Relational physics and the concept of continuity.

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Abstract
The relational view of physics has been much discussed and growing support. Rovelli's Relational quantum mechanics, Einstein's Relativity, Meillassoux's Correlationism are the most prominent examples. In this paper, we complement the relational view of physics with the concept of a continuum. We look at the continuum as a participant in relations.

Keywords Continuum · Relativism · Relational quantum mechanics · Participatory realism

1 Introduction

Both ideas of this paper are widely represented in scientific literature. Here we use them in the most general sense. The Continuum is a fundamental, irreducible mathematical abstraction. The continuum is often equated with real or other numbers for practical purposes. We will use this term in its primary sense, as the opposing concept to discreteness. Relationality is the statement that physics does not describe physical systems, but only the correlations of physical systems.

The list of papers on each of those subjects would require many pages. Nevertheless, the scientific comprehension of both the continuum and relationality raises a number of questions. Difficulties with the continuum can be called the “entry problem:” the continuum is hard to formalize in language. The problem with relationality is the “exit problem:” we have access to phenomena, but not to noumena. We are locked in a correlation cage.

The most relevant to this paper approach to relationality is described in "Relational Quantum Mechanics" by Carlo Rovelli [1], his motivations and next discussions, including the information-theoretic approach and QBism. Some generalizations of relationality can be seen here [2]. Ideas in the spirit of this article can be found here [3]. Some insights into the continuum can be seen here [4], [5].

The topic of this paper is extremely general and, as a result, it inevitably entails many related topics. Many of them are speculative. The format of the article does not allow to cover all related topics to the extent that they deserve it. We will focus on presenting the key idea, and try to at least highlight related topics.

2 Model

I will present the model in terms of its own logic, but it is important to note that the motivation for this article is driven by the fact that ideas therein are compatible with the standard models of physics.

2.1. Abstractions

The concept of continuity inevitably entails the concept of dimension. Dimension is an inherent property of the continuum. This leads to the fact that we are initially dealing with a set of continua of different dimensions and, as a consequence, with choice, difference and relations between them.

It can be considered that the background for this paper is centered on the presence of continuum, called physical space, the three-dimensional emptiness in physical theories. Space can be included in a theory as is, or as part of a dynamic manifold. In both cases, it is postulated. We do not know experiments that directly confirm the existence of three-dimensional space. We "guessed" that it exists by indirect signs, such as the orbits of the planets, the rate of forces decrease, etc. Space is not perceptible and if we call it "abstraction," this will not contradict anything. This abstraction is primitive: the three-dimensional continuum of physical space is not a continuum of "something;" it is not deduced from something simpler.

Three-dimensional space is not by itself special, but it belongs to a special class of low-dimensional or geometric spaces. This class includes dimensionality spaces: three, two, and one. Zero-dimensional space is not a continuum, and higher-dimensional spaces are algebraic. Let us consider the other two spaces the way we "feel" the three-dimensional one - from the inside. This view is also consistent with the concept of the continuum as a primary, fundamental entity: no "outside" exists, there is nothing "before the continuum." Let us formalize such a representation in terms of rotations and permutations:

- in three-dimensional space, we only have rotations, a group of three-dimensional turns;
- in two-dimensional space, we have both 2d rotations and permutation: we may swap "top" and "bottom";
- in one-dimensional space, we have only a permutation; we may swap "right" and "left".

Rotations carry continuous information, permutations carry discrete information. There is now discreteness in our continuous topic: the permutation elements can be counted. Let us form this representation as a table (1).

3d-space	Rotations	Continuity
2d-space	Rotations + Permutations	Continuity + Discreteness
1d-space	Permutations	Discreteness

1. Inside view of geometric spaces.

Erwin Schrödinger called "Our helplessness vis-a-vis the continuum" to be the "godmother to the birth of science" [6]. Our understanding of the continuum, the expression of it in symbols, in language, is complex and far from clear. There is no evidence to suggest that we understand the continuum. The continuum, unlike numbers, existed long before the advent of mathematics. You need to learn a fairly large set of concepts to just get started with topology. The development of a Dimension theory stumbles over the definition of the "dimensionality" concept[7]. Topology uses the set-theory language, despite the status of continuum hypothesis (CH), and in general it is not clear why the continuum should be a "set of something." An independent entity has the right to have an independent logic. Attempts to express one abstraction in terms of another may well lead to useful results, but are unlikely to lead to understanding.

It should be noted that Tab. 1 is not intended as a definition of continuum. Rather it is supposed to give us an initial working understanding of "how we can see it." It is simply a call to look at the continuum "as it is." Our approach, if correct, assumes that one shall see manifestations of the basic physical entities: we started with the primary element. We can also expect that, like in the case of 3d-space, physics will provide us with only indirect signs of the existence of spaces: the continuum is an initial, unobservable, abstract entity, while what we observe are correlations, and the observation itself is a correlation. Next, we will consider some physical phenomena through the prism of Table 1.

2.2. One-dimensional space. Electric charge

The electric charge is quantized: the charge of any physical system is always a multiple of the elementary one. We observe only two types of electric charges. The electric charge is a point-like property; it has no size, which corresponds to the section of 1d space. Charge symmetry is conserved in nature, the universe is electrically neutral, and if we divide a 1d object, we shall receive two fragments as a result of each split, and their number will be equal. The force with which charges of different types interact with the environment is the same for charges of both types. The difference is that in pairs, charges of the same type react to each other differently than charges of different types. And in our view, when we are inside a 1d-space, we see two different directions, which do not differ from each other, except that they are distinguishable. *Electric charge is a property generated by one-dimensional space.*

2.3. Two-dimensional space. Spin

As the name suggests, spin has historically been thought of as a property of a particle that reflects its rotation. Further research showed that spin is not associated with either rotational motion or motion in general. Nevertheless, we note that rotation is in a sense "two-dimensional": there is no movement along the axis of rotation, and arguments excluding rotation as a property of spin do not exclude this two-dimensionality. If we measure the spin of an electron, for example, in an experiment of the Stern-Gerlach type, then we will find it in one of two states: "spin up" or "spin down". These "up" and "down" are determined by the magnetic field. Spins do not "feel" the 3d-space. Measurement of the projection of the electron spin on a certain spatial axis in the general case will show a random result.

The two-valuedness of the spin is qualitatively different from the two-valuedness of the charge. A spin is not a point, it "looks" like a fragment of a surface. The existence of a spin restricts the possible states of quantum systems to strictly two types: symmetric bosonic and antisymmetric fermionic, which corresponds to two types of quantum statistics. We never observe nonsymmetric states, and the symmetry of the hamiltonian guarantees that if a particle is in a state of a certain symmetry, then it will stay on in states of this symmetry. Fermions include one surface of 2d-space, and bosons – objects that include both surfaces. The normal, basic state is bosonic, corresponding to a two-dimensional two-sided space. The universe, the vacuum is characterized mostly by a bosonic state and zero magnetic fields. Fermions look like a defect, half a whole. This defect manifests itself in the form of a magnetic field that separates orthogonal directions in isotropic 3d-space. It is common for fermions to form pairs. *Spin is a property generated by two-dimensional space.*

2.4. Three-dimensional space. Mass

The only non-quantized property of particles is mass, and there is only one line in our list of three spaces that lacks discrete characteristics. Mass is a charge of one type and we have only one symbol in this line of the table. Mass always occupies a volume in 3d-space, if you try to compress it into a point, then at some moment it will collapse into a singularity. General relativity tells us that mass is closely connected to 3d-space. Mass is the main player in classical physics, where it moves along its trajectories. A trajectory is a well-defined concept in 3d-space. If the system has mass, this indicates that it has a rest frame of reference in a 3d-space. An interesting definition of mass can be given based on the essence of black holes: mass is a 3d-space beyond the 2d border.

In the Standard Model of particle physics, the Higgs field is responsible for the generation of initial masses. The Higgs field exists in space by itself. It inseparable from empty 3d-space. It has a nonzero value throughout the space. The Higgs field quantum is the only scalar particle in the Standard Model. *Mass is a property generated by three-dimensional space.*

2.5. Two-dimensional space. Now

The everyday meaning of the term "now" is clear to everyone; we have no difficulty in using this word in everyday life. It is not difficult to predict that you are now reading the word “Now." If something happens it always happens at a present moment, and this is consistent with common sense.

All that exists, all reality has the property of being now. Whatever we do, wherever we move, whatever we face – it all has the property of being now. We do not see stars, we register the annihilation of photons. But, despite such ubiquity of this "now", it is also completely absent in physics. "Now" is nonobservable.

Physics operates with the concept of "time". Time sets the temporological orderliness. «Now» is something between the past and the future. Time is one of the most important concepts in physics, it is closely related to energy. Energy is an abstraction, an invariant, conserved quantity. Energy is conserved due to continuous time translation symmetry. But every time we measure the amount of total energy in an isolated system, we do it in some "now". And the fact that we find the amount of energy unchanged means that all the energy of the system is completely in this Now: it did not remain in the past, and it did not flow into the future. Energy is conserved due to the existence of Now.

Now it is as ubiquitous as 3d-space, but this ubiquity is of a different kind. We are "compressed" in the present, there is an element of zero size in it, but besides this compression in the moment, in "Now", we have complete and continuous freedom of action. We are not afraid to fall out of this moment.

The phenomenon of “now” is connected with the concept of “simultaneity”. If we are in some common Now, we must somehow observe the simultaneity of what is happening. This is what happens in our daily experience, we all exist at the same time. This was the case in physics too, before the Special Relativity (SR). One of the consequences of SR was the relativity of simultaneity, the impossibility of different observers to agree on which events are considered simultaneous. This consequence was often interpreted as a property of nature on the whole: what is the point of talking about simultaneity if it is not observable? A new vision of this phenomenon was given by experiments on the observation of quantum entanglement. The observed correlations of photons that are far apart in 3d-space occur simultaneously, in the common “now”. The property that "gets entangled" is the spin, which we have defined as a property generated by 2d-space. The notion of Now as a macroscopic manifestation of 2d-space corresponds to its microscopic manifestation as a spin through the phenomenon of entanglement. *"Now" is how we observe two-dimensional space from the inside.*

2.6. Model

Let's write out our reasoning in the table.

	Abstractions		Observed	
	Dimensionality	View from inside	Correlates of matter	First-person view
SPACES	**3d**	**∞**	**Mass**	**Physical space**
	2d	**1∞1**	**Spin, Magnetism**	**Now**
	1d	**1 1**	**Electric charge**	

2. Classification of phenomena by type of generating space.

Table 2 presents the key message of this article: at the foundation of reality lies a continuum, an emptiness of three kinds. We took the continuum as an initial condition, chose a point of view, and found traces of the main metaphysical categories: space, time and matter. The model does not contradict physics: it so happened that physics does not describe the genesis of the entities we have considered. The present work can be seen as an abstract, non-correlation, qualitative, pre-dynamic addition to the concrete, relational, quantitative, dynamic picture of physics.

3 Discussions

Next, we will discuss some topics of physics, taking into account the assumptions of the previous section.

3.1. Correlations.

The idea of Relationalism (relativism, correlationism) is widely present in modern natural science. It comes from the fact that physics does not reveal to us the nature of things, it reveals to us the nature of relations. It makes no sense to talk about some physical system S, we never deal with such entities. What we deal with is always a conjunction of systems: S-S'. The Galilean relativity, Einstein's relativity, the essence of experiment, observation, measurement, interaction – all this includes relationality. Modern philosophy comes from the idea "according to which we only ever have access to the correlation between thinking and being, and never to either term considered apart from the other" [8]. Relationality in natural science has grown by itself, contrary to our desire for objectivity.

In this paper, we consider matter as a correlation. We assert that matter is a correlation of fundamental spaces. The third column in tab. 2 represents the correlation properties: we do not observe mass, charge or spin taken separately these properties are always in combinations, which we call particles. The correlation nature of particles is indicated by their various transformations. Another type of correlation is vacuum.

The most powerful space in our model is two-dimensional. It includes both discrete and continuous properties in column 2. Two-dimensional space can be a border, a break for the other two. Nature evidence this feature: we know about uncharged and massless particles, but we don't know particles without spin. 2d-space "observes" both 1d and 3d. In the metric representation, the hierarchy of spaces by the level of complexity looks like 1d<2d<3d, in our representation 3d<1d<2d (this does not imply that the spaces themselves include numbers or transitivity).

Correlations are arranged in a hierarchy. An organism is a correlation of molecules, a molecule is a correlation of chemical elements, etc. In this scenario, some of the correlations are secondary, that is, they represent correlations of correlations. The present work can be seen as a proposal for a way to highlight primary correlations.

3.2. Epistemic limits. Information

The issues of information and the limits of knowledge are actively discussed in the field of quantum foundations. Within the framework of QM, it is meaningless to talk about a complete description of an object or about the properties of non-interacting quantum systems. We also cannot assert that the measured value exists before the measurement. This leads to the question of what information we can get about quantum systems and how we can get it?

Let's quote Anton Zeilinger about the double-slit experiment: "The superposition of amplitudes ... is only valid if there is no way to know, even in principle, which path the particle took. It is important to realize that this does not imply that an observer actually takes note of what happens. It is sufficient to destroy the interference pattern if the path information is accessible in principle from the experiment or even if it is dispersed in the environment and beyond any technical possibility to be recovered, but in principle still ''out there.'' The absence of any such information is *the essential criterion* for quantum interference to appear”[9]. Observation (correlation) and superposition (lack of correlation) are mutually exclusive entities.

Electromagnetism can be defined as the correlation of electricity and magnetism, or the correlation of 1d and 2d spaces. Both of these spaces are easily represented as a wave. Consider a unit correlation between electricity and magnetism – a photon. We have never observed photons, we register their creation/annihilation. A photon for us is the abstraction, the best description of experimental facts. We cannot see a photon in motion. Photon is massless. Its localization in 3d-space is uncertain. Photons have zero spacetime interval. A photon is the primary correlation. Photon exists as a “dialogue” of two spaces. Any intervention in this process will lead to the fact that it will cease to be a “dialogue”.

The amount and type of information we can get from a physical system is limited. If we "ask a question" to the electron spin about its orientation in 3d-space, it will not be able to answer. Spin does not know what "three-dimensionality" is. It does not contain information of this kind. And as a result, when measuring, we always get either "spin-up" or "spin-down" relative to the magnetic field.

The difference between classical and quantum physics lies in the fact that the former describes secondary correlations, while the latter describes primary correlations. The objects of classical physics already exist as correlations of correlations. Quantum physics studies phenomena in which correlations arise from primary entities. We do not observe the Moon in a state of superposition, since it already exists as a correlation of correlations. This observation will not add or subtract anything. Observing the electron's spin gives it an orientation in 3d-space, which it did not have before. Observing a photon gives it a localization in 3d-space, which it did not have before. And so on. Information arises in quantum experiments.

Questions about epistemic limits are formulated using the concept of "information": We have direct informational access to phenomena, but not to noumena. We receive information about the "concrete" in a different way than information about the "abstract". One of the oldest questions in natural science can be formulated as follows: If some fundamental entities lie at the basis of nature, then why do we not observe them explicitly? The "relational" answer suggests itself: these entities fall out of the correlation circle in which we are bound. A natural candidate for the role of such an entity appears along with the assumption that nature began from "something", that it has a logical beginning, an initial element. If nature began with something, then this “something” has nothing with which to correlate: it is entirely alone. From this point of view, the question "What ultimately correlates?" is the question about initial conditions. The continuum is the primary essence; it is not decomposable into simpler ones.

This paper supports epistemic interpretations of QM. An epistemic approach does not have to imply some kind of ontology. There is uncertainty in physics on ontology issues: fields, particles, waves, waves of probability. The present work can be seen as an ontic addition to the epistemic approach.

The concept of "information" is actively discussed in modern science as one of the central ones. This topic is quite speculative. We note that information exists only where there is a balance of difference and "indistinguishability" (or indiscernibility). Remove the differences and you get "nothingness", remove the indiscernibility and you get chaos. The information will disappear in both cases. In nature, it has not disappeared. The classic bit carries this property: "one" is indistinguishable from "one" and different from "zero". When we learned to manage it, the information age began. Our spaces also carry this property: they are identical to themselves and differ from each other.

3.3. Indistinguishability (indiscernibility)

The concept of distinguishability is familiar to us. We were born with the difference "me and the world". The things around us are distinguishable by their places in space and time. In turn, indistinguishability in nature looks like a miracle. The question of the effectiveness of mathematics in the natural sciences is the question of the presence of indiscernibility in nature. Indistinguishability (indiscernibility) is a property of abstract entities. Mathematics is the science of indistinguishable entities in the sense in which the straight line is indistinguishable from the straight line, and the number two from the number two.

The laws of nature tell us about indistinguishability. There is some indistinguishability in the way bodies fall to the ground, and it can be expressed in the form of a physical law. Symmetry is a key concept in modern physics. Symmetries tell us what remains indistinguishable under some transformation. We can talk about the indistinguishability of directions in space, the indistinguishability of the total energy of a closed system, the indistinguishability of identical particles, the indistinguishability of the vacuum state, the indistinguishability of rest and uniform motion, the indistinguishability of the sense of gravity and acceleration, etc. Symmetry is a context dependent concept [10]. This work can be seen as offering such a context, as pointing to the source of indistinguishability in nature.

Relational reality assumes a first-person view. There is no “view from outside the world” or “view from nowhere”. SR postulates the existence of frames of reference. The principle of relativity says us that the laws of physics have the same form in all frames of reference. Physics tells us what remains indistinguishable when the frame of reference changes. However, a frame of reference must be chosen.

QM can be regarded as a probability calculus, a mathematical description of chance events. The question of how randomness enters QM is one of the main questions of its interpretation. If we add “choice” to indistinguishability, we get randomness for free. The choice from indistinguishable options is predictably random.

3.4. Choice

Mathematics uses the concept of choice. This issue is discussed in mathematics under the Axiom of Choice (AC) topic. The AC was explicitly formulated much later than mathematicians began to use it. AC says something about the agent and says nothing about the set. AC, like CH, is independent of axiomatic systems such as ZF. The converse is not true, the axioms must be chosen. Difficulties with the use of AC arise in the case when it is impossible to explicitly specify the choice function. When such a function is known, the choice becomes determined.

The concept of "correlation" includes a choice: there was a correlation of system A with system B, system C did not participate in the correlation. In other words: A chose B, B chose A, system C was not chosen. In QM we have to choose the observable, choose the type of correlation with the quantum system, which determines the type of information that we receive.

There is no "correct" orientation of 2d-space relative to 3d-space, but orientation can be chosen. In an experiment with two perpendicularly oriented Stern-Gerlach apparatuses, the choice of an electron spin will be random. By changing the angle, we will change the degree of indistinguishability of the choice of the electron. The assignment of a probability to a future event is an estimate of the degree of indistinguishability of the choices.

The states of superposition indicate that nature is lazy in choosing, she does not make redundant acts of choice. The double-slit experiment shows that if there is an opportunity not to make a choice, the choice will not be made.

Concepts such as "choice", "information", "probability" are context-dependent and seem subjective. Close to the "subject" concept is "agent", it is used, for example, in QBism. The agent is a participant of reality. An agent is characterized by actions, intentions, reasons, mission, purpose, meaning, or something similar. Buridan's Donkey do not exist, not because donkeys are able to choose from indistinguishable ones. Animals need to eat. Agents participate in the process. The most general process can be shown by starting from an indistinguishable choice of two electrical charges.

If you make a choice between two electric charges or two 1d half-spaces, then this choice will be random due to their indistinguishability. In the observable universe, this choice has been made: the negative charge is carried by the leptons, the positive charge by the baryons. The question of baryon asymmetry is the question of the existence of matter.

The universe is growing and the amount of energy increases as it expands. What can happen to a system that behaves like "The Magic Porridge Pot"? There are two options: to increase the volume (accelerated expansion) or to condense the energy per unit volume (matter). The universe uses both: it expands, matter condenses energy. A necessary ingredient for such a system, the one with which we started – the abstract as a source is inexhaustible.

4 Conclusions

If the ideas of this work are correct, it follows that a crucial experiment will never be possible. Experiments are locked in a relational cage, just as we are locked in a cage of language. This paper can be seen as a listing of indirect evidence. This list is far from complete; one can recall, for example, nonlocality, the absence of magnetic monopoles, the three-dimensional flatness of the universe, etc. We focused on experimental data and did not consider the formalism of standard theories. We have only touched upon huge layers of knowledge from the field of physics, mathematics, philosophy, which cannot be covered in one compact article. The key idea behind this work is quite simple, and I have tried to present it in an appropriate way. My goal was to outline a conceptual framework, to define an approach, a way to look at nature, and also to offer some conditional set of topics for discussion. In support of the hypothesis described in this paper, I can point out that it suggests a very tiny addition to the natural sciences.

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