An Attempt for a Theory of Everything*

Paolo Fabbri

Original work[†] in Italian, of November 23, 2017
Attempt of English translation of February 12, 2018

Abstract

English.

An ultimate non-arbitrary principle is found in Boolean algebra. It generates a quantum theory with local supersymmetry, which does not require renormalization. It nearly suffices to explain all known physical phenomena.

Italiano.

Viene trovato, nell'algebra booleana, un principio ultimo non arbitrario, che genera una teoria quantistica localmente supersimmetrica e non richiede rinormalizzazione. Essa è quasi sufficiente a spiegare tutti i fenomeni fisici noti.

Contents

1 Introduction

In this section, some theoretical developments of physics will be described in extreme synthesis. References will also be strongly synthesized. For those who wished a more detailed exposition, I advise them to consult [1].

*http://pfabbri.interfree.it/toe_en.pdf
†http://pfabbri.interfree.it/toe.pdf

Till now known physics is very well described by a theory (the "standard model") [2] [4], that concerns the behaviour and the interactions of a rather elevated number of fields.

For coherence with quantum mechanics, the classical theory of these fields (waves) is to be replaced by one that takes into account their particle nature [2] [3].

In constructing such a theory, one encounters very serious obstacles:

1. Lack of time derivative of some fields in the Lagrangian density. This implies some conjugate momenta are zero, with the impossibility to invert their expression, in favour of the time derivatives of fields themselves, that are to be inserted into the Hamiltonian.

2. Ambiguity in factor ordering, in the various terms of the Hamiltonian, because it is possible that such factors do not commute. Notice that, only changing the factor ordering, it is possible to transform an operator into any other [5] [1]. In the "path integral" approach, this ambiguity is replaced by that on the "measure" of the integral itself. Both can be absorbed into problem 3 (value of "renormalized" parameters).

3. Infinite corrections to the effective value of parameters present in the Lagrangian. This constrains to suppose that true ("bare") parameters are also infinite and opposite to corrections, so as to compensate them and to leave the experimentally observed effective value as difference ("renormalization"). However, even terms, with their infinite multiplicative constant, absent from the original Lagrangian, may rise as corrections. For them, we do not know what value the experimentally observable parameter must have. Its presence is then a point the theory leaves undetermined. The greater the number of such points is, the less the predictive power of the theory itself is, and the less it is attracting as a fundamental theory (because vitiated by many arbitrary choices). In some cases, the number of parameters, that remain undetermined, can even be infinite. One, perhaps improperly, then says the theory is not renormalizable. In the absence of gravity, the standard model is manifestly renormalizable. Gravity is not.

4. Ambiguity in the choice of "regulator", a mathematical tool that temporarily makes divergent quantities finite, allowing us to effect renormalization. This ambiguity can also be absorbed into problem 3.

5. Possible absence, in the quantum theory, of the classically present symmetries, with the resulting breaking of principles in which we believe, as Lorentz and gauge invariances.

Seemingly, these difficulties, with the exception of the non-renormalizability of gravity, have been solved. The fact that a theory is not renormalizable (or the equivalent problems that one cannot overcome the ambiguities of ordering, of the measure in the path integral, or of the choice of regulator) implies that the theory is well-defined when the energies of particles are low enough, or for processes involving sufficiently great characteristic lengths. In such regimes, the classical limit of the theory is sufficient to dictate the quantum behaviour too. On the contrary, it remains unknown what happens at the high energies or small distances.

One then puts the problem to find a complete quantum theory of gravitation. Moreover, one puts the problem to unify the many fields of the standard model.

Let us begin from the second problem.

Generalizing the internal gauge symmetries of the standard model to one that includes them as a special case, it is possible to unify the internal gauge fields. The leptonic fields are also unified to quark fields.

This picture is named "grand unification" [4].

The unification of all the fields, into a single entity, is more difficult, and is named "superunification".

Let us begin, trying to bind also gravity to the other gauge fields.

The most promising way is to make the hypothesis that it is the only really existing gauge field, but that the space-time dimensions are in greater number than the four known ones. The exceeding dimensions are not observed, because, in the directions along them, space-time is curved to form a subspace ("internal space") of very small extension. Only along four directions, space-time extends to infinity or nearly. As an example, think of a two dimensional space, closed to form the surface of an undefined cylinder. If the circumference, base of the cylinder, has a sufficiently small radius, the cylinder appears as a line, one dimensional rather than two dimensional.

In the passage to the described configuration ("compactification" or "dimensional reduction"), some of the components of the gravitational field distinguish themselves from it and form gauge fields of another type, the symmetries of which depend on the symmetries of the internal space. The components that distinguish themselves are those with one index corresponding to the internal space directions. From the four dimensional point of view, they appear as vectors. In the process, the components, with both indices along the internal directions, also distinguish themselves. They appear as scalars, and can originate Higgs fields, inflatonic ones, or other ones.

It may seem unlikely that the universe has assumed the form of such a long and thin filament. But, if, by random fluctuation, a small size filament had formed at the origin of the universe, known four dimensional physical laws would have been valid in it. Therefore it would have expanded to the present dimensions in the way we know.

Temporarily, the only variable of the described mechanism (said "of Kaluza-Klein") [16] [6] [7] is the form of the internal space. It can already originate various possibilities, but other entities ("branes", "fluxes") are also added to this. Thus, the number of possible results is enormous, and, in practice, any four dimensional theory can be obtained. As the standard model has some properties, very unlikely at first sight, and needful for the existence of life, one thinks a great number of universe-bubbles has formed, and continues to form, by random fluctuation. Each has its apparent physical laws, and we inhabit one of the few compatible with life ("anthropic principle") [22] [8] [9] [10]. The continuous bubble formation, and their successive expansion, from regions of microscopic dimensions to enormous ones, which appear as distinct universes, is in accordance with physical laws and with the theory of "inflation" [11], which seems confirmed by some experiments.

It remains to unify fermionic fields to the gravitational one. One completes the unification, introducing a symmetry ("supersymmetry") [12] [13] that transforms fermions to bosons and vice versa. When it is made local, one discovers it forms a single symmetry with the changes of coordinates (it cannot exist by itself). Therefore, the gravity field is a component of its gauge field. The latter has a fermionic component too, the particles of which are said "gravitinos". It is a remarkable fact, that supersymmetry does not introduce a new gauge field, which one does not know how to unify to gravity, but embraces it in a natural way.

Local supersymmetry is called "supergravity" [12] [14] [15], and the particle associated to its gauge field, with all its components, "supergraviton".

When one compactifies supergravity, besides the already cited bosonic fields, fermionic fields, which can account for fermions of the standard model, also originate owing to the presence of gravitinos.

Grand unification and superunification, like quantum effects that are not fixed by the classical limit, produce new phenomena at the high (or very high) energies, while the standard model is valid at the low ones.

A seeming weakness, of this picture, is that the number of dimensions of space-time is an arbitrary parameter of the theory. Moreover, supergravity is not manifestly renormalizable too.

"String" theory [16] [17] [18], "loop" quantum gravity [19] and "precanonical" quantization [20] [21] are the known to me approaches, that try to face the problem of non-renormalizability. In the following sections, we shall try an alternative way, which has many contact points with [23] [24] [25].

2 A theory of everything

From that we have said, it appears that local supersymmetry and the fact that the theory must be a quantum theory are rather well consolidated principles, and that they are sufficient to explain all known physical phenomena. On the contrary, we do not know anything of what locally supersymmetric specific quantum theory one must choose (that is of high energy quantum effects). One may be tempted to look for such theory imposing only these two principles over it. Unfortunately, they are, in a sense, kinematical: a symmetry law and one that tells us how states are to be described and interpreted. Without the introduction of a "dynamical" principle, one tends to obtain, rather than a theory "of everything", a theory of nothing, in which every fact is possible and there is no law to regulate the happening of events, in clear contrast with experience.

On the other side, to fix a law, which goes beyond the two cited principles, risks to be arbitrary: it seems that there is no criterion to choose amid the infinite number of possible laws.

The suggestion of this article is to look for this law not in physics, but in mathematics. Undoubtedly, the principle interesting us will realize a mathematical structure. Depriving mathematical structures of every meaning we usually attribute to them, and considering their intrinsic abstract properties only, does a non-arbitrary one exist amid the infinite number of possible ones?

The answer is affirmative: Boolean algebra. It is based on some axioms, and does not need others of them are introduced, to prove the verity or the falsity of any statement. Vice versa, all other mathematical structures need Boolean algebra, and are constructed adding new symbols and axioms to it.

We emphasize that structures, that have been introduced and studied in mathematics, are interesting for intrinsic reasons, independently of physical, anthropological, or other meaning, we are used to attribute to them. Therefore, the privileged role of Boolean algebra is objective and is not conventional.

The subject of mathematical structures is well introduced in [22]. To such treatment we shall conform in the following lines.

One defines a "formal system" as an entity constituted by:

1. A set of symbols.
2. A set of rules to determine which sequences of symbols are well-formed formulas (WFFs).
3. A set of rules to determine which WFFs are theorems.

Boolean algebra is a formal system, the symbols of which are: "$\sim$" (usually pronounced "not"), "$\vee$" (usually pronounced "or"), "(", ")" and a certain number of letters: "x", "y", ..., called "variables".

The rules to determine which expressions are WFFs are:

1. One single variable is a WFF.

2. If S and T are WFFs, $(\sim S)$ and $(S \vee T)$ are WFFs too.

The rules to recognize which WFFs are theorems consist in a set of WFFs considered theorems and called "axioms", and in a set of rules to draw new theorems from the axioms.

The axioms are[1]:

1. $((x \vee x) \Rightarrow x)$

2. $(x \Rightarrow (x \vee y))$

3. $((x \vee y) \Rightarrow (y \vee x))$

4. $((x \vee y) \Rightarrow ((z \vee x) \Rightarrow (z \vee y)))$

where the symbol "$\Rightarrow$" (usually read "implies") is only an abbreviation: $S \Rightarrow T$ means $(\sim S) \vee T$.

The rules to draw new theorems are:

1. If S is a WFF and T is a theorem containing a variable, the expression obtained substituting such variable with S is a theorem.

2. If $(S \Rightarrow T)$ is a theorem and S is a theorem, T is a theorem too.

All the theorems of Boolean algebra are obtained from these rules, and, adding symbols, axioms and rules one can obtain all the theorems of all the structures that mathematics has introduced: groups, sets, natural numbers, ...

The symbol "$\wedge$" (pronounced "and") and "$\equiv$" ("is equivalent to") are abbreviations: $S \wedge T$ means $\sim ((\sim S) \vee (\sim T))$, while $S \equiv T$ means $(S \Rightarrow T) \wedge (T \Rightarrow S)$.

1 (pronounced "true") is an abbreviation for $(x \vee (\sim x))$. 0 (pronounced "false") is the abbreviation for (~ 1).

Boolean algebra can be formulated with even fewer symbols than those we have made use of, introducing the symbol "$\uparrow$" and interpreting "$\sim S$" and "$S \vee T$" as abbreviations for "$S \uparrow S$" and "$(S \uparrow S) \uparrow (T \uparrow T)$".

---

[1] In this translation, like in the original work, the fourth axiom is wrong. It is to be replaced by $((x \Rightarrow y) \Rightarrow ((z \vee x) \Rightarrow (z \vee y)))$.

Knowing the truth table of the operators "$\sim$" and "$\vee$", one draws that of "$\uparrow$". The fact that $(x \uparrow x)$ means $(\sim x)$ gives us the diagonal elements of the table of $(x \uparrow y)$, where $(x \equiv y)$. Knowing then $(z \uparrow z)$ and $(t \uparrow t)$, which we indicate with x and y respectively, the fact that $(x \uparrow y)$ means $(z \vee t)$ gives us the whole table of $(x \uparrow y)$:

$\uparrow$	0	1
0	1	1
1	1	0

This truth table is equivalent to the four axioms we have enunciated. Can other single operators, having, in themselves, all the informations on Boolean algebra, exist?

In order that an operator "$\downarrow$" may have this property, one shall be able to realize any truth table by it.

Let us consider a function f of x and y, and let us will it to be 1, when x and y are 0. f will be a sequence of a certain number of x-es and y-s, separated by signs $\downarrow$ and parentheses. As all the x-es and y-s are 0, if $(0 \downarrow 0)$ were 0, all the operations in the interior of f would yield 0-es, which would be arguments of other operations together with other 0-es, and only 0-es would always be generated. Then f would be 0. In order that f may be 1, $(0 \downarrow 0)$, or the element on high on the left of the truth table of $\downarrow$ shall be 1.

Analogously, one proves that, in order that f may be 0, when x and y are 1, the element down on the right must be 0.

The two elements out of the main diagonal remain. If they had two different values, the table would be reduced to one whole row of 1-s and a whole one of 0-es, or one whole column of 1-s and a whole one of 0-es. f would become independent of one of the two variables[2], and would be reduced to $(\sim x)$ or $(\sim y)$. Clearly, the operator $\sim$, by itself, is not sufficient to contain all Boolean algebra (it also needs $\vee$).

Then, the two non-diagonal values must be equal. If they were two 1-s one would get again the table of $\uparrow$. On the contrary, inserting two 0-es in them, one obtains a new operator with the properties we look for. In fact it is sufficient for writing the expressions $(\sim x)$ and $(x \vee y)$, which turn out to be given by $(x \downarrow x)$ and $((x \downarrow y) \downarrow (x \downarrow y))$ respectively:

$\downarrow$	0	1
0	1	0
1	0	0

[2]This is a mistake of the original paper. In this sentence, f is to be replaced by $(x \downarrow y)$.

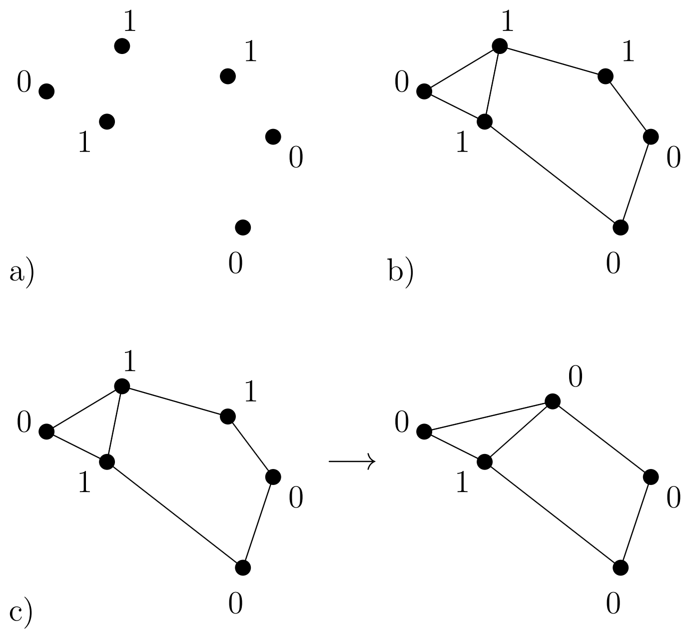


Figure 1: a) Some vertices with their states. b) Coupling of vertices by edges. c) An elementary transition.

This truth table, or, equivalently, that of $\uparrow$, are the fundamental brick of all mathematics. Will they be that of all physics too?

Concentrating, temporarily, on $\uparrow$ only, its table tells us that there exist entities that can be found in two states (0 or 1). Let us represent these entities by points (vertices) (fig. 1a). The truth table couples these entities two by two (x value and y value), attributing one new state (value of $(x \uparrow y)$) to each couple. Let us represent the couples by a segment (edge) joining two points (fig. 1b). The thus obtained structure is named “graph”, and resembles a discrete physical space, where vertices are the points of the space, and edges indicate contiguity relation between the two points that are joined. A suitably chosen graph can approach any space: of any number of dimensions, topology and curvature.

The truth table then resembles a discrete time evolution, in which, at each step, a couple is converted into a new vertex. The state $(x \uparrow y)$ of the new vertex is given by the table as a function of those, x and y, of the two vertices of the couple (fig. 1c). To the new vertex, all the edges that departed from the two vertices of the couple, except the one that joined the two vertices themselves, will be connected.

At each step, the couple to be converted will be chosen, among all the ones of the graph, with a certain probability amplitude, which, willing the space to be homogeneous, shall not depend on the place where the couple is. On the contrary it will be allowed to depend on the particular couple, among the ones foreseen by the truth table. The simplest choice is to make the hypothesis that the four amplitudes are equal. However, in this manner, there would not be phenomena of destructive interference. Therefore, one needs to attribute a phase to amplitudes. The most symmetric choice is to subdivide the whole phase 2π equally among the four possibilities and, save a non-influential total phase and a multiplicative constant to be absorbed into normalization, to propose the following amplitudes:

	0	1
0	1	i
1	$-i$	-1

Interchanging i and $-i$ would also be non-influential, translating itself into replacing the wave function with its complex conjugate, and then leaving its square modulus unvaried.

Notice that the symmetry of the table can fix amplitudes, because the possibilities are four only. With more types of possible transitions, there would be embarrassment in assigning these values.

The sequence of so many of these elementary transitions, will yield a sequence of physical spaces, that is a space-time. To every space-time, which can be built in this manner, it will be assigned a probability amplitude, given by the product of the amplitudes of all the elementary transitions that have generated it. Notice that, reversing the order of two elementary transitions, there is no certainty that the same result is produced. Therefore, the possible space-times are more than one, depending on the order in which transitions have been realized.

Given an initial configuration Γ of the space, and, after a certain time, a final configuration Γ', the sum of the amplitudes of all the space-times, in which a state Γ evolves into Γ', will give an amplitude for such evolution. Knowing the amplitudes associated to all the Γ'-s, they will be allowed to be normalized, permitting us to compute probabilities correctly.

The number of elementary steps needed to build a space-time is, in general, infinite. This for two reasons: it is infinite the time extension of space-time, and it can be infinite its space extension (requiring an infinite number of steps to get a complete region to evolve of one step). Therefore, the total number of space-times is, in general, infinite, and there might be problems to normalize evolution amplitudes. In reality, as a rule, we are interested in

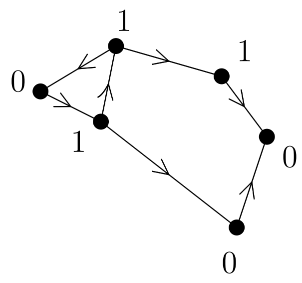


Figure 2: Imposition of arrows to edges.

what happens in a finite region, limited in time and space. And, as a rule, what happens outside this region does not affect the phenomena occurring in its interior. Then, if we compute the processes we are interested in, cutting the space-time extension to a value L, and, successively, we take the limit $L \to \infty$, one should obtain a univocal result.

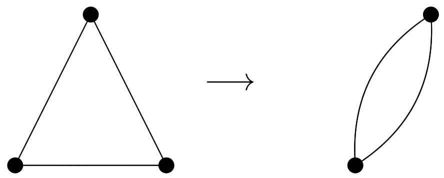
In an arbitrary graph, given a couple with one vertex in the state 0 and one in the state 1, there is no means to understand if it is to be interpreted as $(x \equiv 0)$ and $(y \equiv 1)$ or as $(x \equiv 1)$ and $(y \equiv 0)$. And, in the two cases, the amplitudes are different.

It then becomes necessary to furnish edges with arrows (fig. 2), so that it may be clear in which direction a couple is to be read. Then, the state of the system, besides being characterized by that of vertices, and by their connections, is characterized by the direction of such connections. That is edges can also be found in two states.

Temporarily, the theory we are constructing is not invariant for the inversion of the time axis, moreover, the number of vertices, that is the extension of space, is systematically reduced while time elapses. Both of these problems can be solved, adding, to the set of elementary transitions, their inverses, in which a vertex transforms into a couple, connected by an edge. The two possible directions of this edge, all the possible ways to distribute, between the two vertices of the couple, the edges that met at the original vertex, and, when the truth table allows us to do this, the different possible states of the new vertices are to be considered distinct elementary transitions, among which the evolution can choose, each with its own probability amplitude.

To preserve time reversal invariance, such amplitudes will be equal to the already introduced ones for the corresponding opposite transitions.

The addition of these new transitions makes the range of possible evolutions of the system richer, allowing us to get to any graph from any other.


a)

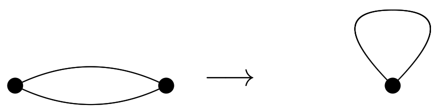

b)

Figure 3: a) Transition to a multiple connection. b) Transition to a connection of one vertex with itself. (The states of the vertices and of the edges have not been shown.)

The transitions we have introduced also permit to generate multiple connections between two vertices (fig. 3a), therefore graphs, containing such connections, shall also be included among the possible states of the system. The fact that the different edges joining two vertices may have opposite directions, implies they may not be replaced by one single edge, which one would not know which direction to assign to.

Having introduced multiple connections, it is also possible to realize connections of one vertex with itself (fig. 3b). One shall take them into account too, in defining the possible states of the system.

A vertex with such a connection shall then be treated as a couple, in which the states of the two vertices coincide. It will be allowed to evolve into a single vertex, in which the connection with itself disappears, and the state of which is determined, by means of the truth table, by the two equal starting-ones. The opposite transition, in which a vertex generates a connection with itself, shall also be considered.

The number of edges that meet at a vertex can range from 1 to any positive integer. A null number of edges, that is an isolated vertex, would have no means to interact with the rest of the graph, and, like any isolated portion of graph, can be omitted.

The last thing one needs to pay attention to is that, till now, we have used the truth table of $\uparrow$ only. The use of $\downarrow$ would realize an analogous but not identical theory. We shall make the hypothesis that the universe may be found in two states, one for each of these two theories, and that its general state is a linear combination of these two. As these two states do not interact between them and the coefficients of the linear combination do not vary with time, their introduction might seem useless. On the contrary we shall see it has important consequences.

3 Properties of the theory

As we have already hinted, a suitably chosen graph can approach a space with any number of dimensions, and, as from any graph one can pass to any other, dynamical transitions from a number of dimensions to another are permitted in our theory. This solves the problem of the arbitrariness in the choice of such number: it is not fixed, but varies with the evolution of the system. In reality, in an arbitrary graph, it can be even ill-defined, but regions like a space with a certain number of dimensions, regions near a space with another number of dimensions, and ambiguous regions can be present. It may also happen that the graph does not even seem to represent a space. Only if, by random fluctuation, proper configurations (proper "vacua") are realized, the state of the system will be interpretable as a space with a given number of dimensions.

When this is realized, such number has a strong stability, because, to modify it, a great number of elementary transitions, all ordered according to a certain scheme, is necessary. Fig. 4 shows the transitions necessary to transform a square, interpretable as a surface element of a two dimensional space, into a segment, interpretable as a length element of a one dimensional space. Such process is to be repeated for all the squares constituting the two dimensional space. Only when a space is very small (constituted by few elements), like before the inflationary phase, the transition will be allowed to happen. (A realistic two dimensional space would have a structure more disorderly, and without privileged directions, than a grid of squares.)

The evolution of the system is clearly influenced by the intrinsic structure of the graph only, independently of the eventual coordinates, which can be assigned to describe physical space macroscopically. Such coordinates can be changed at pleasure, or, equivalently, one can deform the graph, but retaining its topology, and the theory would remain unchanged. Therefore it has symmetry under diffeomorphisms (changes of coordinates) in the space. Will it also have symmetry under diffeomorphisms in space-time?

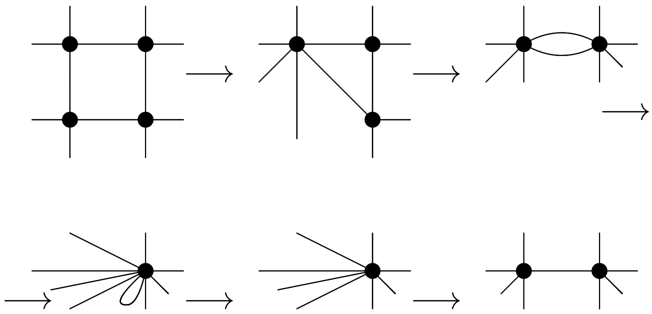


Figure 4: The passage from a two dimensional configuration to a one dimensional one.

In figures 5, time increases upwards. Every line represents a portion of a graph. The areas closed by several lines correspond to elementary transitions. The upper part of their perimeter is the part of graph the transition add to the preceding graph, while the inferior part is removed.

The same elementary transitions can be applied whether to the thick line of fig. 5a, or to that of fig. 5b, or to that of fig. 5c, . . . , getting to construct the same space-time. All such lines can then represent spaces at fixed time. Therefore, there is, in the choice of the time coordinate, the same freedom that is present in general relativity. Moreover, if one chose the thick line of fig. 5d, the area A would not correspond to an admitted transition. There is then a limit to the slope of the spaces at fixed time, as if there was a light cone and time distances were imaginary.

It then seems that our theory has all the symmetries of general relativity, and even explains why time is different from the other coordinates, and why there is a single time coordinate.

Moreover, the theory is "causal", that is there is no possibility, difficult to be excluded at the classical level [27] [28] [29], to travel backwards in time. Such possibility is realized when there are, in space-time, closed time-like lines, which require that, somewhere at a certain time, a direction of the space becomes time-like. In our theory, distances along a given curve can be measured from the number of edges composing it. Alternatively, the volume of a region can be evaluated from the number of vertices it contains. In any case, the space metric will never become time-like.

The theory is also "local", that is each elementary transition changes the

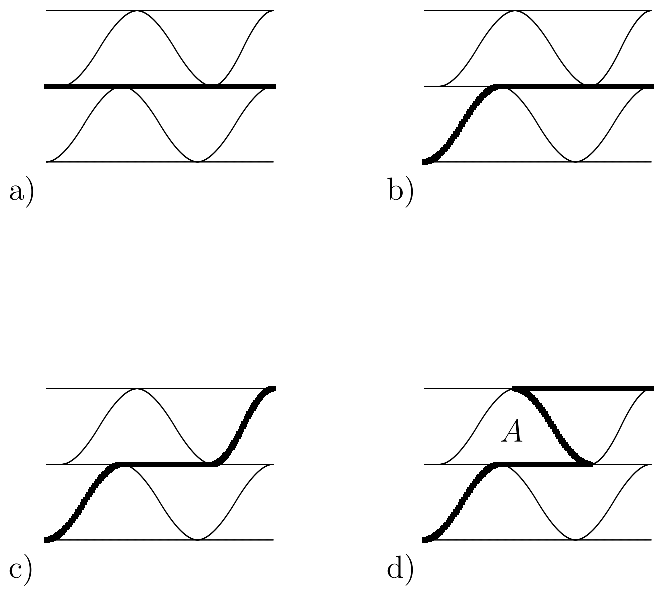


Figure 5: Some different equal time spaces. a), b), c) allowed; d) forbidden.

graph near a vertex only. However it is not “ultralocal”, that is there exist transitions getting several vertices to interact among them.

Moreover, it is clear that, given the discreteness of the evolution process, divergences are not generated, save those, which we have seen how to correct, due to the infiniteness of time and space. Therefore there is no necessity of renormalization: discreteness of space put a cut-off to high frequencies.

At last, let us see a property, that appears astonishing.

Our theory remains unchanged if, at the same time, one reverses the states of all the vertices (that is one interchanges all 0-es with all 1-s), the directions of all the edges, and one interchanges ↑ and ↓. A further interchange restores the original situation.

Therefore, solutions of the theory appear in two states, which we indicate by

$$\begin{pmatrix} |\xi\rangle \\ 0 \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} 0 \\ |\xi\rangle \end{pmatrix}. \tag{1}$$

The operators

$$b = \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix} \quad \text{and} \quad b^\dagger = \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \tag{2}$$

interchange these two states between them, and have all the properties of fermionic lowering and raising operators. In particular, one is the Hermitian conjugate of the other, and

$$\{b, b\} = \{b^\dagger, b^\dagger\} = 0 \tag{3}$$

$$\{b, b^\dagger\} = 1, \tag{4}$$

where the parenthesis indicates the anticommutator. In the classical limit, b and $b^\dagger$ will reduce themselves to “Grassmann” quantities, that is quantities anticommuting among them.

Let us consider the operator

$$\hat{G}_\sigma(k) = \begin{pmatrix} \hat{g}_\sigma(k) & \hat{\psi}_\sigma(k) \\ -\hat{\psi}_\sigma(k) & -\hat{g}_\sigma(k) \end{pmatrix}, \tag{5}$$

where g indicates the gravity field and the other eventual bosonic fields, σ the state of polarization, k the wave vector, and the sign “ˆ” the amplitude (roughly speaking Fourier transform) of the field. ψ is a further field, which, being

$$\begin{pmatrix} 0 & \hat{\psi}_\sigma(k) \\ -\hat{\psi}_\sigma(k) & 0 \end{pmatrix} = \hat{\psi}_\sigma(k)(b^\dagger - b), \tag{6}$$

will have fermionic nature.

Moreover, let us consider the operator

$$Q = b + b^\dagger, \tag{7}$$

which changes the two states (1) one into the other.

The theory is symmetric under the global transformation generated by Q, that is under

$$\delta \begin{pmatrix} |\xi\rangle \\ |\eta\rangle \end{pmatrix} = \frac{1}{i\hbar} Q \begin{pmatrix} |\xi\rangle \\ |\eta\rangle \end{pmatrix} \varepsilon \tag{8}$$

(with a certain infinitesimal ε), which is equivalent to

$$\delta \hat{G}_\sigma(k) = \frac{1}{i\hbar}[\hat{G}_\sigma(k), Q]\varepsilon = \frac{2\varepsilon}{i\hbar} \begin{pmatrix} \hat{\psi}_\sigma(k) & \hat{g}_\sigma(k) \\ -\hat{g}_\sigma(k) & -\hat{\psi}_\sigma(k) \end{pmatrix}, \tag{9}$$

or

$$\delta \hat{g}_\sigma(k) = \frac{2\varepsilon}{i\hbar} \hat{\psi}_\sigma(k) \tag{10}$$

$$\delta \hat{\psi}_\sigma(k) = \frac{2\varepsilon}{i\hbar} \hat{g}_\sigma(k). \tag{11}$$

(10) and (11) change bosons to fermions and vice versa. Therefore, they are transformations of global supersymmetry. Thus, our theory has global supersymmetry, and ψ, the "superpartner" of g, is to be interpreted as a gravitino field.

As the theory also has the local symmetry under diffeomorphisms, which generates gravitational interaction, in order that global supersymmetry may be retained in the interaction terms too, the interactions of supergravity must also be present, that is supersymmetry must be local.

We have then found, that our theory has all the properties we had said to be sufficient to explain known physical phenomena. In reality, if, for example, we consider the gravity field only, the fact, that there is symmetry under diffeomorphisms, implies that, in the classical limit, the Lagrangian density may be written as

$$\mathscr{L} = \sqrt{-g}(\alpha_1 + \alpha_2 R + \alpha_3 R^{\ \ \mu}_{;\mu} + \alpha_4 R^{\mu\nu\sigma\rho} R_{\mu\nu\sigma\rho} + \ldots), \tag{12}$$

which contains, with suitable coefficients, all the terms obtained from the product of Riemann curvatures and their covariant derivatives with indices contracted in any way.

To explain known phenomena, one needs that α_2 is not null. The other terms, except α_1, represent higher order corrections (negligible at low energy).

α_1 is a cosmological constant, which, whatever value it may assume, can be taken back to the observed one, suitably choosing the "vacuum" that is generated by compactification or "symmetry breaking" among the so many ones [8] [9] [10].

Moreover, the value of α_1 and α_2 can be absorbed into the definition of units [30].

We should be very unlucky if, in the infinite number of all the terms of (12), just α_2 was null. Yet, to be sure that the theory is correct, one would need to prove this does not happen. I fear this can be done by numerical way only, and that our computation possibilities are enormously insufficient to this purpose.

For this reason, the theory we have explained represents an attempt only.

References

[1] Original work, in Italian:
Paolo Fabbri, *Concetti Introduttivi alla Teoria delle Stringhe* (2017), http://pfabbri.interfree.it/string.pdf
Attempt of English translation:
Paolo Fabbri, *Concepts Introductive to String Theory* (2018), http://pfabbri.interfree.it/string_en.pdf

[2] F. Mandl and G. Shaw, *QUANTUM FIELD THEORY*, John Wiley & Sons (1984).

[3] V. Parameswaran Nair, *Quantum Field Theory; A Modern Perspective*, Springer (2005).

[4] G. Börner, *The Early Universe; Facts and Fiction*, Springer-Verlag (1988)

[5] Karel V. Kuchař, *Canonical quantum gravity* (1993), arXiv:gr-qc/9304012v1 (pages 15 and 16)

[6] Chris Pope, *Kaluza-Klein Theory*, http://faculty.physics.tamu.edu/pope/ihplec.pdf

[7] J. M. Overduin, P. S. Wesson, *Kaluza-Klein Gravity* (1998), arXiv:gr-qc/9805018v1

[8] N. Arkani-Hamed, S. Dimopoulos and S. Kachru, *Predictive Landscapes and New Physics at a TeV* (2005) arXiv:hep-th/0501082v1

[9] L. Susskind, *The Anthropic Landscape of String Theory* (2003) arXiv:hep-th/0302219v1

[10] Raphael Bousso, Joseph Polchinski, *Quantization of Four-form Fluxes and Dynamical Neutralization of the Cosmological Constant* (2000) arXiv:hep-th/0004134v3

[11] A. D. Linde, *ETERNALLY EXISTING SELF-REPRODUCING CHAOTIC INFLATIONARY UNIVERSE*, Physics Letters B 175 (1986), pages 395-400, http://www.stanford.edu/~alinde/Eternal86.pdf

[12] Robindra N. Mohapatra, *Unification and Supersymmetry; The frontiers of Quark-Lepton Physics*, Springer-Verlag (1986)

[13] Stephen P. Martin, *A Supersymmetry Primer* (2008), arXiv:hep-ph/9709356v5

[14] Friedemann Brandt, *Lectures on Supergravity* (2010), arXiv:hep-th/0204035v4

[15] E. Cremmer, B. Julia, J. Scherk, *Supergravity theory in 11 dimensions*, Physics Letters B 76 (1978), pages 409-412, http://www-lib.kek.jp/cgi-bin/img_index?7805106

[16] John H. Schwarz, *Introduction to Superstring Theory* (2000), arXiv:hep-ex/0008017v1

[17] M. B. Green, J. H. Schwarz, E. Witten, *Superstring Theory*, in 2 vols., Cambridge University Press (1987)

[18] Katrin Becker, Melanie Becker, John H. Schwarz, *STRING THEORY AND M-THEORY; A MODERN INTRODUCTION*, Cambridge University Press (2007)

[19] Hermann Nicolai, Kasper Peeters, Marija Zamaklar, *Loop quantum gravity: an outside view* (2005), arXiv:hep-th/0501114v4

[20] I. V. Kanatchikov, *Precanonical perspective in quantum gravity* (2000), arXiv:gr-qc/0004066v1

[21] I. V. Kanatchikov, *EHRENFEST THEOREM IN PRECANONICAL QUANTIZATION* (2015), arXiv:1501.00480v3 [hep-th]

[22] Max Tegmark, *Is the "theory of everything" merely the ultimate ensemble theory?* (1998), arXiv:gr-qc/9704009v2

[23] Fotini Markopoulou, Lee Smolin, *Causal evolution of spin networks* (1997), arXiv:gr-qc/9702025v1

[24] Fotini Markopoulou, *Dual formulation of spin network evolution* (1997), arXiv:gr-qc/9704013v1

[25] Fotini Markopoulou, Lee Smolin, *Quantum geometry with intrinsic local causality* (1997), arXiv:gr-qc/9712067v1

[26] Ted Jacobson, *Thermodynamics of Spacetime: The Einstein Equation of State* (1995), arXiv:gr-qc/9504004v2

[27] John Gribbin, *Costruire la macchina del tempo*, Aporie (Roma) (1994).

[28] Frank J. Tipler, *Rotating cylinders and the possibility of global causality violation*, Physical Review D 9 (1974), pages 2203-2206.

[29] Matt Visser, *The quantum physics of cronology protection* (2002), arXiv:gr-qc/0204022v2

[30] Paolo Fabbri, *UN APPROCCIO MANIFESTAMENTE COVARIANTE ALLA TEORIA QUANTISTICA DEI CAMPI* (2016), http://pfabbri.interfree.it/covar.pdf (pages 8 and 9)