as fundamentally either continuous or discontinuous may be usefully replaced by one in which both continuity and discontinuity are jointly and dynamically instantiated.

12 APPENDIX A LOGIC AND INFORMATION

12.1 Information Logic (IL)

Logic has been largely absent from discussions of the foundational role of information because the available standard truth-functional bivalent or multivalent logics are unable to capture its complex properties. A first step toward developing a logic applicable to information was made by Floridi [26] in response to the need to formalize the relation of 'being informed' as a different one from 'having knowledge' or 'having a belief'. The term "logic of being informed" recognizes something static and abstract about standard formulations of Doxastic (DL) and Epistemic (EL) Logic, and opens the door to a more dynamic view of information processes. Floridi makes a basic case for a non-doxastic informational approach to the acquisition of knowledge that does not depend on the (tripartite) notion of knowledge as justified true belief.

12.2 Logic in Reality (LIR)

LIR is a new, non-propositional kind of logic that extends the domain of logic to real processes [15]. LIR is grounded in a particle/field view of the universe, and its axioms and rules provide a framework for analyzing and making inferences about complex real world entities and interactive processes at biological, cognitive and social levels of reality or complexity. Logic in Reality ascribes a logical, non-metaphorical content to descriptions of an antagonistic interaction between the individual and the world, as on-going informational processes [27] in which both actors change as the reactions of one or the other, alternately, predominate. Rather than a Logic of Being Informed (IL), LIR is a Logic of *Informing*.

12.3 Paraconsistent Logic

Paraconsistent logic (PCL) represents an advance over standard logics in that it can accept real contradictions, allowing exceptions to Aristotle's axiom of absolute non-contradiction. In principle, it should be capable of describing the complex interactive relations that are discussed here as being characteristic of information. However, the attempt is usually made to have PCL differ as little as possible from the principles of classical logic. The result, in my view, is to drastically restrict the scope of application of PCL in the real world.

12.4 Quantum Logic

Quantum logics would appear to offer a well-known basis for discussing the dual nature of information in our interpretation. Their elements are similar to non-standard probabilities in that the laws of commutation or distribution are not followed. Aerts' quantum formalism [28] can be applied to complex macroscopic phenomena, including the emergence of biological form and human cognition. Situations or entities intermediate between pure classical and pure quantum are possible. Standard connectives take on new, non-classical meaning, suggesting that, as in LIR, there is a close relationship between these logics and physics that may offer new insights into the structure and dynamics of information.

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