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Methexis, Mimesis and Self Duality: Theoretical Physics as Formal Systems

Abstract

The naive idea of a mimesis between theory and experiments, a concept still lasing in many epistemologies, is here substituted by a more sophisticated mathematical methexis where theoretical physics is a system of production of formal structures under strong mathematical constraints, such as global and local symmetries. Instead of an ultimate "everything theory", the image of physical theories here proposed is a totality of interconnected structures establishing the very conditions of its "thinkability" and the relations with the experimental domain.

Keywords

Methexis, Mimesis, Plato Cave, Symmetry, Gauge Theories

The question "What is Maxwell theory?"
I cannot answer in a more concise and precise way
but saying "Maxwell Theory is the Maxwell equations"
H. Hertz, 1894

1. Introduction

Physicists, like artisans, musicians or artists, are generally not so good at explaining what they do. To understand the research activity, Einstein invited to look what scientists *do* and not to listen to what they *say*. It often happens that a physicist or a biologist do not recognize their disciplines – methods, problems, objectives – when these are described or reconstructed by philosophers of science[1]. We have to admit that the matter cannot be solved simply; in other words Einstein exhortation is not a "prescription", but a way to put the problem, eluding the question and bringing it within the "science system", which is that complex game of *denotations* and *connotations* crossing research and are an integral part

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[1] At least until not long ago. New philosophers of science seem to understand the formative lesson coming from biophysics or molecular biology: the *superposition* of competences! Epistemologists like Paul Teller, Tian Yu Cao, Stephen Jay Gould and Brian Copeland-or Giovanni Boniolo, Ermanno Bencivenga, Elena Castellani e Francesco M. Scarpa in Italy – reflect on science *from within*.

of it. It is also possible that the higher and higher formal complexity of the physical theories makes the divergence between "d*oing*" and "*saying*" grow, it could partly explain the current phenomenon of the inflationary expanding of the popular-scientific literature.

A clarifying contribution can come from analyzing physical theories as symbolic systems and their controversial relationship with the so-called *interpretative* dimension. Exploring such sphere should provide us with cogent indications about the *reason why* physical theory has a specific kind of structure, *how* such structures are interconnected and in *what way* they describe (or as it sounds in jargon "rule") a certain empiric domain. Whereas Newton, Lagrange and Laplace mechanics seem to be "naturally" related to the phenomena it describes, i.e. a sort of mathematical "mirror" of natural facts (a classical example is the concept of trajectory), it is surely harder to answer the abovementioned questions when we are in front of a blackboard full of Feynman diagrams or the quantum potential "surreal" trajectories by Bohm ((Hiley et al. 2000; Boscà 2013).

The interpretative question in Physics does not come out with Quantum mechanics, how it is usually believed, but by the maturation of Maxwell-Faraday theory on electromagnetism. About two centuries of empirical observations on magnets and electric currents had already been done, Maxwell "caught" in a unified vision electricity and magnetism by using the concept of field introduced by Faraday, and produced four fundamental equations; the first example of "big unification" in Physics after the one between celestial and terrestrial mechanics by Galilei. This historical example gives us two conceptual ingredients, strongly contrasting, important for our short survey: a) for *strong* reasons of *mathematical symmetry*, in any equation there must be a term which links indissolubly the electric field variation in time with the one of the magnetic field. The meaning of such term was explained much later as prediction of electromagnetic waves; b) the analogies to fluid dynamics started a debate on ether which actually came out to be an attempt *to interpret* Maxwell theory as a mechanic theory. The contrast arises just from the mathematical term, it seems absolutely impossible to frame it within a traditionally mechanic vision of ether. Thus it is a new kind of entity, analogous to Newton absolute space. Just like E. Mach did a critical analysis of the Newtonian space, H. Hertz analyzed mechanic ether by a very sharp Occam's razor.[2] It is not by chance that Hertz was the first to give experimental evidence of the waves Maxwell predicted, these ones were early called *Hertzian waves.* We can say that Hertz *trusted* more in equations than in searching their intuitive interpretation in terms of a not better identified mechanic *substratum*.

[2] See citation in the epigraph from E. Mach, *Die Prinzipien der Mechanik in neuem Zusammenhange dargestellt*, J. A. Barth, Leipzig 1894; *The Principles of Mechanics Presented in a New Form*, Cosimo Classics, 2007.

If we focused on such case is because it already contains *in nuce* many of the crucial elements related to the meaning of physical theories. The work by Hertz, Mach (and later by Poincaré and Weyl[3]) can look – at first sight – like a sort of mathematical fideism less or absolutely not interested in the question of interpretation and , at least, a prelude to Bridgman operationalism (1927). It is not so. We will try to show that the position ushered in by the Hertz famous statement-manifesto in no way denies the dilemma of interpretation, rather it strikes at the root an *artificial dichotomy* between a formal structure and its interpretations, redefining these ones as the set of *functional relations* between entities *compatible with* the formal structure and its developments. All that has not to be confused with merely formalist positions. As Gödel Theorem taught us, a purely syntactical approach does not work even with mathematics (Licata 2008) and it is so understandable we pose the problem of the *meaning* of physical theories. What we exclude is that the sense of Physics can be investigated by *circumventing* formalism and giving an "external" meta-reading. We will see how such position is the most proper to account for the most abstract and sophisticated facets of contemporary theoretical physics, and clarifies in what way the *ontological* task is always swinging between *first* and *second degree* for a physicist (Dalla Chiara e Toraldo di Francia 1973).

In his *Parmenides* and *Timaeus* Plato introduces two fundamental concepts in order to define the relation between ideas and sensible things, respectively *methexis* and *mimesis*. The latter is a relation of imitation which in our case could be compared to a naively analogical conception of models and between the last ones with a suitable substratum or physical entity, ultimate and/or fundamental. In the methexis, or participation theory, it is supposed that in the act of comparing both quantitative proportions and the quality of connections could be explained by means of symmetry and harmony laws. We point out that methexis implies mimesis, reinterpreting it as an *intensive analogy* based on structural choices.Thus theoretical physics configures as a *mathematical methexis* where the game of its structural concatenations defines the *thinkableness* itself of the world of experience.

[3] This short essay has not any ambitions of historical exhaustiveness . we just evoke the "family atmosphere" that the theses here presented share with the tradition going from Leibniz ("metaphysics is all mathematics, so-to-speak, or could become it") proceeding to two big protagonists of the transition from classical to modern physics like Weyl and Poincarè, taken after by Russell ("To create a good philosophy you should renounce metaphysics but be a good mathematician"), sailing along Duhem-Quine thesis, up to the works by Tian Yu Cao and James Ladyman. More than searching for connections to such philosophical lines of thinking, we will try to ground our argumentations on the vision of physical theories deriving from practice.

2. From the raw to the cooked: Theory vs Empireia

Generally, a theory has a structure of composed system of sets on which functional relations are defined. They are of this kind:

$$PT = < Math_0, Objs, P_n>,$$

where $Math_0$ indicates a mathematical structure used as the formal framework. Objs is a finite set of physical objects and P_n a finite number of quantities associated with the physical objects. We remark that such kind of description is highly refined with respect to the data of experience. Actually, experience always refers to an *empirical model* where it is defined a system S (usually a space-time domain) in which there can be observed sequences of input IN and output OUT relative to certain events E on the basis of times T:

$$M_{emp} = < S, E, IN, OUT, T>.$$

How do we pass from a M_{emp} *phenomenic* description to a *formal structure* like the PT? We point out that, in general, it is not always possible. In fact, the relations between E events can be extremely casual and disordered, and it is so possible no development – except for a more or less refined statistics – towards what physicists call "ideal models" (Minati, Licata 2013). Moreover, we can get many different empirical models according to the way the elements in the 5-uple are defined. That's what usually happens for the models in biological, cognitive and socio-economic systems; the fact they cannot be described by a single model, but by a plurality of models, is the mark of the systems' *complexity*. It can be shown that each model accounts for different and complementary aspects of the systems and thus brings a different quality and quantity of information. In fact, it has been proposed to define *semantic complexity* by a number of possible model descriptions (Licata 2012). It is also possible to demonstrate that when the system implies a form of self-description (for ex. observer within the system) such semantic complexity is infinite (Breuer 1995).

A physical theory goes in exactly opposite direction, searching for the highest of abstraction and universality. It does not mean that different "competing theories" cannot work on the same problem; usually, when it is good physics, the theories into play will tend to unification under a new leading theory. The first discriminating step is the existence of a Ψ state transition rule for the classes of E events of the kind:

$$\Psi: E_{in} \rightarrow E_{out}, \textit{ for each } S \textit{ and for each } T. \quad (1)$$

The universal quantifier applied to the domain of S system and to any possible base of times for the events E(x,t) indicates that the empirical evidences are sufficient to justify the use of the fundamental criterion of concretization of the physical laws, the *isotropy and homogeneity principle* of the state transition rule for a class of events *with respect to space-time.* In other words, it is assumed – until proved otherwise – that an expression like the (1) is valid not only in a specific space-temporal domain, but is universally valid. It is such "usage axiom" which justifies the inductive procedures of physicists.

What distinguishes a universal theory in physics from a "local" empirical model is so the accent on precise rules governing classes of events. So a theory is a "regularity grid", and what stays out of it is what we call *casuality*. Causality and casuality are complementary, legitimate citizens of the physical world, to such an extent that D. Bohm defined the physical laws nothing but "statistical lines of tendency" for classes of events (Licata 2013). We can sum up by saying that a physical law identifies a class of symmetries {Ψ (E)}.

And yet it is not enough to get a physical theory. The necessity to build an explicative model of phenomena requires an *abductive effort* (Pierce 1903), and the passage from recording the E(x,t) events to building a PT where a finite number of physical objects Obj, with P_i properties are constrained by a structure $Math_0$ which defines, contextualizes and prescribes the use of the conceptual universe of the theory. It is important to note that the objects Obj are not necessarily *observable* material entities – which always allow to specify an operative procedure so to have a one-to-one correspondence between objects and measures – , there can also be not directly observable entities (for example, quarks outside the nucleus bag, see Cao 2010) or of a more abstract mathematical nature (such as the trajectories in Bohm Quantum Potential or Feynman Path Integrals). In other words, a PT generally contains also those entities we – borrowing and generalizing Bell – could call *beables*:

> (...) it is interesting to speculate on the possibility that a future theory will not be intrinsically ambiguous and approximate. Such a theory could not be fundamentally about 'measurements,' for that would again imply incompleteness of the system and unanalyzed interventions from outside. Rather it should again become possible to say of a system not that such and such may be observed to be so, but that such and such be so. The theory would be not be about `observables' but about "beables". (Bell 1987)

In such a scenario, the operationalism is a sound compatibility criterion between the universe of PT and the experimental procedures more than a "logic"; also because those ones are always built following the prescriptions contained in the PT[4]. We passed from recording events E(x,t) – here and now – to a more general construction guided by the

[4] Such passage could be seen as a sort of self-referentiality. Fortunately, in the experiments made to obey PT indications, Nature sometimes replies with a definite: "Wrong"!

way how $Math_0$ defines the Obj *observables-speakables – beables*. A model can precede a PT, like a sort of "raw" material, or can be completely independent (the so-called "floating models", whose aim is to describe a set of phenomena which can almost be defined as a system $S(E_i)$, but they cannot yet aspire to be considered a PT).

Actually, it is the idea itself of *modelling* (for instance, the sculptor with clay) which evokes the peculiar characteristics of this activity:

1. A small object, usually built to scale, that represents in detail another, often larger object;
2. A preliminary work or construction that serves as a plan from which a final product is to be made;
3. One serving as an example to be imitated or compared;
4. One that serves as the subject for an artist, especially a person employed to pose for a painter, sculptor, or photographer;
5. To make conform to a chosen standard;
6. To make by shaping a plastic substance;

And so on. The aim of modelling is to give a description of the event E(x,t) dynamics of a system S. It can be done, in the first place, also with simple statistical or polynomial interpolation methods, and there often is a quite direct reference to the space-time configuration of the objects whose behaviours define the E(x,t). In addition, the theoretical premises are almost absent sometimes, the empirical model has just to account for a domain of observations in the most direct way[5]. *Empeiria* and *mimesis* are the dominant elements.

Although the process of idealization appears as a fundamental ingredient of the theoretical building (see for the Poznan School: Coniglione 2004), a PT also requires a *structural consistency* with the previous knowledge. "Many are called, but few are chosen"! (Matt. 22, 1 – 14). Models can cover different features of the world like an archipelago, partly overlapping; a PT must be universal and *fit into* a mathematical chain of this kind:

$$T_{i-1} \ll T_{i,} \quad (2)$$

where the symbol « is used to indicate that T_{i-1} is 'weaker than T_i in physical terms', which is to say that the latter, at the limit, contains the preceding theories"[6].

This theoretical matryoshka poses two important problems, at the

[5] We are not taking into consideration here the *theoretical models* where a PT is applied, under suitable hypotheses, to a specific domain S. Currently we aim to underline the difference between empirical "floating" models and universal physical theories.

[6] It could be objected that such vision à la matryoshka doll is quite simplified and , for example, it is already a not banal problem to define exactly where the classical limit for each quantum system is. It is true. As a matter of fact, we are following a procedure of idealization which however we find useful and not excessive as the famous "*let suppose that elephants are perfect spheres"*.

beginning and at the end of the sequence. The theory opening the sequence, in fact, has not been chosen for abstract logical reasons, it is simply historically earlier, i.e the Newtonian physics. The later theories has inevitably inherited its conceptual configuration and had to deal with it. From a logical viewpoint, we have always to look at the most recent theory to get an organic picture (for instance, it is by means of quantum and relativistic physics we can understand *a posteriori* the characteristics of classical physics and its axiomatic limits). The other question is the possible existence (and nature!) of an ultimate theory able to include all the previous ones within a unitary frame of the structure and the history of the universe. In particular, the question is what kind of object Obj could be at the core of such a "final" theory, a question inherited by a *hybris*, that is the Newtonian particle. We will see that the beables of a theory are actually defined by a *play of relations* fixed by the theoretical chain (2), rather than by fundamental constituents.

3. Groups, Symmetries and Compensative Gauging

As we have seen the concept itself of "physical law" lies on the symmetry of space-time isotropy and homogeneity[7], which is a global symmetry. There are some others – such as the Lorentz-Poincaré invariance, substituting the Galilei ones, or the De Sitter symmetry used in Cosmology – which are formally characterized by the fact they leave a mathematical object invariant under global transformations of the whole *substratum* on which the object is defined. For example, Maxwell equations are invariant under a set of transformations of the space-time coordinates that are the Lorentz transformations. The physical meaning is very elementary: all inertial observers defined on space-time "see" the same equations at the basis of electromagnetic phenomena. The price to pay is obvious as well, even if it is difficult to accept for those who insisted in maintaining a *naïve* idea of space-time, as an ever existing object rather than a "theatre of coordinates" defined by the measures of the actors animating it. We are speaking here of the famous length contractions and time dilatations, which has spilled so many vain floods of ink.

We introduce here, trying to keep low the rate of mathematical

[7] This is an *axiom* necessary to the gestation itself of physics implicitly born within the Newtonian physics. At the end of '800 and the beginning of '900, it will be expressed explicitly during a long period of critical revision of foundations after the birth of relativity and quantum physics; today it is a *requirement* which the theories aiming to explain the *nature itself* of space and time must met. The space-time has nothing intrinsically *fundamental* in itself, except its long permanence as an *historical category.* Therefore, also the distinction between *external* (linked to space-time) and *internal* (linked to particles) likewise appears *conventional*. More precisely, we work with *metrics* which define space-time.

technicality, the decisive notion of *group*. We propose an ironic as well as exact "definition" for not experts:

> The Theory of Groups is a branch of mathematics in which one does something to something and then compares the result with the result obtained from doing the same thing to something else, or something else to the same thing (The World of Mathematics, James Roy Newman *(1907 – 1906)*

The concepts of "symmetry", "invariance" and "transformations" can be characterized in simple and precise way by this mathematical object (Neuenschwander 2010; Haywood 2013). In particular, the "Emmy Noether's Wonderful Theorem" showed the deep connection between conservation laws and global symmetries. The most of contemporary theoretical physics' apparatus comes out as an extension of that wonderful piece of mathematics. In fact, what can we say about the situations where quantities are not conserved and global symmetries are violated?

That's when the concepts of *local symmetry* and *symmetry breaking* come into play by fixing the most fecund lines of development of theoretical physics. In fact, when we impose on the equations of a physical theory to stay invariant in their form in passing from a global to a local symmetry, it will be necessary to introduce some *compensation terms* (in math jargon "to make a gauging") corresponding to the action of a new *field of forces.* The concept of force so gets free of the *anthropomorphic flavours* to become a *connection* on mathematical spaces. In a bit more formal terms: a gauge theory is a type of field theory in which the Lagrangian (the dynamics of a system) is invariant under a continuous group of local transformations. These theories are called theories of the *gauge fields.* Global symmetries tell us something about the observers defined on a substratum, whereas the local ones describe the interactions and thus the dynamics of the entities living in it. It can be demonstrated that all the interaction theories are gauge theories: the Glashow-Weinberg-Salam Electroweak theory, Quantum Cromodynamics (quarks and hadrons), General Relativity, the GUTs (Great Unification Theories) and the several families of String Theories (Healey 2009).

The natural "language" of this kind of theories is the differential geometry; we will try to give an idea of them by using the diagrams of Category theory, following the exposition in (Mignani, Pessa, Resconi 1999), with a bit of "elementary lexicon". Let consider the figure 1:

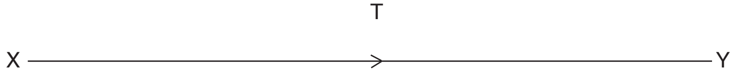

FIG. 1

where T is an operator defining the passage from X to Y in a suitable, abstract space or substratum. T can be a global symmetry, or a local one. In the latter case, T is a gauge transformation. The most important information in the diagram is that both global and local symmetries must be coherent. The next diagram contains the conceptual core of gauge theories:

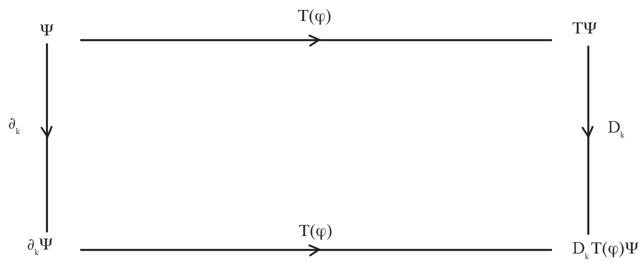

FIG. 2

Here Ψ is a field defined on a substratum and $T(\phi)$ is the gauging on the quantity φ. The directional derivative ∂_k of Ψ is indicated by $\partial_k \Psi$, but the gauging change it into a more complex expression which implies a generalization called covariant derivative D_k. This one is a *connection operator* between the spaces defined on the same substratum. In this way, the term $D_k\, T(\phi)\, \Psi$, on the lower right, – closing and guaranteeing the symmetry – indicates the action of a new field of force linked to ϕ and characterized as a particular geometrical "deformation".

Less immediate are the diagrams indicating that the connection operators must satisfy the *commutation relations* (or anti-commutation), which fix the field potentials and the dynamical equations:

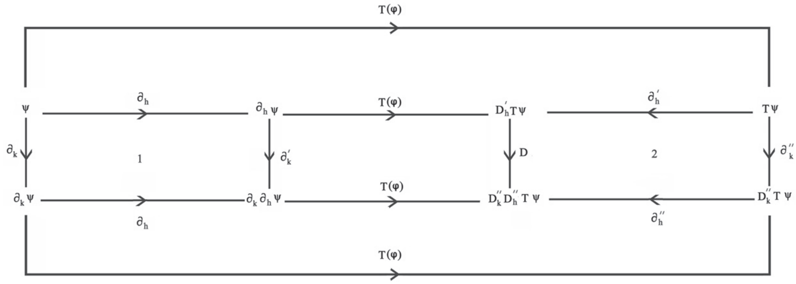

FIG. 3

And, increasing the *Chinese-box*, the most general form:

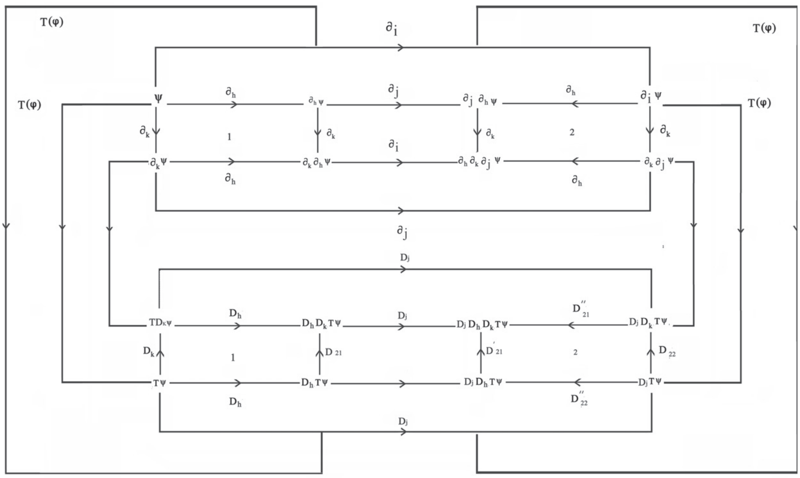

FIG. 4

Such play of constrains on local symmetries is a mighty "mathematical machine" to build unified theories. By the right gauge conditions it is actually possible to investigate the relations between different forces. Obviously, Physics is an experimental science and the success depends on the hypotheses on the substratum and the specific condition on gauging. Do not forget that this scheme, for its very nature, can give us neither the values of the *fundamental constants* (such as Planck constant) nor the values of the *field source* (such as the electron charge). These are events of the kind E(x, t) and have to be derived from experience and introduced – as it is used to say – "by hand" in the equations.

The above figure suggests the sense of what is meant by unified theory. Each group can be *made up* with others, or *contained in* a bigger group. The obtained symmetry indicates that interactions had the same intensity for the value of a certain parameter (for example, temperature in the standard model), and they differentiate below a critical value in a *symmetry breaking* chain process. Thus, we can say that through gauging we look for the tiles of the original symmetry lost in the history of the universe. That's the meaning of acronyms like SU(3) x SU(2) x U(1) (Great Unification Theories based on the extension of the standard model), or E8, the *gargantuesque* and *extremely simple* Lie group proposed in 2007 by Garrett-Lisi (Garrett-Lisi 2007):

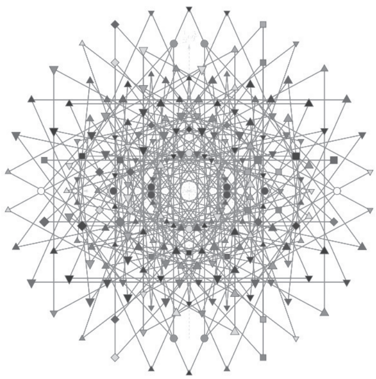

FIG. 5. *The* E8 *root system, with each root assigned to an elementary particle field.*

Beyond the changing fortunes of the Garrett-Lisi theory (Distler & Garibaldi 2010; Triantaphyllou 2013), to date nobody can say what will be the form of the theory able to connect space-time, gravity, nuclear and electroweak forces, usually indicated by SL(2C) x SU(3) x SU(2) x U(1).Anyway, we can already set some really *hard* questions. After the genial though unfortunate H. Weyl intuition in 1918 (Weyl 2013), the current form of gauge theory (Yang-Mills non-abelian theories) was born from an analogy with consolidated techniques in condensed matter (superconductors and superfluids) (see the historical papers by Nambu 1960 and Goldstone 1961).This seems to suggest one of the classical *founding reasons* of *mimesis* dated back to *Strena Seu de Nive Sexangula* by J. Keplero (1611): a symmetrical object indicates something on the structure of its composing entities.

When we speak of entities not directly observable from which to derive the space-time itself, with dimensions over 4 (Kaluza-Klein theories), what is the sense of such statements? Is quantum vacuum a condensate? What do symmetries indicate? At its bottom, what stuff is the world made of?

4. What we talk when we talk of *particles*

The current vulgate maintains that the task of physics is to investigate the "ultimate constituents" of matter. We have already pointed out that the contemporary concept of particle is still Newtonian in its essence, just a bit more "complicated" by quantum features: a mathematical point endowed with properties. If such *strange* entity, similar to a Janus Bifrons – half mathematics and half physics – was anyway useful to describe the motion of rocks and planets, much more problematic appears its use in quantum physics, where the concepts of trajectory and motion are *fuzzy*. Actually, it is now possible to show that the most of the "paradoxical" features of quantum physics (wave/particle dualism, state vector collapse, cats in linear hanging between death and life) are the consequence of the surviving of classical concepts in the theory, just like the particle (Preparata 2002; Cini 2003; Licata & Fiscaletti 2014). For an unambiguous vision of these problems (or pseudo-problems) we must look at the "niece" of QM, the Quantum Field Theory (QFT); the broadest and the best experimentally confirmed physical theory. In a nutshell, neither corpuscles nor waves find their fundamental citizenship in this theory, there only are quantized field modes. The famous wave-function is thus the "covering" of a lot of elementary events, the notorious "collapse" is the local revelation of a quantum, and the trajectory is an approximate, emergent concept (Vitiello 2005). So, QFT is the fittest place to contextualize the use of the term "particle".

Let remind that the only observable events in a laboratory are of the kind E(x,t). When we say "we observe a particle X", actually we measure properties we assign to an entity X. In addition, such measurements cannot always be done simultaneously (quantum non-commutativity), and finally these sets of properties can appear and disappear in quantum vacuum. By using the powerful language of transactions (Chiatti 2013; Kastner 2013; Licata 2014), it is possible to summarize the quantum universe in a diagram:

$$\begin{array}{ccccc} & |Q> & <Q| & & t=t_1 \\ S & \downarrow & \uparrow & S^+ & \\ & |R> & <R| & & t=t_2 \end{array}$$

$$<R\,|\,S\,|\,Q><Q\,|\,S^+\,|\,R> = |<R\,|\,S\,|\,Q>|^2$$

FIG. 6

where we shall have at $t = t1$ the event of the creation-destruction of a quality Q ($|Q><Q|$) and at $t = t2$ the event of the creation-destruction of a quality $R(|R><R|)$, with S time evolution operator (like Schrödinger equation), so that $S\,S^+ = S^+\,S = 1$. The above product of amplitudes corresponds to the well-known Born rule on quantum probabilities. This ring describes the evolutionary processes ruled only by S as well as the non-local ones, where both S and S^+ are involved, such as the quantum jump.

It is clear now that "particle" is a *comfortable* label to indicate the permanence and the way how some group of properties show up as events E(x,t) (Pessa 2011).It is just QFT to provide the possibility to clarify thoroughly the meaning of common expressions such as "the particle X is made of particles y_n", an expression corresponding to the reductionist interpretation of the theoretical chain (2). Such kind of interpretation has a very limited value within a sub-class of field theories called *Effective Quantum Field Theories* (EQFT). These theories are organized like a tower of levels, each one linked to a scale parameter, i.e. it individuates a phenomenological range of energies and temperatures. It is possible to pass from a level to another one by a rescaling operation of the kind $\Lambda_0 \rightarrow \Lambda(\sigma) = \sigma\Lambda_0$ where Λ_0 the *cut-off* parameter related to a fixed scale of mass-energy into play. This operation is carried out by using a powerful mathematical tool, the renormalization group, which makes a sort of selection between the symmetries of a level and those subsumed from the next one[8]. In this sense, and only in this one, we can say, for instance, that a hadron "is made of" quarks (Castellani 2002; Licata 2008b). In other words, renormalization operates as a *code shifting* as for the term "particle" between a level and another.

The ontological responsibility of a physicist in stating something as "there exists a particle X" thus is always conditioned in accepting such code as well as the mathematical and experimental procedures behind it. If it is true for entities that can be tested in a laboratory, what can we say of the elusive "ultimate" entities which should stay beyond space-time, in that Plank wall supporting quantum gravity theories?

5.The Reasonable Effectiveness of Symmetries

We paraphrase here the title of the famous paper by E. Wigner (Wigner 1960) because our reflection on the power of symmetries, from the global ones to the local gauging, has led us to set the question again. We seem that the unquestionable effectiveness of symmetries comes from our *cognitive deep attitude* which "meets" the nature thanks to the fundamental choice of science to reason not by single events, but by *classes of equivalence.* Attitude then becomes a generator of *strategies*, it is just the case of gauge theories where it is the *imposing* a symmetry that reveals us something about the entities into play (Mouchet 2013).

More generally, there are some who proposed to see a universal dynamics for biological processes and linguistic production in *compensative gauging*, as it happens in autopoietic systems by Maturana and Varela, where the metastable equilibrium between system and environment is continuously refining as the emergent relations modify (Mack 2001)[9].

[8] Of course, we are talking of symmetries referred to the properties of interactions. As for quarks, the extraordinary history of the octet's way is told in (Cao 1998; 2010) in technical way, and in (Johnson 2000) in a more conversational way. Analogously, for the "concurrent" S matrix theory, see (Cushing 1985, 1990).

[9] In a paper of the same author , "Gauge theory of things alive and universal dynamics" (1994) in arXiv:hep-lat/9411059, W.O. Quine is cited as a precursor in using Gauge

There is a beautiful metaphor on symmetry owed to Majid (1991) which makes the effectiveness completely reasonable and communicable also to not mathematics, we propose it here with some variations. Lets image an object X, about which we will not state anything characterizing, in a room and a set of observers (humans, animals, robots, aliens) who can perceive it by their own specific sensorial and cognitive "systems" and form a representation A based on the datum *a* (*a* can be a verbal description, a picture, any actual recording of X an observer does.) Scanners and psychiatrists can examine the observers by any possible instrument, from dialoguing to neuroimaging, and they too will form their own representation A of X. What really characterizes the object – and interests a theoretical physicist! – is what all the representations of the kind below share in common:

$$A(\phi) = \phi(a), \quad (3)$$

Where $\phi(a)$ indicates the datum *a* of the observer ϕ with respect to X. What counts is the *invariance of representations* and the general form of (3) which constrains them and reflects one into the others, thus a symmetry. The interesting passage is that, in a sense, the object X "has vanished", replaced by the invariance of its representations.

By extension, it is exactly what happens to physical "objects": the historical notions of "field", particles", "field modes", "string", "loop", "twistor" are labels whose meaning is individuated by the play of relations and invariances. It can be useful to represent a physical object "like" (mimesis), but its meaning is always defined and fixed "by means of" (methexis). It is never by a *naïve* analogy that a theory is developed, but through the extension of its formal structure. Moreover, S. Majid proposes the self-duality as a constructive constraint between theories; in not technical words we can define it as the capacity of "virtuous" theory to contain the other ones and reflect them in its internal structure. It is possible to trace an out-and-out direction of the mathematical development of theories, showed here below:

transformations in linguistics, it is quoted the famous passage from *Word and object* (MIT press, 1960): "He (Quine) says "the infinite totality of sentences of any given speaker's language can be so permuted or mapped onto itself that (a) the totality of speakers disposition to verbal behavior remains invariant, and yet (b) the mapping is no mere correlation of sentences with equivalent sentences, in any plausible sense of equivalence however loose. Sentences without numbers can diverge drastically from their respective correlates yet the divergences can systematically so offset one another that the overall pattern of associations of sentences with one another and with non-verbal stimulation is preserved".

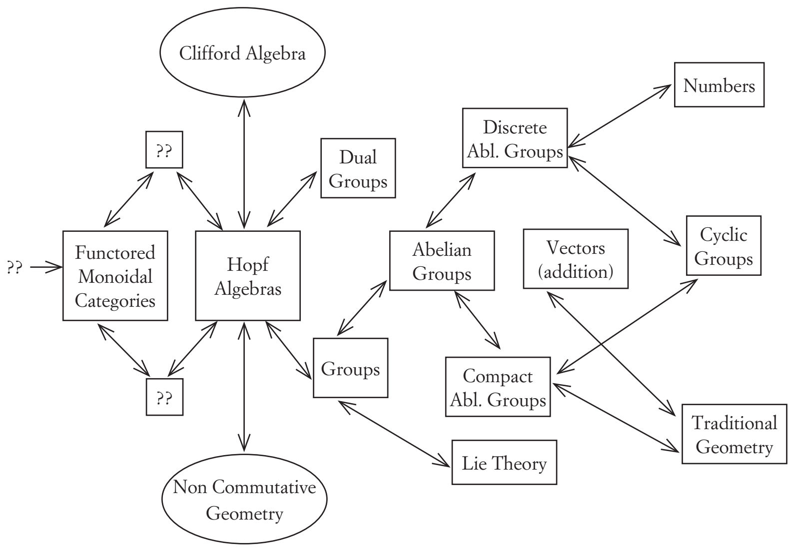

FIG. 7

The self-dual theories are along the central axis, the others are deformations of dual theories. The area richer in problems is that of Hopf algebras, its connections with the Clifford algebras and non-commutative geometries [see for ex. Majid 2008]. The arrows indicate that the axioms of a theory are seen as restrictions of more general cases. Instead of the "fundamental bricks", we find here a broader and more complex suggestion. We are not speaking of an "ultimate" structure. In fact, it is possible that physical knowledge proceeds by progressive increasing and specialization of these categories. Furthermore, Holger Bech Nielsen in his works on *Random Dynamics* has showed that a rather limited number of very wide set-like categories can lead, by progressive constraints, from proto-laws to the physics' laws as we know them; actually there do not exist experimental tools to go much beyond the current range of investigation. In other words, an unthinkable and inaccessible complexity could be hidden and compatible with so general assumptions to sound generic. In the frame of a radical emergentist approach, Robert Laughlin starts from the instability of Yang-Mills equations to criticize any fundamentalist nomological attitude: "if a strategy to solve such equations is adopted, it should be better not to speak of a Theory of Everything, but just of patenting a technology to calculate them" (Nielsen 1989; Gaeta 1993; Laughlin 2005).

What we find instead of an "everything theory" shaped as "fundamental object" or ultimate mega-structures is a much stronger notion: *totality*. It is conceived as a configuration of interconnected structures which reflects our experience of the world and "saves phenomena" setting the very conditions of their *thinkability* ; for ex. a structure of this kind:

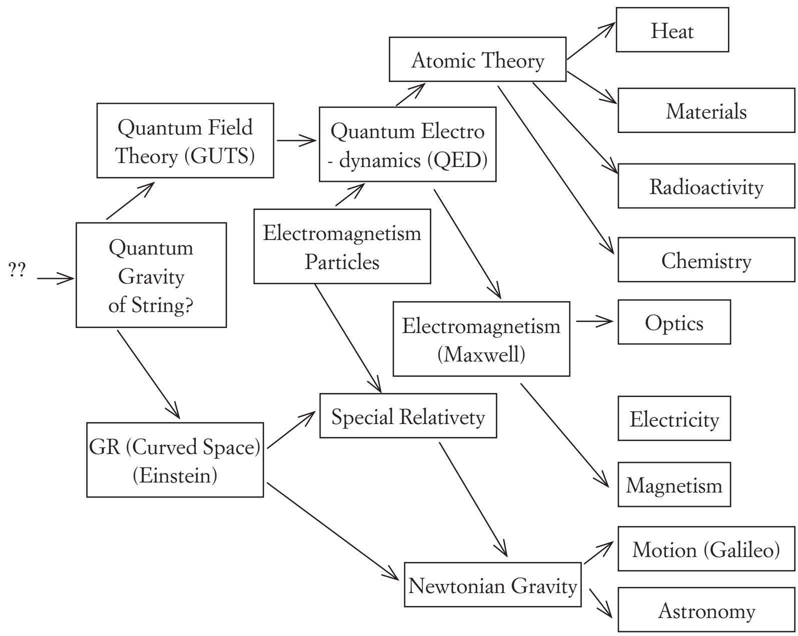

FIG. 8

The concept of totality suggests us that the "question" zone – *Quantum Gravity or Strings?*- in no way has to be seen as "terminal" or "founding" because it could give rise to a new *gemmating* of structures. Anyway, it would be *impracticable* trying to deduce optics starting from the theory of twistors; each of these theories have their own applicability range, their own heuristic language, a history of conventions which badly lend itself to be "reduced" to something else. What the map of totality says to us is a different thing, that is there exist very strong constraints on modifying each point of the structure and, above all, on the possible lines of development: "the problem is not only to decide what is wrong, but by what it can be replaced (…) and so, please, don't send us any letter to say how the matter should work… it is impossible to explain honestly the beauties of the laws of nature in a way that people can feel, without their having some deep understanding of mathematics. I am sorry, but this seems to be the case." (Feynman 1964).

No *ad hoc* modifications are possible, any new local hypothesis has telluric consequences on totality and the old *unity of the nature* – the expression of that principle of space-time isotropy and homogeneity we started from – becomes here a complex play of constraints and formal compatibility. So, there is no Laputa machine able to crank up the entire theoretical chain from a single structure, but an interconnected and stratified totality which defines its own *narratability* and whose interpretations (entities, *beables*) modify as it develops (Greimas 1987; Eco 1972, 2000). On the other hand, such idea of a totality as an archipelago of structures developing like ice crystals in a liquid, conceptual environment is the only way to avoid the conflict between theory and meta-theory, typical for purely formal model and naïve interpretations of "everything theories".

7. The Signs on a Blackboard (How to Live Happily in the Plato's Cave)

During the Quantum Theory gestation, Niels Bohr used to warn about extending the specific concepts of our embodied cognition[10] to domains very far from experience (Kumar 2010). He was right. Modern physics has shown that the shaky mimesis still connecting the classical physics formulations to "the elements of physical reality" of our intuition had to make way for a more refined mathematical methexis with a cogent internal logic and a not banal connection with experiments. Going back to our starting case, for instance, it means to renounce to a mechanist representation of ether as a "support" of the concept of field. This concept will then find new constraints with the advent of quantization. Definitely, Feynman diagrams are not trajectories!

We have no problem in admitting that the description of physical theories here presented is highly stylized and really *a posteriori*. Where did physical sense, imagination, good rhetoric, paradigms and revolutions get to? We think that the "dramatic" aspects of the investigation of the physical world have widely been expressed elsewhere.[11] The picture here presented is a *system of production of signs* consisting of classes of interconnected relations whose focal, propulsive nodes are the structures we call theories, having a form which constrains the empiric domain of their testability.[12]

When a not-expert observes blackboards like these:

[10] Of course, it was not called so then!

[11] It is essential the epistemological debate between the '60s and the '80s: [Lakatos, Musgrave 1970;Lakatos 1976; Motterlini 2000]. An exemplary case of dramatic complexity is the birth itself of the modern *scientific heresy* from medieval thought [Grant 1996; Singer 1941 first ed. 2011]

[12] If the complex relation between theory and experiments maybe prevents us from endorsing completely that experiments are "reified theorems" (G. Bachelard), an experiment is surely the fruit of the cognitive design adopted by community according to the accepted theories.

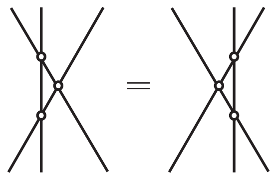

FIG. 9

$$
\begin{gathered}
-\frac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac{1}{4}g_s^2 f^{abc} f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \\
\frac{1}{2} i g_s^2 (\bar{q}^\sigma_i \gamma^\mu q^\sigma_j) g^a_\mu + \bar{G}^a \partial^2 G^a + g_s f^{abc}\partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
M^2 W^+_\mu W^-_\mu - \frac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \frac{1}{2c_w^2} M^2 Z^0_\mu Z^0_\mu - \frac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \frac{1}{2}\partial_\mu H \partial_\mu H - \\
\frac{1}{2} m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \frac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c_w^2} M\phi^0\phi^0 - \beta_h[\frac{2M^2}{g^2} + \\
\frac{2M}{g}H + \frac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu (W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - \\
W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - \\
W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \\
\frac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + \\
g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \\
\frac{1}{8}g^2\alpha_h[H^4+(\phi^0)^4+4(\phi^+\phi^-)^2+4(\phi^0)^2\phi^+\phi^-+4H^2\phi^+\phi^-+2(\phi^0)^2H^2] - \\
gMW^+_\mu W^-_\mu H - \frac{1}{2}g\frac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \frac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - \\
W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \\
\phi^+\partial_\mu H)] + \frac{1}{2}g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + \\
igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + \\
igs_w A_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac{1}{4}g^2 W^+_\mu W^-_\mu[H^2+(\phi^0)^2+2\phi^+\phi^-] - \\
\frac{1}{4}g^2\frac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2+(\phi^0)^2+2(2s_w^2-1)^2\phi^+\phi^-] - \frac{1}{2}g^2\frac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) - \frac{1}{2}ig^2\frac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac{1}{2}g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) + \frac{1}{2}ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - \\
g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar{\nu}^\lambda\gamma\partial\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m_u^\lambda)u^\lambda_j - \\
\bar{d}^\lambda_j(\gamma\partial + m_d^\lambda)d^\lambda_j + igs_w A_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \frac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] + \\
\frac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2-1-\gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(\frac{4}{3}s_w^2 - \\
1-\gamma^5)u^\lambda_j) + (\bar{d}^\lambda_j\gamma^\mu(1-\frac{8}{3}s_w^2-\gamma^5)d^\lambda_j)] + \frac{ig}{2\sqrt{2}}W^+_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + \\
(\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \frac{ig}{2\sqrt{2}}W^-_\mu[(\bar{e}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+ \\
\gamma^5)u^\lambda_j)] + \frac{ig}{2\sqrt{2}}\frac{m_e^\lambda}{M}[-\phi^+(\bar{\nu}^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1+\gamma^5)\nu^\lambda)] - \\
\frac{g}{2}\frac{m_e^\lambda}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}}\phi^+[-m_d^\kappa(\bar{u}^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + \\
m_u^\lambda(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \frac{ig}{2M\sqrt{2}}\phi^-[m_d^\lambda(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m_u^\kappa(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1- \\
\gamma^5)u^\kappa_j] - \frac{g}{2}\frac{m_u^\lambda}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \frac{g}{2}\frac{m_d^\lambda}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \frac{ig}{2}\frac{m_u^\lambda}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) - \\
\frac{ig}{2}\frac{m_d^\lambda}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \bar{X}^+(\partial^2-M^2)X^+ + \bar{X}^-(\partial^2-M^2)X^- + \bar{X}^0(\partial^2 - \\
\frac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2 Y + igc_w W^+_\mu(\partial_\mu\bar{X}^0 X^- - \partial_\mu\bar{X}^+ X^0) + igs_w W^+_\mu(\partial_\mu\bar{Y}X^- - \\
\partial_\mu\bar{X}^+ Y) + igc_w W^-_\mu(\partial_\mu\bar{X}^- X^0 - \partial_\mu\bar{X}^0 X^+) + igs_w W^-_\mu(\partial_\mu\bar{X}^- Y - \\
\partial_\mu\bar{Y}X^+) + igc_w Z^0_\mu(\partial_\mu\bar{X}^+ X^+ - \partial_\mu\bar{X}^- X^-) + igs_w A_\mu(\partial_\mu\bar{X}^+ X^+ - \\
\partial_\mu\bar{X}^- X^-) - \frac{1}{2}gM[\bar{X}^+X^+H + \bar{X}^-X^-H + \frac{1}{c_w^2}\bar{X}^0X^0H] + \\
\frac{1-2c_w^2}{2c_w}igM[\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-] + \frac{1}{2c_w}igM[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \\
igMs_w[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \frac{1}{2}igM[\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0]
\end{gathered}
$$

FIG. 10

(*Fig. 9 The Yang-Baxter equations; Fig. 10 Variations on Lagrangian density in Standard Model*)

it is clear that he may ask "what do they mean?" If we answer (we try to) by using that informal language typical of physicists when speaking each others, full of metaphors, we would be struck by *Bohr curse*, because what comes out is a *gibberish* centered on the figures of our intuition which completely exclude the subtle relations defining the entities of the discourse and providing them with a semblance of consistency[13].

The fact is that a Physics' theory is to such tales in the same relation a symphonic poem is to a text evoked in music. In this regard F. Mendelssohn wrote:

> People often complain that music is too ambiguous, that what they should think when they hear it is so unclear, whereas everyone understands words. With me, it is exactly the opposite, and not only with regard to an entire speech but also with individual words. These, too, seem to me so ambiguous, so vague, so easily misunderstood in comparison to genuine music, which fills the soul with a thousand things better than words. The thoughts which are expressed to me by music that I love are not too indefinite to be put into words, but on the contrary, too definite (Letter to Marc-André Souchay, October 15, 1842).

On the other hand, "making it speakable" and "double understanding" – internal and external to the system – are problems that science share with arts, in particular with contemporary art (Iaria 2014): theoretical physics, like music and art, cannot be said otherwise[14].

Paraphrasing Wittgenstein (1958), it seems that the problems of physical representation of the world come out more from language and common sense than from its practice. I am forced to use them both, but considering that the totality we examined is referred *from its very internal structure* to the *sense experiences* , if someone asks me what reality is for a physicist, I cannot do anything but to point out the blackboard.

What I cannot create, I do not understand
(The last blackboard of R. P. Feynman, 1988)

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[13] When speaking of *scientific pragmatism*, we find opportune doing it in the noblest way: "Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object" (Peirce in Houser et al. 1992).

[14] In this way we think to acknowledge indirectly also the fecundity of "not-constrained" language!

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