Is a classical Euclidean TOE reasonable?

A. Arbona

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We analyze both the feasibility and reasonableness of a classical Euclidean Theory of Everything (TOE), which we understand as a TOE based on an Euclidean space and an absolute time over which deterministic models of particles and forces are built. The possible axiomatic complexity of a TOE in such a framework is considered and compared to the complexity of the assumptions underlying the Standard Model. Current approaches to relevant (for our purposes) reformulations of Special Relativity, General Relativity, inertia models and Quantum Theory are summarized, and links between some of these reformulations are exposed. A qualitative framework is suggested for a research program on a classical Euclidean TOE. Within this framework an underlying basis is suggested, in particular, for the Principle of Relativity and Principle of Equivalence. A model for gravity as an inertial phenomenon is proposed. Also, a basis for quantum indeterminacy and wave function collapse is suggested in the framework.

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I. INTRODUCTION

It is frequently discussed whether a Theory of Everything (TOE) is feasible as an ultimate synthesis for the physical description of nature. We will not address this issue here, but assume this approach is indeed possible. Instead, here we want to speculate about the feasibility of a classical and Euclidean TOE, that we define as a TOE which is based on an Euclidean framework of space and an absolute time over which deterministic models of particles and forces are built.

Obviously, this approach goes against the accepted axiomatic base for Special Relativity, General Relativity and Quantum Theory. Of course, the experimental results related to these theories must be reproduced in such a possible TOE, but its axiomatic and interpretational base should be completely reevaluated if we ever want to consider the classical Euclidean approach (called classical approach frequently from now on). Basically, this would mean to go back to the interpretational standards of the XIXth century and reject the conceptual revolutions of the XXth century physics, including our modern idea of space-time, its geometry, and the fundamental indeterministic character of the physical laws.

An important point to state before considering such a wild speculation is that we should bind ourselves to Occam’s razor\(^1\). If we ever discover that the classical approach is feasible but at the cost of an overwhelming complexity on the underlying axioms, we should not consider such an approach as reasonable. Only if the axiomatic basis is economical in assumptions and parameters, in comparison with the Standard Model, we would consider it as an alternative. Special Relativity, General Relativity and Quantum Theory have been placed at the core of the Standard Model precisely because of their axiomatic simplicity. Any alternative model cannot pretend to substitute or reinterpret them without being similarly economical (or even more economical).

However, we should not overlook the fact that there is a profound inconsistency at the core of the Standard Model: Quantum Theory and General Relativity, as they are understood today, are incompatible (even the relationship between Special Relativity and Quantum Theory is not as smooth as desirable, as we will see). The current attempts at solving this problem are indeed complex in their underlying assumptions. String Theory, for instance, which is usually considered the main hope for solving the inconsistency, challenges Occam’s razor with such a complexity that leads many researchers to state that we only have a superficial grasp on its structure. In this framework, the tolerable complexity of a classical approach would become quite high.

All this stated, it would seem quite hopeless to achieve the goal of a classical approach if it was not for significant advances in several models and research programs which stand up to the Standard Model. We will account for some of these models on sections III to VI.

This paper has two goals. The first is to be a short review of several hypothesis and research programs dealing with the unsolved inconsistencies in fundamental physics, as the incompatibility between Quantum Theory and General

\(^1\) “Entia non sunt multiplicanda praeter necessitatem”
Relativity, and with unsatisfactory (to a minority of physicists, at least) axiomatic groundings for the well-accepted fundamental principles of physics. The second goal is to try to provide a speculative framework where some of these alternative models could be coherently combined. This will help in offering a qualitative perspective on the feasibility of a classical Euclidean TOE.

A. Outline

The following sections are organised as follows: in section II we review some of the most worrying mismatches and open questions in the Standard Model. We have selected those that better reflect, in our opinion, the weaknesses of the Standard Model and the complexity which raises from patching it without reconsidering a reinterpretation of its basis. In section III we shortly describe a non-standard approach to the underlying principles of Special Relativity. This is to show that one can consider hypothesis which imply a violation of Lorentz invariance, or of the universality of speed of light in vacuum, on special circumstances. In section IV we will confront the standard axiomatic grounding for General Relativity with an alternative grounding: gravity as an emergent phenomenon. This alternative dodges the problem of the quantisation of gravity. Also in section IV we will review the present status of the two non-standard alternative hypothesis for explaining inertia. In section V we will discuss the Copenhagen approach to Quantum Mechanics and the efforts to develop a deterministic and local alternative, as well as other options. Also in section V we will discuss the standard approach to Wave Function Collapse and alternative hypothesis. In section VI we discuss the problems originated by the supposed point-like nature of particles. In section VII we will explain why we think it is relevant to put all these apparently disconnected issues together as parts of a research program. We will propose a speculation for a unifying explanation to the groundings of Quantum Theory, gravity, inertia and Lorentz invariance. In section VIII we will conclude by summarizing the assumptions one needs in order to seriously consider a classical approach and its relative complexity, in comparison with the Standard Model. In the Appendices we will speculate further about a precise toy model for the classical approach, about the emergence of spin in these kind of models as well as about some qualitative experimental predictions of the approach.

II. THE HOLES IN THE STANDARD MODEL

In the following subsections we will introduce a selection of relevant challenges that the Standard Model faces. They range from experimental or observational challenges (dark energy, the weightlessness of the void) to theoretical (the quantum gravity deadlock, the origin of inertia, the conservation of energy) and interpretational (the quantum collapse). Together, they pose a serious threat to the self-consistence of the Standard Model and suggest that, rather than ad hoc patching, a complete reevaluation of the basic postulates is reasonably in order.

A. Unifying Quantum Field Theory and General Relativity

The efforts towards the unification of General Relativity and Quantum Field Theory (QFT) date back to the 40’s. Despite a great deal of effort invested in this quest, the goal looks still far from reach. It is not strange that doubts on the feasibility and sensibility of this unification have risen.

In fact, not everyone is convinced that we need to quantize General Relativity in order to unify it with Quantum Theory. Feynman, for instance [3], suggested that maybe gravity does not need to be quantized since gravitation can be the source of quantum collapse itself. This possibility has been further explored by Fivel [4]. Fivel notices that assuming there is a fundamental force driving collapse, this force is at least as weak as gravity.

In a different direction, since Sakharov [5] there have been many approaches to gravity as an emergent phenomenon. Recent results [6] show that possibly gravity-like interactions are the natural long-distance effects of most reasonable quantum fields. Also in the spirit of deriving gravity from Quantum Theory, it has been suggested that the quantum void is the origin of gravity [7].

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2 See, for instance, the review by Thiemann [1] and references therein, to appear in the Living Reviews [2].

3 We use emergent in the sense that the phenomenon emerges from other more basic interactions, as the Van der Waals forces emerging from electromagnetism, for instance. We will repeatedly use (maybe even abuse) this term in this paper to refer to such phenomena that are not fundamental but derived from others. This is to be opposed to fundamental phenomena that are grounded on irreducible axioms or assumed postulates.
An alternative research program has been summoning the efforts of many theoretical physicists in the last two decades: String Theory. One of the main reasons to pursue String Theory disregarding its lack of contact with actual experiments is that it provides a mathematical frame where gravity could be quantized. There are many introductory good reviews on String Theory [8, 9] so we will not describe the string approach on the problems we will consider. Furthermore, we can consider that what we are seeking here is to collect and review a collection of hypothesis, toy models and research programs that together could make up for an alternative to String Theory as the next step in fundamental physics.

It is generally accepted, anyway, that the solution to the fundamental incompatibility between QFT and General Relativity will imply a profound reshaping of the principles of at least one of those two fundamental theories. In the proposed framework on section VII the fundamental principles in both theories are questioned. The standard principles are recycled as emergent laws with just statistical or long-distance sense.

B. A dynamics for Wave Function Collapse

The former problem of incompatibility is not usually bound with the phenomenon of Wave Function Collapse (WFC) in a basic manner, if we exclude the Feynman-Fivel remark (see previous subsection)\(^4\), but for reasons that will be later explained, we will include it in the list of problems. The WFC phenomenon as interpreted and postulated in Quantum Theory is not a problem from the scientific point of view, since it is rooted as one of the axioms of Quantum Theory, and remains consistent with all observations up to date. However, it has been considered as a philosophical or interpretational problem by many renowned physicists, starting with Einstein [10–12]. One of the circumstances that better show the strange behaviour of matter under WFC is the EPR phenomenon [13], which will be one of the basic gedanken test beds for our qualitative framework.

The efforts in order to construct a theory that provides a dynamical rather than axiomatic explanation for WFC have been frequent [12, 14–16]. Considering that the WFC axiom is tightly linked to the non-deterministic nature of Quantum Theory, the hypothetical achievement of the goal of a dynamical theory for WFC would hopefully let us advance in a program to get rid of indeterminism in the axioms of Quantum Theory [12].

C. The origin of inertia

Another fundamental question that has been central in the development of the modern gravitational theory is the origin of inertia. Since Mach, there is a philosophical school that relates inertia to an interaction with the most external shells of the Universe [17–19]. As it is well known, Einstein was heavily inspired by this relation in his works towards General Relativity. Inertia, in this view, is a gravitational effect.

We will see in section IV that this approach is not still generally accepted, and that there is a second school\(^5\) that binds inertia to the properties of the local void [7, 20–22]. This concept seems radically opposed to the Mach-Einstein line of thought, although the differences shorten if we link the local void with a stochastic background (a sort of ether) in thermal equilibrium with the external shells of the Universe. This second point of view on inertia will play a central role in our discussion.

D. The void: just a Zero Point Field?

Regarding to this ether, a question that is sometimes related to the problems of inertia and gravity is the origin of the void, in the sense of the source of such phenomena as the Casimir effect or spontaneous emission. The void is modelled in Quantum Theory as a Zero-Point Field (ZPF), and this approach is in agreement with all experiments up to date.

From this point of view, the ZPF derives from Quantum Theory. However, the opposite view is gaining adepts: to derive Quantum Theory from the ZPF phenomenology [23]. Along this way, an alternative program, known as Stochastic Electrodynamics (SED) [24, 25], tries to reproduce all the electromagnetic void phenomenology without recurring to Quantum Theory. SED assumes the existence of a random background wave noise filling the void. This approach addresses the problem of indeterminacy.

\(^4\) One may also consider Pearle (see subsection V D 4) as a proponent of a relationship.

\(^5\) Of course, there is also the default assumption so that inertia is actually fundamental and intrinsic to bodies.
E. The cosmological role of the void

It is known, furthermore, that something is missing in our understanding of the influence of the quantum vacuum at cosmic ranges. At least three issues show that the Standard Model needs a patch.

First, if the quantum vacuum is subject to the gravitational force, the resultant energy would be many orders of magnitude (around 120!) higher than observed [26], which has been named the vacuum catastrophe [27]. It seems that not only gravity resists quantisation, but quantum vacuum resists to the supposed universality of gravity. This helps in raising the suspicion that maybe geometry is not the ultimate description of gravity.

Second, the expansion of the Universe has been found to include a runaway term: the expansion is accelerating [28]. This term is usually attributed to a dark energy of the void. Hence, the quantum vacuum is subject to some kind of force that permits runaway solutions. It is not clear how this fits in the Standard Model in general, and in the model of the 4 forces of nature in particular. For this reason, this apparent force is sometimes called quintessence, the fifth element. The possibility that we have missed a fundamental force in our description of nature is quite real.

Finally, the nature of the quantum vacuum seems to be changing along with the expansion of the Universe. The fine structure constant has been found to be diminishing when cosmological lapses of time are considered [29]. This challenges the view of the quantum vacuum as a static given background on which the rest of physics operate. The quantum vacuum is probably dynamic and its evolution is linked to the evolution of the observable Universe. This gives further credit to the option of deriving Quantum Theory from the ZPF phenomenology.

F. Special relativity and the conservation of energy

The standard space-time of Special Relativity implies, through Noether’s theorem, that (in particular) the relativistic energy-momentum is conserved. However, the theoretical and experimental support to this conservation law is far from encouraging. To appreciate the weakness of the energy conservation law, we note that it fails in some way in all scales: it fails at a cosmological range (dark energy and inflation) [28]; at microscopical ranges it continually fails, although not on average (the Heisenberg uncertainty); it even fails at its safest old stronghold, the macroscopic ranges, when acceleration-related phenomena are involved (radiation reaction) [30].

It is not then reasonable to think that conservation of energy is not fundamental at all? However, as mentioned, we know through Noether’s theorem that the conservation does not come from the properties of particular theories of fields and particles, but from the same structure of space-time. Thus the question reverts to: is not then reasonable to think that we have seriously misunderstood the fundamentals of space-time?!

Notice, also, than in two of the three scenarios (dark energy and radiation reaction), acceleration and runaway solutions seem to loom. We will suggest this is also true in the third scenario and this will drive us to a reconsideration of which kind of space-time we need for a background and what kind of theories we should build on this background.

G. The alternatives

In the four following sections we will discuss the origin of these limitations of the Standard Model in terms of four putative pillars for the modern description of nature: Special Relativity, General Relativity and inertia, Quantum Theory, and point-like particles. We will also introduce alternatives that seem interesting in the spirit of the classical approach.

III. THE FIRST PILLAR. THE PRINCIPLES OF SPECIAL RELATIVITY

As it is well known, Special Relativity is built on top of the Principle of Relativity (Lorentz invariance, that is, the equations driving physics on any inertial frame are invariant) plus invariance of $c^8$. Nonetheless, this approach, while being the way Einstein unleashed Special Relativity and the way Special Relativity is always taught, is not the only possibility. There is another point of view, which can be useful to construct Special Relativity, as reviewed,
for instance, by Bell [31, 32]. We will call it Lorentz’s approach. Lorentz’s approach (see next subsection) is not as elegant and concise as Einstein’s, but it proves useful in order to provide some insight to certain (academic) problems. What is more important for us is that Lorentz’s approach is not rooted on top of the Principle of Relativity plus \( c \) as a bound speed, which can then be considered as consequences of other principles rather than the axiomatic roots of relativity. In this sense, Special Relativity could be considered as emergent.

Whether we prefer one of these approaches or the other is just a matter of philosophical taste as long as the theory is considered closed and finished (at least, as far as electromagnetism is concerned). However, if Special Relativity was going to be affected by some sort of new phenomena or theory, the distinction could prove critical. Lorentz’s approach would tolerate certain modifications of Special Relativity affecting the Principle of Relativity or \( c \) invariance, as far as we recover the predictions based on these principles in most situations. Einstein’s approach would not, since the Principle of Relativity is considered a given principle on top of which the rest of physics is raised: a metaprinciple [33].

In fact, the generalisation from electromagnetism to the rest of physics by constituting relativity as a metaprinciple above all physics is considered the great triumph of Special Relativity. It is? We should not rule out the possibility that the extension was too hasty: even when most physical theories seem to bind to Lorentz invariance, there are parts of physics that could escape this principle (at least in the broad sense that includes \( c \) invariance), that would be then downgraded to an emerging phenomenon.

A. The relativity of Larmor-Lorentz-Poincaré [31]

Take as a starting point the experimental fact that the speed of light has a well-defined value in a certain reference system (given by the far stars, for instance - the comoving frame of the Universe), together with the remaining electromagnetic laws (summarized in the Maxwell equations). If one provides a simple model of matter based on electromagnetism, then the basic results of Special Relativity emerge naturally for this basic model. Maxwell equations are valid in any other reference system and the speed of light is the same on such reference systems. Rods physically contract and matter slows down its processes. Lorentz transformations show up. Bell calls it the Larmor-Lorentz-Poincaré approach and we refer it as Lorentz’s approach for short. Of course, one has to carefully reproduce the analysis for more complicated physical systems; for instance, those involving nuclear forces or radiation reaction.

On the other hand, the Principle of Relativity takes the experimental facts as postulates, and then the proofs get simpler and much more elegant.

Nevertheless, any fact of physics forces us to adopt one view or another yet. Einstein’s approach is clearly more useful, has an elegant mathematical generalisation and then it has become the standard axiomatic explanation. However, we should not overlook that if we ever observe a violation of the standard postulates of relativity, Lorentz’s approach could cope with it under some circumstances, but Einstein’s could not. That also means that we should not always reject a hypothesis or model based on the fact that violates the postulates of relativity, if the violation appears on limited circumstances.

B. Violations of Special Relativity?

We have already seen in the introduction that the standard space-time of Special Relativity faces trouble when energy conservation is considered. This suggests a possible deeper underlying basis for the Minkowskian space-time.

Lately, furthermore, there has been an increasing theoretical evidence that Einstein’s approach is possibly too restrictive. To show this, we will basically follow the discussion by Liberati, Sonogo and Visser (LSV)[33]. Special relevance is given to the Scharnhorst effect [35] and to special spacetimes: the Wormhole, the Alcubierre warp drive and the Krasnikov tube [36]. Recently, it has also been suggested that the value of the speed of light (the fine structure constant, in fact) in the vacuum may be decreasing in time, due to the influence of some sort of cosmological phenomenon [29]. Finally, we should also consider that there is an increasing feeling that phenomena related to quantum entanglement reflect a conflict between Special Relativity and Quantum Theory.

These evidences can be integrated into Special Relativity in two ways. One can reformulate Special Relativity so that the Principle of Relativity is preserved in a restricted sense, and renounce to invariance of \( c \). Alternatively, one can go further and recover Lorentz’s approach to Special Relativity, centred on electromagnetism or on any other

9 For a complementary and very interesting summary of the historical process of the rise and fall of the electromagnetic TOE, see chapter 28 on Feynman’s lectures [34].

10 See Magueijo et al. [37] for a reason to derive the \( c \) variation from a fine structure (\( \alpha \)) variation.
theory with the capability of being used as TOE. We bet for a variant of this second option because it is one of the keys in order to get a positive answer to the entitling question of this paper, as we will discuss later.

We will explain the two possibilities, but first let us briefly introduce some of the mentioned theoretical evidences.

1. **The Scharnhorst effect**

The Scharnhorst effect refers to a superluminal (faster than c) photon propagation in the Casimir vacuum (in a cavity with perfectly reflecting boundaries) due to higher order QED corrections. Certain frequencies are forbidden in the cavity, so diminishing the energy density of the vacuum. Therefore, if the energy density of unbounded vacuum is arbitrarily taken to be zero, then the Casimir vacuum has negative energy density. This lower energy density induces, among other effects, a higher value for the speed of light.

This is, by the way, another example of the difficulties that Special Relativity has with the concept of energy in some limits.

2. **Special spacetimes**

There are a remarkable set of spacetimes which permit superluminal travel: wormholes, the Alcubierre warp drive and the Krasnikov tube. All of them violate the weak energy condition [36].

Although classical forms of matter obey this energy condition, it is nonetheless violated by certain quantum fields (for instance, in the Casimir vacuum, as we have just mentioned).

C. **Solutions**

The solution to these challenges can be approached from two radically different positions:

1. **Approach 1: Maintain the Principle of Relativity**

Now, the principle-centred approach to these challenges is as follows. If one assumes as postulates the 3 following hypothesis:

1. In an inertial frame, the space is homogeneous, isotropic, and Euclidean, and the time is homogeneous
2. The Principle of Relativity
3. Precausality (causality in the standard sense, but without any reference to coordinate systems)

then the existence of the Lorentz group is implied, containing a parameter representing an invariant speed [33].

This does not imply an upper bound for the speed. However, given a propagation phenomenon (like a wave-like propagation on a fluid with a certain sound speed, which plays the role of an invariant speed) in one reference frame, one can always find time and space coordinates, in any other frame, such that the Principle of Relativity is satisfied and an analogous equation holds true in the new frame, as LSV state.

Once a finite value for $c$ is found experimentally, the whole formalism of Special Relativity follows on the basis of postulates 1-3.

LSV note that one can always choose the value of $c$, because such a choice is essentially equivalent to giving the prescription for synchronization. However, the natural choice (so that the laws become simpler, that is, Lorentz invariant) is to take the *sound speed* as the synchronization speed. It is easy to see that if the coordinates in two reference frames are to be related by a Lorentz transformation with invariant speed $c$, synchronization must be performed using signals that travel at the speed $c$. For synchronization, then, one must use signals travelling at the invariant speed $c$, if one wants to satisfy the Principle of Relativity.

In this formulation, Special Relativity can tolerate superluminal signalling at the kinematical level. There is nothing in postulates 1-3 that implies a maximum speed. The existence of a speed bound has to be added as an experimental input, or equivalently, as an additional property of the laws of nature. If we rely on the calculations of QED, we have
to admit that $c$ is not such a bound, but a sort of sound speed that characterizes for some reason all the known laws of nature, although this sound speed is not usually surpassed.

There are some consistency issues that need to be addressed, however. First, in the Scharnhorst effect light behaves in a non-Lorentz invariant way. But this is only because the ground state of the electromagnetic field is not Lorentz invariant (due to the boundaries, the Casimir plates).

Also, causality paradoxes might show up. LSV show this is not the case in the Scharnhorst phenomenon. If one synchronizes with the invariant speed, one can still send signals at a higher speed so that causal effects may be reverted in order in some reference systems (tachyons going back in time). No causal paradox arises, though, if one can find a preferred reference frame which defines the absolute time-ordering of the causal influences. Imagine $a$ causes $b$ through a tachyonic signal in a certain reference system. There are other reference systems where $b$ happens before $a$. The deep reason for this is, however, that we build those reference systems by using synchronisation at a finite speed that can be surpassed. There is no causal paradox in that if one admits there can be a preferred reference system. In the Scharnhorst effect there is such preferred system: the rest frame of the Casimir plates. Coordinates are arbitrary. To choose a reference system where the effect happens before the cause is just a bad decision for a coordinate system, but does not pose a paradox by itself.

### 2. Approach 2: Lorentz relativity

A natural step would be to reconsider the role of Lorentz invariance, regarding it as a symmetry property of specific theories rather than as a fundamental meta-principle of all physics. As long as those specific theories are just approximations to a more accurate physical theory, violations of Special Relativity can emerge.

So one can even dismiss the postulate 2: the Principle of Relativity. This is Bell’s and Lorentz’s point of view. Lorentz invariance is then a property of electromagnetism. And a more profound understanding of electromagnetism could imply that Lorentz invariant is not completely general.

This second approach has the disadvantage of needing an explanation for Lorentz invariance as a quite generalised principle, embodied in several laws of physics. Historically, Lorentz realised of this. His approach was to consider electromagnetism as the fundamental theory of nature and to build models of matter (electrons in particular) based on pure electromagnetism. The electromagnetic picture of the world is indeed an interesting academic exercise, but does not solve the problem as this picture has been abandoned as a possible TOE.

We need then to provide a fundamental reason for the coincidence in several laws of nature at approximately fulfilling Lorentz invariance (if electromagnetism is not the TOE we might need to find another candidate characterised with a sound speed $c$). We will try to provide such a reason in subsection VII D 2.

The advantages of the approach, on the other hand, are the a priori absence of paradoxes provoked by the Scharnhorst phenomena and relatives or by certain spacetimes, as well as the possibility of finding a cure for the inconsistencies of Quantum Theory and energy conservation, as we will later recall.

### IV. THE SECOND PILLAR. THE PRINCIPLE OF EQUIVALENCE, GRAVITY AND GEOMETRY.

The Principle of Equivalence is one of the pillars of General Relativity. Even most of the theories that have been proposed as an alternative to General Relativity attach to this principle. There are good reasons for that, but the main one is that the refutation experiments have established that the principle is fulfilled with astonishing fractional exactitude: a part in $10^{13}$.

It is clear, then, that the same force or pseudo-force that accounts for inertial forces is also at the rooting of gravitational forces. The relation is necessarily profound, although when we turn to numbers and try to derive inertia from General Relativity (as an emergent phenomenon) the proof faces important challenges, as we shall see in subsection IV B. The reason could be that even when they are related, inertia cannot be fully inferred from gravity because they both emerge from a more fundamental force, or even that gravity should be derived from inertia and not the other way round. This drives us to the question of whether General Relativity is itself a fundamental or an emergent phenomenon.

Einstein showed that gravity can be understood as geometry. This heavily points in the direction of gravity as a fundamental phenomenon. However, we should remark that certain forces that act homogeneously over mass have this

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11 This is true while one does not consider WFC as a dynamical phenomenon.
12 We recommend again Feynman’s lectures [34].
capability of being described through geometry (we will analyse this in the next subsection). In other words, again we found a causal dilemma in the founding principles: is gravity on the first place just a geometrical phenomenon, or gravity is a special force which happens to interact homogeneously with inertial mass and can be described, for elegance and simplicity, formally as a geometry? The distinction would be pointless, matter of taste again, if General Relativity were a final theory. However, the incompatibility between General Relativity and QFT is generally attacked via the quantization of General Relativity. If gravity is strictly geometry, we need then to build a quantum geometry, which is something that has been intensely tried for decades without success (although many theorists believe that String Theory will permit it). On the other hand, if geometry is just an elegant mathematical shortcut for most situations in gravity-conducted events, there is no point in pursuing a quantum geometry.

A. Gravity as an emergent phenomenon

Regarding geometric-like forces, we can recall the fact that the refraction coefficients in materials, and so the curved paths of light in those materials, can be described from the phenomenological point of view as a geometry [42]. That works at large scale, although if we dive into the microscopic machinery, the geometrical description cannot explain all the details of the behaviour of light.

This can be directly related to the efforts in analogue models of General Relativity that have been recently attracting much interest. Since actual experiments on intense gravitational fields are not possible today, some physicists started developing analogue models of General Relativity in the frame of other branches of physics: acoustics, optics, and solid state, essentially. The idea is to simulate some features of General Relativity (as black holes) within a system in a lab [43]. They have shown that the internal forces in these systems, while acting on a certain wave function (as light) can be interpreted as a metric. Furthermore, Barceló, Visser and Liberati (BVL) have recently shown that one-loop effects contain a dynamics over that metric, in the same geometrodynamical spirit of General Relativity [6]. This approach is partially similar to Sakharov’s [5]. Sakharov found out that if we renormalize on a curved space rather than in flat space there appear remaining terms in the action. The first of them is formally identical to that of General Relativity. The rest he called them quantum corrections to General Relativity. Sakharov provides a hypothesis for the dynamics of curved space but not for the original reason of curved space itself. The BVL approach is more profound, in our opinion, since the metric is not arbitrarily provided but derived from the (Euclidean) physics of the system. In this sense General Relativity can be dubbed as an emergent phenomenon, since emerges as a long-distance effect of other more fundamental forces. If so, this approach could play a role on a classical approach: it permits us to recover Euclidean geometry as the underlying geometry.

A real difference between the analogue models and gravity is the strong coupling between this force and inertia. The simple example with refraction just works with light, but fails to explain the behaviour of other kind of waves. It fails because the interaction does not couple to inertial mass, but to other properties of the waves. More sophisticated models also have to battle against different metrics obtained for different fields (which can be called birefringence), although we will later suggest that this can turn into an advantage (see section VII G 1). Gravity, on the other hand, does couple to inertial mass. This is stated by the Principle of Equivalence, and has been experimentally shown to be highly accurate, as it was previously remarked.

B. The roots of inertia

1. Inertia and Mach’s principle

Let us jump then to the question of inertia and its relation to gravity. The problem of inertia was one of the main reasons that drove Einstein to the theory of General Relativity. The issue was known long ago, and was popularised by Mach. To summarize it, the problem comes from the fact that inertia is a force that depends on local acceleration. However, how does one establish a reference to which a system does not accelerate, or equivalently, how can we define absolute acceleration?

First, a precision is in order regarding the Mach’s principle. This principle embodies a much wider collection of issues. It has been so used and reinterpreted that is presently blurred enough to provide conflicting predictions on certain scenarios. The account of Bondi and Samuel [44] provides a listing of eleven different formulations of the Mach’s principle. The first of them (Mach0), Local inertial frames do not rotate relatively to the Universe, is in fact an experimental observation rather than a principle, and then is what cosmological theories are confronted with. In this sense, Mach’s principle is the experimental observation that the inertial frame defined by local physics (zero Sagnac shift) coincides with the frame in which the distant objects are at rest [44]. The Sagnac effect is the modern
version of the Newton’s bucket. When other variations of the principle are considered, then theories can be considered Machian or Anti-Machian depending on its fulfillment of the particular version of the Mach’s principle.

Following Mach, Einstein developed a theory that would explain inertia as an interaction with the far stars. With this, one can introduce a reference system that does not accelerate with respect to the far stars, so one can refer to absolute accelerations and then make sense of inertia. However, when we try to calculate in detail how inertia emerges from a gravitational interaction with the farthest regions of the Universe, several problems arise. But let us first describe the three options where all accounts of inertia can be classified into.

### C. Theories of inertia

The first option is that inertia is an intrinsic property of massive bodies. This is simple and self-consistent\(^\text{13}\), and the default explanation if we cannot produce anything better [20]. However, if we can explain inertia by other means, we then remove an unnecessary and strange postulate, which simplifies the theory. Thus it is worth to take a look at the alternatives.

The second option is that gravity is the source of inertia, as Einstein (initially) believed. In fact, it has been shown that General Relativity implies that the external shells of the Universe interact with local (from our solar system, for instance) matter with a force that is proportional to acceleration [17, 18]. Several problems remain, however. First, if we want to honour the Principle of Equivalence, the factor in that proportion needs to be somewhat artificially adjusted. Second, the instantaneous character of the inertial force needs some explanation, since the external shells of the Universe are quite away, but the gravitational reaction force, which is supposed to account for inertia, is doubtlessly instantaneous.

This paradox is very serious and the possible solutions within the orthodox view are all quite unnatural. One possibility, defended by Ciufolini and Wheeler [19], for instance, is that the force is propagated instantly. This is a very radical and complex reconsideration of the Standard Model. It relies on the fact that the Einstein equations contain both hyperbolic evolution equations (6 of them) and elliptic equations (4 of them), which are in fact constraints on the evolution of the system. The equations can only describe the coherent evolution of the metric and the matter (the left-hand and right-hand sides of the Einstein equations) and then we cannot externally alter the evolution of matter at will: the constraints must be respected. This in turn puts constraints on the evolution equations of matter. So if this program can be brought to and end, it tells us that inertia must be implicit in the evolution equations of matter\(^\text{14}\): that is not, in fact, anything very different from the point of view that inertia is intrinsic to matter, unless we take indeed the constraints as really decoupled from matter and being carriers of a new non-local force. In the first case the postulate of intrinsic inertia is maintained and it is hard to defend that we have saved any complexity. The second option is a quite ad hoc postulate with very important side effects on the rest of physics. Non-local forces introduce a deep level of complexity in the description of nature.

Another possibility within the gravitational origin of inertia is that defended by Woodward and Mahood. According to their theory, a local acceleration creates a wave which travels to the ends of the Universe, makes it wiggle so that it creates a return wave which travels back in time towards the source of the perturbation and interacts with it causing inertia. This mechanism is recycled from a theory developed by Dirac, Feynman and Wheeler, which they hoped was a response to the inconsistencies of point-like electrodynamics. The theory was abandoned long ago in electrodynamics, but in General Relativity is defined as the last hope for preserving Einstein’s view that the theory would explain inertia. Dobyns, Rueda and Haisch have a good account that details why this possibility is not very satisfactory [20]. We will give more details about it in the conclusions of this subsection. Also, this orthodox approach goes against our proposed paradigm\(^\text{15}\), as we will show, so we adhere to the refusal.

The third option is an alternative hypothesis has been recently concentrating some efforts. The hypothesis is still not a finished theory but a framework in construction. The main point in the hypothesis is that inertia is the result of a local interaction of matter with the quantum Zero-Point Field (ZPF) [7, 21, 22]. The advantage of the hypothesis is that circumvents one of the two problems above: the interaction is local. The difficulty in explaining the factor

\(^{13}\) Although quite peculiar when combined with Special Relativity: Special Relativity does not permit an absolute space in terms of speed-related effects. Intrinsic inertia, on the other hand, requires an absolute space in terms of acceleration. This point of view may be valid but it rather makes us feel there is something we do not properly understand about the structure of space.

\(^{14}\) Unless gravity is shown to explain the equations of matter. This means building a gravitational TOE, which Einstein unsuccessfully tried for 30 years.

\(^{15}\) Even without considering the particular use of the macroscopic (or rather cosmological) travel to the past, whose consequences and possible paradoxes if generalized to all physics can be hardly seen as a simplification with respect to the default explanation of intrinsic inertia.
in the force is maintained. This and the fine-tuning of factors are completely different from the gravitational theory, though. We attach to a variant of this point of view for reasons that we will comment in section VII.

1. Summary: gravity = inertia + geometrodynamics (general relativity)

The Principle of Equivalence simply states that gravitational forces are equivalent to inertial reaction forces. But that does not mean that either the Principle of Equivalence or General Relativity explain inertia. To affirm that General Relativity is the origin of inertia is another completely different hypothesis that tries to close the loop, and which should be separately considered. In fact, the claim that inertia is a geometrodynamical effect is quite circular [20].

The alternative and consistent view in order to explain the Principle of Equivalence is that, once inertia is externally (through an interaction with the ZPF, for instance) or intrinsically given, if the spacetime is curved then gravitational forces are in fact inertial reaction forces. What General Relativity does is to assume the space is curved and to provide a dynamics for it (the geometrodynamics), but that does not explain neither inertia nor the gravitational forces (which are the same thing).

In fact, the attempts at explaining inertial forces in the framework of General Relativity are attempts to derive forces on matter generated by geometrodynamics, which is quite paradoxical. One of the approaches is to use the linearisation of General Relativity, which is the choice of Woodward of Mahood based on an argument by Sciama (used by Sciama to refute General Relativity, by the way). Another approach is to consider that the elliptic constraints of geometrodynamics generate forces on matter, as we have discussed.

The confusion comes when we do not distinguish gravitational forces (weight) from geometrodynamics. Weight is the resistance of a body to be separated from its geodesic, which is nothing else than inertia. But nothing in geometrodynamics can explain the force that bodies feel when they separate from geodesics, because geometrodynamics just describes geodesics.

In conclusion, inertia in flat spacetime is weight in curved spacetime. General Relativity explains neither, but only how geodesics evolve. Why test particles feel forces when they deviate from geodesics is something that only a general theory of inertia can explain.

D. The current views on inertia and gravity

In the last two subsections we have addressed the current approaches to gravity and inertia separately. Now we will integrate them into combined theories of gravity and inertia.

We have explained that the phenomenon of gravity is the sum of geometrodynamics (General Relativity) plus inertia. A first family of theories (Woodward and Mahood, Ciufolini and Wheeler) speculate that General Relativity as dynamics of geometry is an almost final theory (only its quantisation pending) and additionally a theory of inertia. While the first statement can be defensible, the second is quite problematic, or even paradoxical.

A second option, the conservative approach in the Standard Model, is that General Relativity is a final theory, which describes the dynamics of geometry, and that inertia is an intrinsic property of bodies. This approach is perfectly consistent, if we disregard the problems of General Relativity with QFT.

The third option (Sakharov, BVL) states that geometrodynamics is an effective phenomenon created by one loop effects of QFT. The underlying spacetime is Minkowskian. Inertia is also intrinsic to bodies in principle.

The fourth option (Haisch, Rueda, Puthoff) is that inertia emerges from an interaction between the ZPF and test particles. There is a natural tendency in these theories to also consider geometrodynamics as emerging from the ZPF, although this second step is more involved than the first.

V. THE THIRD PILLAR. QUANTUM THEORY: INDETERMINISM AND NON-LOCAL COLLAPSE

There are two aspects of Quantum Theory that many scientists find hard to swallow: its axiomatic or fundamental indeterminism and the vague, if consistent, measure process related to the collapse of the wave function, with its associated implicit non-locality.

For these reasons, many physicists have considered the theory as a provisional phenomenological construction. Its axioms, certainly vague and unquestionably self-consistent, should not be seriously taken without further analysis. The precision of the predictions, however, drove the orthodox view, heralded by Bohr, to ignore such considerations in favor of the apparently simplest approach: to take the axioms as given metaprinciples, and with them, rooting the fundamentals of physics on indeterminism and non-locality.
The scientific debate on both aspects is frequently clarified through the discussion on the so-called EPR paradox.

A. Indeterminism and non-locality: The EPR paradox

The paradox of Einstein, Podolsky and Rosen (EPR) [13] was proposed as an argument to show that Quantum Mechanics could not be a complete theory, but it should be supplied with additional variables. These additional variables would then ideally restore the apparent lack of causality and locality in the theory.

Rather than the original EPR argument, a more incisive version by Bohm and Aharonov is normally used as the discussion arena [45]. The EPR argument à la Bohm-Aharonov is as follows: consider a pair of spin $1/2$ particles created somehow in the state spin singlet and that move in opposite directions. Stern-Gerlach magnets, for instance, are provided to obtain measures. If when measuring the projection of one of the electrons we obtain $+1/2$, as the spin projection, then the measure of the other device must return $-1/2$, and vice versa. This follows unquestionably from Quantum Mechanics and does not depend on the distance between the two measuring devices, that can be large enough to discard non-superluminal influences. As we can predict the outcome of the measure on any component of the second spin, then the result of the second measure must be predetermined. As the original quantum wave state does not determine the result of the first measure, this predetermined property suggests the possibility of a more complete specification of the original state.

The standard interpretation assumes alternatively that the first of the two EPR observations fixes what it was until then unfixed, not only in the first particle but in the second, which raised well-founded concerns about the locality of QFT. To EPR this was a spooky action at a distance. In fact, as Bell stresses [32], Einstein was more concerned on non-locality rather than on indeterminism. What was sacred for him was the principle of local causality, or no action at a distance. To avoid this spooky action, EPR and followers are forced to attribute, to the affected space-time, properties which were real before the measure, properties which are correlated and predetermined the result of these observations. As these properties, fixed before the observation, are not accounted in the quantum formalism, then to EPR the quantum formalism is incomplete.

B. The orthodox interpretation: the subject-object duality

Quantum Theory in the Copenhagen interpretation deals basically with observations. It divides the world in two parts: an observed part and an observing part. Quantum Theory always refers to an external observer (which is quite amazing, in particular, when taking the cosmological perspective of the Universe as a whole).

In fact, the orthodox response of Bohr to EPR implies that we must consider the experimental device as a whole, and not try to divide it in pieces and analyse it, with indeterminacy quotas separately located as if the device was nothing but a complex quantum system. The subject is classical, the object is quantic, and they obey different laws.

Even when indeterminism could be questioned as part of the underlying axioms, non-locality would be considerably trickier. The profound reason is that the theory has to do, basically, with the results of measures and then it presupposes an externally given distinction between the system (or object) and the measurer (or subject). The interface between them is not supposed to be dynamical, which permits non-local phenomena when the quantic object is measured by a large enough classical subject.

C. The problems of the orthodox view

The orthodox view leaves many questions unanswered: are instantaneous the jumps? Is there any way to predict a collapse? What or who is a measurer? What is the frequency of collapses? On what depends? How do we describe the quantic-classical transition?

1. The ill-defined triggering of the collapse process

One of the most apparent non-localities of Quantum Theory is the instantaneous, and global in space, Wave Function Collapse after the measure. Quantum Theory does not provide any means to establish what triggers a collapse, whether it is instantaneous, non-dynamical and non-local or, on the contrary, a dynamical process. As the orthodox view solves these questions through the uncanny subject-object duality, the only answer is that it simply happens when a measure is performed. However there is no simple way to define the concept of measure, which is
vaguely placed as something that happens at the classical level, more or less driven by the observation (of a conscious being, to make things worse).

The solution of the external conscious observer à la Copenhagen in order to complete the theory is just so complex that should be abandoned on pure application of Occam’s razor\(^\text{16}\). How can one define in a simple way, without considering the interaction of millions of atoms, the concept of consciousness? How can that be formalised in a solid mathematical way?

So we are just left with suppositions about the nature of the collapse triggering. *Shouldn’t we necessarily admit that processes more or less of the sort of a measure happen more or less always, more or less everywhere? Is there but an instant then in which the jumps do not exist and the Schrödinger equation can be applied?*\(^\text{32}\).

2. **Non-locality: the collapse and correlations**

The supposed non-dynamical collapse process, furthermore, introduces the problem of non-locality and the confrontation with Special Relativity. Taking EPR as a paradigm, we can see that the logic drives us to a deadlock: the correlation in EPR implies than the result on one of the experiments reveals the result of the second experiment, whenever the analyzers are parallel. Quantum correlations are not apparently explainable in a local way, which raises the need for the non-dynamical mysterious WFC. This would not only be a long-distance eerie influence, but it would propagate faster than light.

In a theory where parameters are added to Quantum Mechanics in order to determine the results of experimental measures, without changing the statistical predictions, there must exist a mechanism so that the orientation of a measuring device can influence the result provided by the other instrument, no matter how far it may be. Moreover, the involved signal must propagate instantly, and then the theory could not be Lorentz invariant. Of course, if the predictions of Quantum Mechanics have a limited validity, then the situation is different. In particular a superluminal signal could be enough.

\section*{D. Alternatives}

1. **Decoherence**

Decoherence is the minimal modification to the Copenhagen approach in order to remove some of the most obvious incongruences of this interpretation \(^\text{46}\). By introducing decoherence, the conscious observer is replaced by a noisy environment which triggers the measures and the collapses. The resultant theory is still non-local and indeterministic.

2. **Theories of local hidden variables**

The relevant question in order to get rid of quantum indeterminism and non-locality with minimal changes is whether a scheme of hidden variables with the desired local value (in the sense of respecting Special Relativity) can be found. Bell and followers showed that this is not possible, though, if one is to reproduce all the results of Quantum Theory \(^\text{47–49}\). Some hoped that the predictions of Quantum Theory in conflict with the local hidden variables theories would prove mistaken. However, the experiments showed this hope was vain. Quantum Theory is right and the local hidden variable theories are wrong \(^\text{50}\)\(^\text{17}\).

Hidden local variables are then not compatible with the statistical predictions of Quantum Mechanics. It is the requirement of locality, or more precisely that the result of a measure on a system is not affected by operations on a distant system with which it has interacted in the past, what creates the strongest difficulty.

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\(^{16}\) Even when the axioms look simple.
\(^{17}\) There are still many papers produced nowadays on possible flaws of Bell’s conclusions, although most researchers would agree that we should attach to those conclusions by now. We do not consider the possibility of building a classical approach that is partially based on a flaw of Bell’s theorem, and that obviously makes the path towards a classical approach more challenging.
Non-local hidden variables

Nonetheless, several hidden variables interpretations of the elementary Quantum Theory have been explicitly built since the seminal works of de Broglie and Bohm [51]. They match all the predictions of Quantum Theory. Of course, these interpretations have a profound non-local structure. The descriptions of de Broglie-Bohm and followers embody a quite remarkable characteristic: the consequences of the events in one place propagate faster than light to other places. At least in principle, therefore, a cure can be found for indeterminism, but not for non-locality (in the sense of Special Relativity, we should stress).

The conflict raises then again when we have no choice but to admit that the equations for hidden variables have generally a non-local character. In many alternative theories, there exists a causal explicit mechanism so that the disposition of one of the measuring devices influences the results obtained on a distant device. In fact, the EPR paradox finds its solution in the form Einstein would have liked the less.

As Bell tells us, one of the options to skip this non-dynamical WFC is, in fact, that causal influences propagate faster than light. The role of the Lorentz invariance in the complete theory would be then quite problematic (which is anyway not a burden from our point of view: see section III).

This is then the second true problem of the Quantum Theory: the manifestly essential conflict between any precise formulation and Special Relativity. That is, we find ourselves facing an apparent incompatibility, at the deepest level, between the two fundamental pillars of the contemporary physical theory (the first and third ones, in our particular listing). This piles on the incompatibility between the second and third pillars.

Dynamical collapse models

Another development line towards a greater physical predictability would be to have a jump in the equations as a dynamical process in definite conditions. The jumps violate the linearity of the Schrödinger equation, so the new equation should be non-linear. In the same line as the orthodox proponents, the evolution of the statevector should be modified but to do it so the collapse is not instantaneous but, rather, follows a well-defined dynamics of a modified Schrödinger equation.

Even without an explicit dynamical process, the theory can be made more consistent. A specific example of spontaneous WFC is specially simple and elegant [14]. The wave evolves according to the Schrödinger equation but it collapses from time to time. The collapses are fortuitous and spontaneous, mathematically represented by a probability of collapse. This theory does not add variables. By adding mathematical precision to the jumps of the wave function, it makes more precise the action at a distance of ordinary Quantum Mechanics, and thus we get rid at least from the need of an observer. The most molest aspect of the theory is again the difficulty in reconciling it with Lorentz invariance, which is not anyway an essential trouble for us, as already mentioned (What we cannot accept if we attach to the classical approach is strict non-locality, but downgrading Lorentz invariance poses no problem).

Even when this sort of models make the Quantum Theory more precise and less self-inconsistent, they add a new postulated element, so increasing the complexity of the Standard Model. An even better solution would be then to provide a reason for the probability of collapse.

Dynamical collapse models with a chooser

In order to describe more accurately the apparently random choices made by nature the Schrödinger equation must have a chooser in it. P. Pearle has a good review [52] on formalisms and models which modify the Schrödinger’s equation so that it describes a WFC as a dynamical physical process. One of the strongest motivations for this addition, as mentioned, is to avoid that either human beings or unknown choosers are essential to the description of nature.

Pearle settled on modelling that chooser by external random noise [53]. With external random noise as the chooser, it turns out that the mechanism for obtaining agreement with the predictions of Quantum Theory is very simple, which suggests one is on the right path [52].

Collapse models should provide an explanation for the random results which occur in nature and are unexplained by standard Quantum Theory: the results was this rather than that because the noise fluctuated this way rather than that way [52]. What is left unexplained is what is this noise and how its fluctuations can be computed. Pearle thinks that small perturbations in the gravitational field are the ultimate source of noise. We commented on section II that Feynman and Fivel also defended that point of view.
ZPF (in the SED sense of HRP) is a better candidate of noise chooser for us. This is not paradoxical since we segregate the ZPF phenomenology from the rest of QFT. In fact, we have already suggested that ZPF can be seen as the root of QFT rather than the other way round. By building QFT on top of the stochastic ZPF we are automatically provided with a source of noise, and with it with a reason for the apparent indeterminism of Quantum Theory.

The fact that we cannot usually predict the outcome of a quantum system remains, as the complete knowledge on the details of the noise is impossible. The noise plays the role of the hidden variables. Analogously, the description of the Brownian motion, for instance, could have been in principle developed in a purely statistical way, while making the statistics later understandable with the hypothesis of the molecular constitution of fluids. The additional fact that the measure perturbs the system (see next section) increases the difficulty to model the underlying noise.

6. Non-Lorentzian deterministic dynamical collapse models with a chooser

Although this later approach is valid and goes in the right direction for the purposes of the classical approach, there is the possibility of going further: to model a collapse which is not only well-defined (deterministic), but also dynamical (that is local). This is only possible, of course, at the price of sacrificing Special Relativity. We will try to provide a prescription for such a framework in section VII.

VI. THE FOURTH PILLAR. THE PROBLEMATIC POINT-LIKE PARTICLE

One of the burdens that sunk the interpretational paradigm of XIXth century physics was the failure of the point-like models for particles. QFT overcame this problem with the wave-particle duality and renormalization, which in opinion of many are gross hacks (from the interpretational point of view). Renormalization has been one of the great steps forward in physics and has given us Quantum Electrodynamics (QED), the most precise physical theory ever. Nonetheless, it lacks mathematical elegance and seems too complicated. The machinery of QFT permits to deal with point-like particles, but at the price of an ugly squeaking. The so-called finite QED [54], for instance, looks for a cure to this problem. However, up to now we do not really have a satisfactory way to combine point-like charges and electrodynamics.

In String Theory particles are not point-like, but they have a structure, which avoids many problems and could allow the description of many quantized forces, including gravity. As we advanced in the introduction, however, we are not interested in this way, so we will not give further details on this.

Any time we try to ground the particle concept, problems arise. So a valid question is: what do we need particles for? In fact, do they exist at all? Of course, existence is not a very well-defined physical term. What we mean is, it is necessary for physical models of nature to be based on particles? Could they just be an emergent phenomenon and useful to describe certain situations in nature, but actually not fundamental?

VII. AN ALTERNATIVE FRAMEWORK

In this section we will try to integrate some of the alternative hypothesis described in the previous sections into a coherent alternative framework for the classical interpretation of Special and General Relativity, and Quantum
Theory. Several assumption we make are, we believe, quite general within a classical Euclidean TOE. Others are more questionable, but nonetheless interesting in order to proceed further. We group this later assumptions under the name Spin Force Model (SFM).

A. Assumptions

Let us assume our observable Universe can be represented by a fluid\textsuperscript{20} on an Euclidean space, governed by deterministic laws (in the form of partial differential equations) free of singularity-causing shocks. The space is isotropic and homogeneous, and it is embodied with an absolute time \( t \). We also assume that the blob of fluid that amounts for our observable Universe suffered an explosion and it is expanding against a (relative) void. The expanding blob is locally in an approximate thermodynamic equilibrium regarding to internal (turbulence-driven) noise if we consider small lapses of time (compared to the time since the explosion), and if we ignore areas of high concentration of the fluid (which we will associate to matter and radiation). This fluid in thermodynamic equilibrium is assumed to be the vacuum of QFT (the ZPF). Let us call it ether to distinguish it from the thinner void outside the blob.

We assume a conservation law for the fluid, so that we can describe it through a density function \( \rho(x^\mu) \). We further assume that the fundamental Lagrangian density ruling the fluid dynamics only comprises \( \rho(x^\mu) \), its first derivatives \( \partial_\mu \rho(x^\nu) \) and the relative acceleration that characterises the motion of the fluid, \( \partial_\mu a(x^\nu) \) \textsuperscript{21}:

\[
\mathcal{L}(x^\mu) = \mathcal{L}(\rho(x^\mu), \partial_\mu \rho(x^\nu), \partial_\mu a(x^\nu))
\]

where we have introduced the vector of coordinates \( x^\mu = (t, x^i) \), \( i = 1..3 \) which represents the absolute time plus 3 space coordinates\textsuperscript{22}.

At times, it will be convenient to simplify the description of the dynamics of the system through the introduction of an effective force, which we will call ether force. So we will refer to the dynamics resulting from the evolution of \( \rho(x^i) \) and \( a(x^i) \) in the equation (1) as ether forces, for short, whenever those dynamics can be assimilated to an effective force. This approach will provide us with the basic tools to explain inertia and Special Relativity.

Within the SFM, by definition, we still further assume that the underlying theory presents vortex-like solutions that can supply the phenomenology we need to describe particles, including possibly spin. Additionally, in the SFM the ether force is supposed to be spin-dependent\textsuperscript{23}, that is, each spin component of a point in the fluid only interacts with the same spin components of the neighbouring points. This particular assumptions will let us obtain a seed for a theory explaining Quantum Theory and the Principle of Equivalence.

If we attach to this point of view, then the four pillars need reinterpretation. Lorentz invariance should be explained as a property emerging from the fundamental form of (1). Inertia should be the reflection of the stochastic average ether forces between ether and matter when there are relative accelerations. Gravity should amount for a long-distance effect of this same ether force. Quantum uncertainty would be explained as the effect of the random noise of the ether, which exists at a certain range in space. The WFC would be directly inferred from the ether force, in a mechanism very close to inertia. Particles would not exist as permanent point-like structures, but just as high-density waves on the low-density ether. The particle properties would emerge from the collapse of these waves.

At a cosmological level, a suitable present condition for the observable Universe is an expanding sphere with localized high-density regions of the fluid representing matter (stars, planets and dust, mainly). At a fixed time, these high-density regions are in equilibrium, at macroscopic ranges (defined below), with a homogeneous low-density fluid that fills all the space, which we have called ether for short, although it has to be understood in the previous sense. As the sphere expands, the density of the ether diminishes, so modifying the sound speed \( c \) (increasing it, like in the Scharnhorst effect).

\textsuperscript{20} In the broad sense of a continuous field locally described by a density and kinematical parameters.

\textsuperscript{21} We should not completely discard that higher derivatives are needed.

\textsuperscript{22} We follow the standard convention of distinguishing space coordinates with Latin indexes and space-time coordinates with Greek indices. Notice, however, that here the aggregation of space and time has only a notational purpose. The space-time is not to be understood as Minkowskian.

\textsuperscript{23} Then in the SFM the spin may need to be axiomatically introduced. However, we do not discard that this phenomenon can itself be derived from the model. See Appendix B for a speculation on that possibility.
B. Dynamics on different ranges

Let us point out, before we continue, that this model implies four different ranges in space, with different physics on each.

1. Subthermal range

The shorter range is that where the density, speed and acceleration of the fluid vary smoothly. Such a range, let us call it subthermal range, must exist because we assumed well-behaved fields in our definition of the fluid model. The initial conditions must be smooth and the equations cannot bear shocks. The dynamics on this range are ruled by the fundamental Lagrangian (1).

The fundamental equations can be seen as providing the dynamics for $a(x^i)$. The Cauchy problem would be completed by adding the continuity equation and providing initial data for $\rho(x^i)$, $v(x^i)$ (the speed), $a(x^i)$ and $e(x^i)$ (the jerk), where we define

$$e(x^i) \equiv \partial_t a(x^i)$$

2. Thermal range

A medium range is that where density, speeds and accelerations vary dramatically at neighbouring points, so that the fluid behaves as a stochastic background in thermal equilibrium. Let us call it thermal range (it would presumably correspond to the Planck scale). The thermal range shares many properties with the Brownian motion and with turbulent phases in fluid mechanics. Let’s define $T_{th}$ as the typical time scale for the fluctuations, and $D_{th}$ as the typical spatial scale.

To describe the dynamics on this range, the fundamental subthermal Lagrangian (1) is not appropriate unless numerical simulation is involved. For a mathematical treatment it is better to move to derived quantities on a pseudo-thermodynamic level in order to deal with the stochastic background, and then consider the dynamics of the perturbations.

We will consider the mean values of density ($<\rho>_th$), speed ($<v>_th$), acceleration ($<a>_th$) and jerk ($<e>_th$) on the thermal range. We assume the equilibrium of these values at the thermal range in a certain neighbourhood. That is, they are independent from $x^\mu$ in this neighbourhood. In the comoving reference system we have then that

$$<v>_th = 0$$
$$<a>_th = 0$$
$$<e>_th = 0$$

The description of the thermal background at this range completes with the specification of the remaining momentum orders for $\rho$, $v$, $a$ and $e$:

$$<\rho^2>_th, ..., <\rho^n>_th$$
$$<v^2>_th, ..., <v^n>_th$$
$$<a^2>_th, ..., <a^n>_th$$
$$<e^2>_th, ..., <e^n>_th$$

which are also invariant under spatial and temporal variations in the macroscopic range (see below). The maximum order $n$ depends on the form of (1). These momenta, however, are not generally invariant under variations at cosmological ranges.

We can assume that the system is described through an effective Lagrangian which describes the dynamics of the perturbations on the static background described by the thermodynamic quantities. That is, the dynamics of the system could be described by the mean values of density, speed, acceleration, jerk, their standard deviations and
possibly higher order momentums of these three magnitudes\textsuperscript{24}, as well as by the variables describing the perturbation. By defining the n-th order momentum of $X$ by $< X^n >$ we can formally write

$$L_{th} = L_{th}(\delta_{th}\rho(x^\mu), \partial_{\mu}\delta_{th}\rho(x^\mu), \partial_{\nu}\delta_{th}\mathbf{a}(x^\mu),< \rho^n >_{th}, < v^n >_{th}, < a^n >_{th}, < e^n >_{th}, N(x^\mu)), n = 1..m$$

where $N(x^\mu)$ represents a source of noise, $\delta_{th}$ represents the deviations relative to the background means and $m$ is to be derived from the precise formulations of (1). As we assume isotropy, these means are described by scalar variables.

Notice that to solve the Cauchy problem, (10) needs to be supplemented with initial conditions for the perturbations on the density $(\delta_{th}\rho(x^i))$, speed $(\delta_{th}\mathbf{v}(x^i))$, acceleration $(\delta_{th}\mathbf{a}(x^i))$ and jerk $(\delta_{th}\mathbf{e}(x^i))$ of the fluid.

The stochastic thermodynamic background provides in this range a reservoir of noise which could be described through thermodynamic quantities, in particular through a energy, temperature and entropy\textsuperscript{25}. This noise will be interpreted as the source of the uncertainty in Quantum Theory. In particular it will provide the virtual particles that characterize Quantum Field Theory. Then the equations for $\delta_{th}X(x^\mu)$ are not deterministic when this noise is considered.

3. Macroscopic range

The broader range is that where the neighbourhoods where stable vortex solutions are absent (the ether) can be seen as homogeneous (the constant density, speed and acceleration can be modelled as a simple non-dynamical background, without the fluctuations that characterize the thermal range, from which an entirely new space-time will emerge) ignoring the details of the underlying noise, which can be then described through more appropriate derived quantities.

The assumed equilibrium requires that, across the ether, the integral standard deviation (and higher order momentums) of $\mathbf{a}(x^i)$ on typical volumes are small-enough so that they can be locally taken as null. We can call it macroscopic range.

The mean values of the kinematical quantities ($< X_{(e)} >_m$) in the ether the same as in the thermal range:

$$< v_{(e)} >_m = < v >_{th}, \quad (11)$$
$$< a_{(e)} >_m = < a >_{th}, \quad (12)$$
$$< e_{(e)} >_m = < e >_{th} \quad (13)$$

In the comoving frame:

$$< v_{(e)} >_m = 0, \quad (14)$$
$$< a_{(e)} >_m = 0, \quad (15)$$
$$< e_{(e)} >_m = 0 \quad (16)$$

The higher momentum orders are also null:

$$< v^n_{(e)} >_m = 0, \quad (17)$$
$$< a^n_{(e)} >_m = 0, \quad (18)$$
$$< e^n_{(e)} >_m = 0 \quad (19)$$

for any $n > 1$.

\textsuperscript{24}No simplification emerges yet in considering a purely Gaussian noise.

\textsuperscript{25}Notice, however, that energy in the standard sense, and with it temperature, entropy and other thermodynamic quantities, is not yet defined at this level. Here we have instead a pseudo-thermodynamics based on the conserved quantities implicit in (1). See subsection VII G 3 for details.
(20)
\[ <p^n_{(p)} > m \neq < p^n_{(e)} > m, \]
\[ <v^n_{(p)} > m \neq < v^n_{(e)} > m, \]
\[ <a^n_{(p)} > m \neq < a^n_{(e)} > m, \]
\[ <e^n_{(p)} > m \neq < e^n_{(e)} > m \]

The detailed description of the particle involves a statistical description of the thermal averages of the shape of the particle all over the region where the particle is distributed. These functions are neither isotropic nor homogeneous in general:

\[ <p^n_{(p)} > th (x^i) \neq < p^n_{(e)} > m, \]
\[ <v^n_{(p)} > th (x^i) \neq < v^n_{(e)} > m, \]
\[ <a^n_{(p)} > th (x^i) \neq < a^n_{(e)} > m, \]
\[ <e^n_{(p)} > th (x^i) \neq < e^n_{(e)} > m \]

for \( x^i \in \mathcal{X} \), where \( \mathcal{X} \) is the neighbourhood that comprises the particle and \( x^i \) is expressed in the comoving reference system, so that the functions do not depend on \( t \).

And then the thermal Lagrangian for a certain particle becomes in a first instance

\[ \mathcal{L}_{th} = \mathcal{L}_{th} (\delta_m \rho_{(p)} (x^m), \delta_m \rho_{(e)} (x^m), \delta_m \partial_{(p)} (x^m), \delta_m \partial_{(e)} (x^m), \]
\[ <p^n_{(p)} > th (x^i), <v^n_{(p)} > th (x^i), <a^n_{(p)} > th (x^i), <e^n_{(p)} > th (x^i), \]
\[ <p^n_{(e)} > th, <v^n_{(e)} > th, <a^n_{(e)} > th, <e^n_{(e)} > th \]

for \( n = 1 \ldots m \) and \( x^i \in \mathcal{X} \).

The dynamics in the macroscopic range for an isolated particle \( (\mathcal{L}_m) \) comes from the interaction between its deviations relative to the background and the background. The mean effect is a minimisation of the relative acceleration between the particle and the ether, that is inertia. This can be described through the relativistic kinematics. We will further explore the relationship between the particle and the ether when we analyse the second pillar. There we will consider which quantities can \( \mathcal{L}_m \) depend on. The true dynamics in this approximation will come from the perturbation that particles exert on each other, which modify the equilibrium \( <X_{(p)}>m \) values.

As the isolated particles, the ether neighbourhoods are not dynamical. They constitute the Minkowskian space-time.

4. Concluding remarks on ranges

We should still consider a fourth range: the cosmological one, but we will go back to this later.

One can make an analogy between the former 3 ranges and the equivalent electromagnetic ones in Brownian motion: the subthermal would be that describing the interior of the molecules, where quantities vary smoothly (except around the nucleus, perhaps). The thermal would be that describing the atoms while in Brownian motion. Finally, the macroscopic range would be that describing the fluid at such a scale that all the matter fields become continuous. One can describe phonons there, for instance, without paying attention to the real structure of the fluid background. In the same way, three time ranges must exist.

We will suggest that Special and General Relativity, inertia, and the standard energy-momentum conservation laws are approximate effective theories that work well on the macroscopic range but not in the finer ones. QFT will be suggested as a correct approximation to the thermal range, and hence more fundamental than Special and General Relativity. The clashes between these theories and QFT (see sections III and IV) should then be solved favourably to QFT. That does not mean that we accept the axioms of QFT as truly fundamental, but just effective at the thermal range and wrong at the subthermal range. At the subthermal range we assume a classical Euclidean description.

Let us see in more detail how a framework for all this can be raised. First we will revisit the four pillars and provide an alternative interpretation for their groundings.
C. The fourth pillar. Vortex dynamics

We have already adopted the point of view that particles, in the sense of permanent and point-like structures, do not exist. If we restrict ourselves to the alternative framework we are describing, then we should provide mechanisms for the emergence of fermions, bosons, and their interactions purely on the basics of fluid dynamics. This is beyond the scope of this paper. Anyway, some speculations are provided in the Appendix B and some basic necessary features will be discussed below.

If we can assume that particles do not exist, there is no reason for waves to get concentrated in points. They concentrate (in a small region but not in a point) when a WFC happens (a metastable state) or in stable configurations such as atoms, but the rest of the time they should travel quite freely out of matter (in the same sense as the free wave function of QFT) and stochastically fill the space. As we have assumed a singularity-free model, we can attach to this view.

Fermions should be then interpreted as vortices on the fluid. Generally, vortex-like structures on a fluid with a well-defined sound speed will propagate slower than phonons (which propagate typically at \( c \), the sound speed), as they keep part of their structure while traveling (which invests part of the speed in internal rotation, that is, keeping its spin properties).

In general, fundamental bosons could be mapped to macroscopic-range phonons travelling through the background fluid at the sound speed, while fermions and derived bosons (those composed of fermions) would keep a permanent internal rotation, so travelling at subsonic speeds. Supersonic speeds are also possible when the macroscopic range approximation is not valid.

Inertial mass would be derived from the interaction of the internal rotation of these vortices, which necessarily create an acceleration field, with the corresponding spin components of the surrounding ether. The specific value of inertial mass should be computed from the dynamics of the fluid vortex lines, based on the fundamental fact that ether forces emerge when there are relative accelerations. It is presumably very difficult to compute analytically these values from most models deriving from (1). Numerical simulation should prove a more practical tool.

The long-range effect of these vortex structures must necessarily depend on this same effect between internal rotation (spin) and surrounding ether, as we must recover the Principle of Equivalence. We will come back to this when discussing the second pillar.

D. The first pillar. Acoustic relativity

As advanced in the introduction of this section, we understand Special Relativity as an effective theory valid on the macroscopic range. On this range, the ether is seen as homogeneous and isotropic. Causality is always granted as the underlying theory provides an absolute time. No paradoxes related to causality violation can appear neither they need to be separately considered. To obtain Special Relativity, as we have explained in section IV, we only need to provide a reason for Lorentz invariance and a sound speed.

1. Speed of light

The sound speed is given by the propagation speed of macroscopic-range waves (phonons) traveling on the background fluid. This speed depends on the average dynamic structure (determined by mean, variance, and maybe higher orders, of density, speed and acceleration on the underlying fluid) on the thermal range. That is

\[
c = c(<\rho^\alpha>_\text{th}, <v^\alpha>_\text{th}, <a^\alpha>_\text{th}, <e^\alpha>_\text{th})
\]  

(29)

This speed is homogeneous in a certain neighbourhood while the distributions of \( \rho, v, a \) and \( e \) in the neighbourhood are homogeneous. This is true at the macroscopic range but fails at the finer ranges. Even at macroscopic ranges, the local sound speed may change due to variations in the structure of the background. Supraluminal signalling can then be possible if the ether is affected by macroscopic phenomena. The Scharnhorst effect, for instance, induces a variation of \( <\rho> \) at a macroscopic range\(^{27} \), so affecting the speed of sound.

\(^{26}\) In the broad sense of a permanent or characteristic internal rotation that represents a footprint of the vortex. It may happen that the quantic spin do emerges from this rotation, as we will comment in the Appendix B.

\(^{27}\) We recall that \( <\rho>_\text{m} = <\rho>_\text{th} \)
2. Lorentz invariance

Consider a reference system described by its speed \( v_0 \) and acceleration \( a_0 \) relative to the average speed \( < v >_m \) and acceleration \( < a >_m \) of the underlying ether. Suppose that we are studying a macroscopic-range phonon. In this approximation we can separately describe the macroscopic wave and the underlying ether.

We will take a reference system comoving with a macroscopic wave representing a fermion, which can travel at speeds which range from 0 to \( c \) with respect to the ether. We are interested in finding out which quantities can participate in the effective Lagrangian \( L_m \) derived from the equation (29), whose detailed description we have delayed and that approximately describes the macroscopic wave disregarding the background (incorporating it through constants and modifications of the terms in the Lagrangian), and how Lorentz invariance (or a whole effective Minkowskian space-time) emerges from this approximation.

We start by considering the superposition of the macroscopic wave (the particle) and the background. The particle distinguishes from the background in that it has an internal structure (the thermal range) which means that the comoving reference system the integration on times \( dt >> T_{th} \) of \( < \partial_\mu a_j >_{th} \) differs from zero on different regions of the particle in this range, while this does not happen to the background, which is chaotic. In the effective macroscopic-range Lagrangian \( L_m \), this internal relative accelerations are concealed from the point of view of the simplified macroscopic description of the particle (its particle numbers, its kinematics and the forces that appear between particles).

Now consider the dynamics emerging from the kinematical relation between the particle and the background. If the particle accelerates relative to the background, we can decompose the gradients of acceleration in two terms: the internal particle gradient which comes from the own particle structure and the gradient coming from the relative acceleration of the particle to the background. This second term provides a dynamical effect, according to the nature of the fundamental Lagrangian, that only disappears when the relative acceleration is smeared (i.e., inertia). We will consider this further when discussing the second pillar. The dynamics provided by the fundamental Lagrangian should provide a mechanism for dissipating the relative accelerations. If we consider a gradient in speed now, we can as well decompose the gradients of speed in internal and background-relative. This terms does not provide any dynamical effect, according to the Lagrangian. Then, as the fundamental Lagrangian is invariant under boosts, the equations for the particle disregarding the background are Lorentz invariant. This translates into Lorentz invariant equations when we consider an effective Lagrangian describing the interaction between a particle and the background.

Lorentz invariance is then provided by the nature of the underlying ether force: it only depends on relative accelerations. Then, effective macroscopic-range forces as (we assume) electromagnetism, can only depend on relative accelerations \( a_0 \) to the ether (but not on relative speeds \( v_0 \) to the ether). Of course, initial data, which includes typical speeds in the stochastic motion of the fluid \( < v >_{th} \) and the sound speed \( c \) of macroscopic waves (29), can enter the effective equations. The important thing is none of these speeds depends on the relative speed of the reference system to the underlying ether.

Relative speeds between particles could in general also have dynamical effects. This is because the equilibrium values, in terms of the \( v \) and \( a \) fields of a particle in the thermal range are perturbed by the presence of another particle. Any change, either in relative position or speed, of this perturbation has a dynamical effect, as the internal gradients of acceleration of the particle need to accommodate to the perturbation. Relative position and speed to the background, on the contrary, do not perturb the equilibrium of the particle.

Summarising, the interaction of a stable particle with the background provides the phenomenology of Special Relativity. On this approximation a particle can be described kinematically through constants and the assumption of a background Minkowskian space-time. When we consider more than one particle it is not possible to keep this simplified description, as the vortices affect each other. From the point of view of effective theories we can still maintain the description of the particle as if isolated, but the price to pay is the introduction of forces or interactions between the particles.

These elements are enough to derive Special Relativity [33] on the macroscopic range for any interaction that derives from the ether force. This provides an underlying hypothesis for the Lorentz’s approach on Special Relativity. The space-time of orthodox Special Relativity is downgraded to a helping tool with no profound meaning. The underlying space is Euclidean and can coexist with an absolute time.

This point of view can be easily understood with a fluid example due to LSV [33]. They consider a fluid Universe, with hypothetical beings whose internal structure is completely mediated by phonon exchange, and whose rulers and clocks are likewise held together by phonon exchange, and who are completely blind to electromagnetism so they cannot not discover the real underlying electromagnetic basis of their laws. They would discover an acoustic Lorentz invariance with their rulers and clocks transforming according to the laws of approximate acoustic relativity (Lorentz
group with $c$ as the sound speed). With this, motion becomes undetectable\textsuperscript{28}. The fluid would play the role of an ether whose presence is masked by the length contraction and time dilatation effects. Thus, we would have a fluid dynamical analogue of special relativity à la Lorentz. Of course the underlying physics (electromagnetism) is also Lorentz invariant in this example (although with a different sound speed), but this is not essential.

E. The second pillar. Gravity and inertia from an ether force

Gravity and inertia can also find a place as effective theories on the macroscopic range.

We believe that inertia is a manifestation of the average ether forces on accelerating objects. We will try to describe the mechanism on which this could be based. Along the way, the first steps on an explanation for WFC, to be completed in VII F 2 will appear.

To explain gravity, we adhere to the group of theories which derive it from the quantum (here understood as thermal-range effects) phenomenology, like those described in section IV A (BVL, HRP), although rather than deriving gravity from a particular quantum field, we should derive it from the long-range properties of the average ether forces.

1. The origin of inertia

How does inertia emerge in this framework? Consider phonons on the macroscopic range (in the SFM picture, at the moment). Acceleration generates acceleration in waves with homogeneous spin, considering our assumption of a spin-driven ether force.

The equilibrium state in the macroscopic range, then, must be that with no relative acceleration between the waves and the background. When a macroscopic wave accelerates respect to the ether in its neighbourhood the equilibrium is broken and can be restored by two alternative outcomes:

1. The macroscopic-range phonon may manage to drag part of the surrounding thermal-range ether background on which it travels (its supporting inertial system, in fact) along its movement, and so to cause a WFC. If it can drag enough stuff to account for the numbers describing a metastable vortex state, then we get a temporary condensed state that we call particle. Of course this can only happen when the dragging collapse has a central point and develops radially. This is the only time when particles exist, as very condensed wave-structures (but not point-like anyway): the rest of the time they behave as purer (in the sense of not so non-linear) waves. This point only makes sense within the SFM.

2. The ether background, over which the wave travels, manages to stop the accelerating wave. This is what we call inertia: resistance to relative accelerations. It is useful to see it from the perspective of the accelerating wave: it is initially stopped, and the rest of the Universe accelerates homogeneously, so the wave is at the end dragged and accelerated to keep the same acceleration as the rest of the (local) Universe. In this case the acceleration is linear rather than radial. This second outcome is feasible even outside the SFM.

How does this hypothesis compare with the two approaches to inertia mentioned in section IV? It follows the basics of the HPR hypothesis. A local force, related to the void (in the sense of subsection IV B), generates inertia, which is a variant of the HPR model. The local void (the ether in the nomenclature of this paper) is in the end provided by the surrounding Universe (the far stars), or at least is in equilibrium with it, so the fundamental part in the view of the Mach School is preserved\textsuperscript{29}. For instance, if we decrease the density of matter in the Universe then the equilibrium at a fixed time is restored by decreasing the density of the ether $<\rho>$ (as in the SED model), which in turn decreases the intensity of inertial forces. Inertia is therefore provided by the far stars as in Mach’s view in some sense. However, the interaction is not instantaneous, but mediated by a field in equilibrium with the far stars: the ether field. With this, the need for a mechanism explaining the instantaneous interaction of matter here with the far stars there vanishes. Also, inertia cannot be derived from gravity, for it is a rather fundamental mechanism. To explain it, no reference to gravity has been made. And what is more (see next subsection) we think the SFM can explain gravity as an inertial force.

\textsuperscript{28} As we have seen, this is achieved by forbidding friction-related speed effects, which do not appear in the proposed form of fundamental equations. The background fluid, which we have called ether due to the lack of a better word, cannot be detected by its effect on relative speeds, but only on relative acceleration, which permits dodging the inconsistencies of the XIXth century ether models.

\textsuperscript{29} What is not preserved is Einstein’s implementation.
It seems, summarising, that the ether force has a strong link with inertia. Inertia is a stochastic short range manifestation of this fundamental force. The Principle of Equivalence forces us to attribute the origin of weight to this same force, as commented in section IV. Further analysis, however, is needed to explain geometrodynamics.

2. The origin of gravity

As we expect the spins in the cosmic void background to be homogeneously distributed, as they are in matter, big concentrations of matter should feel ether forces as independent of spin (within the SFM; without the extra SFM assumptions we do not need this consideration in the classical approach). The mass (inertia) of a simple wave is explained regarding to the ether forces that appear when it is accelerated respect to the ether. The inertial mass of macroscopic objects can then be explained as an average spin force in the SFM, and generally as an average ether force in the classical approach.

In the approach in subsection VII D 2 that permits the derivation of Special Relativity, we assumed no influence of the matter onto the ether term. This is true in a limit case where matter can be considered in the sense of test particles on the background. The direct influence of the background on matter, that is inertia, is in fact part of the picture that explains the emergence of Special Relativity. But we still can consider the effect of the matter term on the background. Generally, the matter term can modify the surrounding background. This could imply, for instance, a modification of the average density or other parameters. This is reflected on a change on the basic parameters defining the background (c and $\hbar$ in particular, as functions of $\langle \rho^n \rangle$, $\langle v^n \rangle$, $\langle a^n \rangle$, and $\langle e^n \rangle$). From this point of view we can then forget the source of the perturbation and describe the resulting scenario purely on the basis of the new statistical parameters which describe the ether. These modified properties of the ether will influence any test particle in the same way, which raises the opportunity of describing the picture in geometrical terms. A connection should be provided for the basic parameters of the geometrical description (the metric) and the statistical parameters describing the ether background. For instance:

$$g_{ij}(x, t) = g_{ij}^0(c(x, t), \hbar(x, t), \ldots)$$ (30)

plus gauge conditions to define the coordinate system.$^{30}$

This approach can be considered in the line of Unruh’s method [56] on deriving the metric from the Lagrangian of the matter fields. It is relevant to consider the work by Barceló and Visser [6], which shows how long-range effects of reasonable quantum fields can induce a geometrodynamics. Here, however, we are a step below QFT.

In subsection VII G 4 we will analyze how the incompatibilities between General Relativity and Quantum Theory can be approached.

We will try now to precise further how matter modifies the surrounding ether. This is only valid in the SFM. In our discussion on the fourth pillar we described fermions and some bosons as divergenceless vortices of the fundamental fluid. We will analyse the asymptotic effect of a large aggregation of such vortices at large distances.

Notice first that a static vortex, independently of its particular structure, is reflected in an acceleration field with certain characteristics. A divergenceless vortex needs that the average acceleration at a certain distance to the vortex is radial and directed inwards. Of course, at certain angles the acceleration can be directed outwards, but not on average. Generally, the vortices are described by a symmetry axis which determines the orientation of the acceleration field around the vortex. If we consider a conglomerate of such vortices so that the axis is randomly oriented in space, then the acceleration field at a large distance from the conglomerate is spherically symmetric and points inwards.

We now consider how this affects the structure of the stochastic ether background at a large distance from the conglomerate. Away from any body, the average acceleration and speed of the ether is null everywhere in the comoving global reference system. In the neighbourhood of a conglomerate of vortices, however, there is a mean radial acceleration towards the body. This does not mean that the ether falls down into the body: simply it needs to locally rotate around the body. Consider a small volume of the ether away from the body. Let us say that the plane perpendicular to the radial acceleration is locally described by the $xy$ coordinates, while $z$ represents the radial axis. The module of the thermal speed of the ether noise ($\langle |v| \rangle_{\theta k} \equiv \sqrt{\langle v^2 \rangle_{\theta k}} \neq 0$) will increase in the $xy$ plane, so that we can describe the motion of the ether as a random noise plus a constant radial acceleration towards the body.

$^{30}$ A natural choice of gauge conditions would be to take a null shift ($g_{0i}(x_i) = 0$, with the spatial coordinates comoving with the ether) and $dx^0 = dt$ with $t$ representing the absolute time (so that $g_{00}$ reflects the slowing of the physical process due to the kinematical changes of the underlying ether).
If $<|v|>_th$ and $<|a|>_th$ represent the average module of the speed and acceleration of the ether fluid away from bodies in the ether comoving reference system, $a_g$ is the average radial acceleration at a distance $R$ of the body, and $v_g$ is the average increase in tangential speed, then in the vicinity of a body we have that in the comoving reference system

\[ <|v_z|>_th = <|v|>_th, \] (31)
\[ <|v_{xy}|>_th = <|v|>_th + v_g, \] (32)
\[ <|a_z|>_th = <|a|>_th, \] (33)
\[ <|a_{xy}|>_th = <|a|>_th - a_g, \] (34)
\[ a_g = \frac{v_g^2}{R} \] (35)

The overall effect is that although there is not a macroscopic axis of rotation for the ether around the body, microscopically (in the thermal range) the ether is orbiting the body. The ether accelerates towards the body although there is no net flux of fluid around any spherical surface centered on the body.

Now we concentrate on the effect of this phenomenon on a test particle. We know that inertial forces tend to stick test particles to the ether in terms of acceleration, so the test particle feels the acceleration field $a_g$ generated by the body. If $a_O$ is the acceleration of the body, then $a_O = <a>_th - a_g$. In the comoving frame (of the ether at a great distance from the body) $a_O = -a_g$. As the test particle is characterised by a stable structure, this acceleration cannot be manifested microscopically as rotations around different axis, but actually falling into the body or rotating about a well-defined axis. This attraction is independent of the characteristics of the test particle, so it can be defined in terms of geodesics, or geometry.

Once we have geodesics, if we add the requirement that the acceleration is of the Newtonian type in classical regimes, that is $v_g$ proportional to $\sqrt{M}$ (where $M$ represents the inertial mass of the body), we automatically have General Relativity as an emergent phenomenon. This condition poses a restriction on the particular choices we can take on (1), as it partially defines the long distance structure of the stable vortices that are solutions of (1).

In conclusion, gravity (weight) is an inertial reaction force caused by the perturbation that a massive body exerts on its neighboring ether. The gravitational mass of a body is the same as its inertial mass because gravity is just an inertial force. Notice that the geometrodynamical approximation is valid in the macroscopic range, but not in the thermal one. This releases us from the need of a Quantum Gravity.

F. The third pillar. Indeterminism from noise, collapse from ether force

The models of inertia and Special Relativity described above can be fitted in the classical approach in general. For the explanation of General Relativity we have needed specific features of the SFM. The same happens when modelling Quantum Theory. We lean on two phenomena: Pearle’s random choosers and WFC. The former phenomenon can be generally described within the classical approach. The latter, however, needs the assumptions we defined as the SFM.

With this, our framework may provide a basis for Quantum Theory as an effective theory on the thermal range. Let us explain how to model the apparent fundamental indeterminism and the collapse process.

1. The origin of indeterminism

At the thermal range the local values of density, speed and acceleration of the ether are randomly distributed following a noise pattern, in a sort of Brownian motion. As explained in section V, stochastic classical interactions with a background noise (Pearle’s chooser) can reproduce the probabilistic features of QFT. The basic problem of providing a source for the noise is trivially solved here.

Notice that being the ether our model of ZPF, Quantum Theory is derived from the ZPF, in opposition to the orthodox view. This supports in part the SED vision (see section II) and the HPR notions on the ZPF.

The question of a dynamical model for collapse needs a more detailed analysis.

2. The origin of the Wave Function Collapse

Can we complete this model with an analogue for the WFC? We have supposed that ether forces originate it when a variation of acceleration happens. This initial seed gets amplified by the characteristics of the fundamental force by
unleashing a runaway solution. But then, what causes the seminal gradient in acceleration on the wave? There can be just one answer: the detector as perturbed by the surrounding noise. We find here an alternative explanation to the known fact in QFT that the measure perturbs the system (that is the particle): that is right, since the measure is the only way to get the particle, as in Jordan’s view. Particles only exist when they are measured (we refer to real particles; for a discussion on virtual particles see the end of the subsection VII G 2). In fact, the measure builds the particle when the detector causes the component of the inertial system sustaining the particle to collapse towards the detector itself.

To get a measure we need that some part of the detector (an atom, an electron) starts to interact with the external wave. Notice that the part of the detector is also a wave in the fluid, so we should assume that there is a strong non-linear wave interaction that causes the initial acceleration. The end of the process is the destruction of the relatively stable initial state of the detector by the collapse of the external wave upon it, and the formation of a new metastable state.

The WFC would be a phenomenon parallel to the gravity-induced dragging of inertial frames, although in the WFC-dragging the spin would play a major role. We will complete the explanation when we discuss how the EPR paradox is to be approached from our point of view.

G. Aspects of the dynamics of ether

Assuming the explanations for the origin of the four pillars we have just developed, there are several scenarios and phenomena that need to be analysed under this new prism. In this subsection we tackle some of them.

1. EPR and collapse-related issues

Let us recall EPR. We will try to complete the explanation of subsection VII F 2 on the dynamics of WFC and its relationship with inertia.

Suppose we have emitted two electrons in the spin singlet state. The total spin of the system is zero and we have two detectors that are prepared to detect electrons with opposed spin projections. In standard Quantum Theory, one says that both electrons share a wave function that is distributed in space, the total spin of which is zero. When one of the electrons interacts with the detector it collapses within a certain spin: its (part of the) wave function suffers a WFC. The other electron can be meters away and collapse almost immediately into the second detector, also by WFC. The spin of the second electron is what it needs to be in order to conserve the total spin of the original system. However, in many situations there is no time for a non-supraluminal signal to travel from the place of the first collapse to the second to inform about the spin state of the first electron.

Most attempts in modelling this system in a deterministic way adopt the point-like paradigm: the electrons are real and concentrated on a small volume or a point, so either there are some variables that a priori determine the outcome of the spin measure or a signal is send in a non-local way. While we design the models to respect the point-like paradigm and the principles of relativity, they are shown to fail to explain experiments (by Bell’s theorem), unless non-local influences from detectors to distant particles are introduced. It would be very complex to provide an underlying deterministic mechanism for such an influence on point-like particles. In our opinion, the burden for the hidden variables approaches is that they have tried to attack the third pillar while leaving the first (Special Relativity) or fourth (point-like particles) untouched.

Let us explore the situation in the frame of our alternative approach. We have recovered determinism, and superseded the point-like paradigm and the speed of light in vacuum as a bound speed, as we have described them both as emergent phenomena. Imagine that when two electrons are emitted they are just a system described by a classical wave in the strict sense (so we do not assume the probabilistic axiom of standard QFT), without any particle property. We are then not allowed to talk about two electrons individually, but just about a wave bearing the charge (-2) and spin (0) equivalent to two electrons\textsuperscript{31}. When emitted, the macroscopic wave expands and mixes with the ether and, at some time, part of this wave interacts with one of the detectors. What happens at that moment is a very remarkable fact, for it is highly non-linear: a WFC. We do not want to consider it axiomatically but dynamically. The detector can only interact with a wave with certain spin (say +1/2), and so it does: it selects, from the wave surrounding it, the spin component that matches its own configuration. This surrounding wave must be attracted by some interaction with the detector, if we ever want to explain the phenomenon dynamically. So let us recall that a force is acting

\textsuperscript{31} This is in fact the Jordan-Schrödinger point of view.
there (which derives from the SFM). Clearly a force such this cannot be directly derived from electromagnetism or the nuclear forces, as it is inertia-like (that is, acceleration-driven) due to the characteristics of the collapse process. This fact ranks collapse as an interaction closely derived from the fundamental ether force (which we have already used to explain inertia and gravity), as opposite, for instance, to electromagnetism, which does not have traces of acceleration dynamics and then needs to be considered as less fundamental. The ether force makes the (spin +1/2 projection of the) surrounding wave collapse towards the detector. Remember that we have postulated the ether force to be spin-selective.

However, in order to get the equivalent properties to one electron concentrated at the detector, the component of the wave with the right +1/2 spin has to be summoned from all over the entire wave, even from the part close to the second detector. Let us explain later what these facts imply, and assume by now we can explain them. The result of the process would be the following: by ether force, detector one has attracted in a superluminal fashion (driven by a runaway solution) the part of the wave that is equivalent to one electron with a certain spin (+1/2, in this case). The rest of the wave remains distributed about the original region, and has the properties of an electron with the right spin (−1/2) to match the second detector. So now, the second detector can repeat the process and attract the remaining spin −1/2 wave (or it can fail to do that, so we would say that the second electron escaped undetected). Up to now the explanation is quite the same as in Quantum Theory, except that we take the wave function as a closer representation of the actual underlying reality (rather than the point-like electron probabilistically distributed by the amplitude of the wave), so we ignore probabilistic factors, and that we try to include a model of the WFC in the picture.

We go back now to the pending issue of how the ether force causes the WFC of half of the original wave (the half with appropriate spin +1/2). First, as advanced, one can see that the collapse must be superluminal. We use now here our interpretation of the first pillar. If a force drives it, then this force does not apparently respect the concept of c as a bound speed. We need to provide a mechanism for accelerating parts of a wave beyond c in almost zero time (but not exactly zero, if we keep dynamical). This can be done through a model supporting runaway solutions (which (1) provides). This acceleration needs to be spin-selective: it has to be null for all components of spin except for the one that initiated the collapse. And this is in fact the main reason to postulate that the ether force is spin-selective.

Of course, this picture requires some explanation on the role of the conservation of energy and momentum. To tackle the apparently instantaneous collapse we have invoked self-acceleration: acceleration in any part of the wave should cause acceleration in nearby regions\textsuperscript{32}. Only this way we can explain that the initial collapse near the detector propagates at an enormous speed through the entire wave. We know, though, that this behaviour can induce violations of the principle of conservation of energy in the form of runaway solutions. Runaway solutions are forbidden in traditional physics. However, in a random ether background governed by an acceleration-driven ether force, the runaway tendency can get controlled (that is, limited in time and behaving stochastically). Local runaway solutions do not imply global runaway solutions. The question of the conservation laws will be commented on section (VII G 3).

Another point of view to take into account is that of inertia. As the wave has a certain energy, which means certain inertia, then this inertia needs to be somehow suspended or modified to allow for the action of the ether force with its fantastic accelerations. Notice that we could dismiss the need for an explanation for the role of inertia, since we have developed the hypothesis that inertia is an effective interaction in the macroscopic range (so less fundamental than collapse, in fact), but it is instructive to see how we could adapt the theory of inertia to keep it valid even in collapse-driven situations.

In Special Relativity, the speeds are of course always measured within an inertial system, within which the speed cannot usually trespass the limit c (we have seen exceptions to that in subsection III B, soft violations in a sense). Even in WFC, and EPR in particular, we may consider that no hard violation of the Principle of Relativity occurs if the inertial system can be described as collapsing in parallel with the electron. In general, any dynamical and superluminal WFC would be explainable even without any knowledge of the underlying theory if there were a collapse of the inertial system sustaining the collapsing wave. The ether force, as described above, is spin-selective, so that the inertial systems would also be spin-selective. That is important for the explanation of EPR: in the first collapse in EPR, the inertial system for the spin measured in the first detector would collapse towards the detector. The orthogonal inertial system would remain unaffected, but would collapse later together with the collapse of the rest of the wave (the second electron)\textsuperscript{33}. It is tautological to remark that inertial systems are determined by inertia, that is, in our view, by the stochastic background. Therefore, a spin component of the stochastic background is wiped out by the WFC in the present hypothesis. This creates the condition for a negative density of energy\textsuperscript{34}, that is because

\textsuperscript{32} This is one of the reasons for the first order derivatives in (1).

\textsuperscript{33} This birefringence of the inertial system reflects a property from the fundamental underlying force, and also affects gravity in principle, although because of the statistical nature of gravity, the effect is irrelevant.

\textsuperscript{34} Which, as discussed in III B, is the stigma of superluminal phenomena. Here we see the reason why.
we usually define the zero of energy as the energy that holds the normal vacuum, which is not void at all, but filled with a stochastic background field. Consequently, anything that reduces the density of energy of the vacuum induces formally a negative energy density; a reduction of inertia, in other words (like in the Casimir plates).

A final point to discuss is that, in fact, the suction does not need to extend indefinitely in space. Detectors cause WFC all the time, even when there is not any electronic stuff around. This is because electrons are made of the same fluid stuff as the ether. Then the detector can always steal part of the surrounding ether to create a virtual electronic WFC. However, this creates a zone of negative energy around the detector, that will tend to be filled again by the stolen fluid.

When we have an excess density provided by the electronic wave, on the other hand, the zone of negative energy can be compensated by the electronic wave rather than by the fluid collapsed on the detector. Then the wave of negative energy advances (faster than c) from the detectors outwards, while filled by the electronic wave, and finally vanishes as completely cancels with the positive energy wave representing the electron. This way, the virtual collapse becomes real thanks to the excess fluid above the average density which was released as an electronic wave. The collapse is then local and almost instantaneous, as it feeds initially from ether surrounding the detector. The presence of the electron simply avoids the reversal of the process.

If this framework makes sense, then it explains why the reasons of EPR against Quantum Theory are unsuccessful. They had in mind a relative independence of well-separated objects in space (say A and B): an external influence on A has no direct influence whatsoever on B. But this is false in our opinion: an external action on A means a measure on A, which means a collapse and a modification of all the surrounding ether, including the part close to B, so B is affected. A influences B through changes in the structure of the void, and the influence is superluminal (although dynamical and finite in speed). Summarising, it is the ether itself that collapses on A, and the collapse of the ether creates the particle.

2. Real and virtual particles

Now within this scheme we can also explain virtual particles. As advanced, the same phenomenon described above can happen spontaneously in the ether, where some local attractor instability (a forming vortex-like structure) plays the role of the detector. The main difference is that here there is not initially a spare energy density above that of the mean void (which is the footprint of matter), so the energy subtracted, for instance, to create a pair of virtual particle-antiparticle creates a zone of negative energy, that is, reduces the intensity of the ether. This system is obviously unstable, as random fluctuations will tend re-equilibrate the density of energy, so destroying the newly created particles. In fact, the only difference between real and virtual particles would be that real particles are surrounded with a saturated thermal bath, while virtual particles are surrounded by a bath with a comparatively low energy density, which tends to re-absorb the particle to reestablish the equilibrium.

The magnitude of such a phenomenon is provided by the Heisenberg relation on uncertainty. \( \hbar \) becomes the measure for the transition from the thermal range to the macroscopic range: even when energy and momentum are not strictly conserved in the thermal range, the violations are stochastically limited in time and space. This permits temporary violations and then all the phenomena linked to virtual particles, which implies a violation of energy and momentum. We will provide more detail in the next subsection.

3. Conservation laws

A major problem with a model including runaway solutions, like ours, is the role of the conservation laws (conservation of energy-momentum, in particular). These laws need to be downgraded or reinterpreted.

We have assumed our model is built on an isotropic and homogeneous space. Regarding the Noether theorem, the model presents invariance over time displacements and space displacements in the framework of the Euclidean space and absolute time. That is, the fundamental equation for the dynamics of the fluid must incorporate 4 conservation laws linked to these displacements. Also, 3 additional conservation laws emerge due to the Euclidean space invariance.

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35 This is sensible in macroscopic-range forces, as inertia and gravity, because these are forces that operate on an idealised background, which has then to be ignored. In thermal-range phenomena, the energy does need to be considered, as we do not operate in such an effective background, but we are describing it together with its perturbations.

36 Notice that this effect does not provide different predictions from Standard Quantum Theory, as the process can be described quantically as a chain of interactions between the detector and a cloud of virtual particles surrounding it and between this cloud and the real electron.
under space rotations. Hence, the equivalent concepts of energy, momentum and angular momentum are valid at the level of the fundamental dynamics of the fluid. There is no Lorentz invariance associated to them and at this level a limiting speed is not included in the dynamics. These are, of course, not the standard conservation laws of the Standard Model. In fact, the conserved quantities can include variables such as relative acceleration and its derivatives, but not relative speeds.

To obtain the usual conservation laws we need to consider the approximate theories on the macroscopic range. In this range the ether constitutes a background with the properties of spatial homogeneity, time homogeneity and fulfillment of Special Relativity (as a sound speed has emerged and Lorentz invariance applies). Effective theories in this framework can be built on an effective Minkowskian space-time disregarding the ether background. For these effective theories, effective conservation laws will emerge for energy-momentum in the standard relativistic form. As these laws are based on the homogeneity of the Minkowskian space-time, they are accurate while the Minkowskian space-time approximation is valid, that is, at the ranges where the ether background is homogeneous and isotropic (this is our definition of the macroscopic range). These are the standard conservation laws.

The standard laws are violated, in particular, at the thermal range, which is the playground of Quantum Mechanics. At this range, the effective Minkowskian space-time is not longer homogeneous. The ether noise shows up at this range, allowing for local violations of energy-momentum. A stochastic local increase of the ether density would appear to increase the classical energy through a violation of its conservation law. The Heisenberg relation gives the order of magnitude of this phenomenon. That means that local violations of the energy conditions happen all the time. However, we can set a weaker averaged energy condition so that energy conditions are approximately respected when appropriate spatial and temporal means are considered. The ether dynamics tends to stochastically compensate deficits or surpluses of energy and keep the equilibrium. This provides a basis for the Quantum Interest Conjecture of Ford and Roman.

An analogue for that would be a probe particle affected by the Brownian motion of a surrounding fluid. In the classical limit (big particle), one can simplify the model by representing the noisy background fluid by an homogeneous framework and then obtain an effective theory for the dynamics of the particle, including conservation laws derived from the homogeneity of the background fluid (in particular, the particle moves on a straight line). This approximation fails when the mass of the particle is not much bigger than the mass of the particles that constitute the fluid. In this case, the simplified background is not homogeneous anymore, and the probe particle can show violations of the effective conservation laws (for instance, its movement can depart from a perfect straight line, which is a violation of the momentum conservation law of the simplified model).

Not only the thermal range shows violations. At classical ranges violations are not ruled out by the model. In fact, those violations are currently accepted.

At the cosmological range, the ether fluid is not homogeneous: is is spherical and it is in expansion. Then, violations of energy can appear: the accelerated expansion of the observable Universe is associated with a dark energy term, as if classical energy was being constantly introduced all over space. This gives a reason for the violation of the Strong Energy Condition (SEC).

Regarding the form of the conservation laws, the effective Lagrangian for standard theories includes masses and relative speeds of fields or particles. Inertial masses are an effective concept, derived from the short-range ether force, as discussed in subsection VII E1. The standard relativistic conservation laws are dependent on these quantities. Kinetic energy, for instance, is a concept dependent on the support of an underlying effective inertial system, without which it has no sense.

The fundamental conservation laws, on the other hand, cannot depend neither on inertial mass, since it is a derived concept, nor on relative speed (as a consequence of Michelson-Morley experiments, or from our point of view, from the restriction that speed does not appear in the fundamental Lagrangian (1)). They can only depend on the quantities that enter in the Lagrangian ruling the ether dynamics. We have assumed in section VII A that these quantities are the density of the ether fluid $\rho$, and the gradients in acceleration $\partial_ia_j$. Then the ether conservation laws should be formulated in terms of ether density rather than inertial mass, and the relative acceleration, rather than relative speed.

4. Gravity and the ZPF

Regarding our description of gravity on subsection VII E2, we note that the geometrodynamical approximation is valid while we can consider that

37 See, for instance the review by Barceló and Visser [57].
• the interaction of two (or more) masses is not direct (meaning quantum-like, or thermal, interactions), but indirect through general (only affecting general parameters describing the ether) mutual modification of the underlying ether.

• the neighbouring ether can be considered as an homogeneous kinematical background whose detailed description we can override.

On this basis we have to note that the ZPF is a part of the kinematical underlying description of the background. Gravity, on the other hand is an approximation to one of the influences of matter on this term. It is not meaningful, then, to consider the background as one of the roots of gravity. Gravity is produced by the matter phenomena which represent an excess of energy over that of the background. The background itself is to be seen as homogeneous and not containing energy (which is the perspective in the macroscopic range: the ether has energy from the thermal-range approximation, but not in the macroscopic-range one), from the gravitational point of view. Then the void has no weight in the macroscopic range. The quantum description, which needs to consider the energy of the ZPF is more fundamental than gravity, in the sense that does not consider the ether as a pure kinematical background, but depends on its dynamics.

The General Relativity and Quantum Theory representations are on different levels of approximation to the fundamental theory, and they represent different regimes. Their conflicts only reflect that.

5. Cosmic evolution

A dynamical ether governed by the ether force could explain some of the cosmological problems of the Standard Model. We mentioned in section II that the runaway force accelerating the expansion of the observable Universe needs some explanation based on the nature of the quantum vacuum. In our suggested framework, runaway solutions are implicit. At a macroscopic range the runaway behaviours cancel out statistically: we choose the origin of coordinates as $<a>=0$ as there is no way to select a preferred direction; also we recalled earlier than on the macroscopic range $<a^2>_m=0$ (compared with cosmological time scales). This is not true at the smaller thermal range, where runaway dynamics explain the WFC, for instance. At a cosmological range, there is an asymmetry along the radial direction (the expansion of the Universe), so this direction can present a global runaway solution (its exact nature would depend on the equations governing the ether force and the initial conditions of the observable Universe at the Big Bang).

This corresponds with the cosmological constant (if placed on the left in Einstein equations, as in Einstein’s original view\(^{38}\) or quintessence (if placed on the right, as required in the inflaton picture). In fact it is difficult to decide a position since dark energy is neither geometry nor matter, but a direct result of the more fundamental underlying theory, of which both Riemannian geometry and matter are simplifications in certain regimes. Its dynamics must be directly traced to the fundamental Lagrangian (1). In fact, the dynamics of the cosmological constant, if they can be settled experimentally\(^{39}\) should provide important clues on the real form of (1).

We can extract some consequences to the dynamics of the ether along the expansion of the observable Universe. As we have assigned a conservation law to the amount of ether (or in general to the cosmic fluid, in ether or matter form), so it is not created or destroyed, then the ether must thin down with the expansion of the Universe. This thinning can be traced as the reason for the diminishing value of the fine structure constant as well as a possible reason for the anomalous Pioneer acceleration\(^{58}\) (this was the third problem reported in the void-related unsolved issues in the Standard Model).

6. Beyond the observable Universe

On an even more speculative fashion we could imagine the cosmological scenarios where our observable Universe fits in. If we are just seeing an expanding blob of fluid, can be something else beyond its limits? Certainly one can imagine an spatially infinite Euclidean space (or a finite 3-dimensional surface of a 4-sphere, for instance, if we prefer a closed model) where Universes like ours explode and mix with each other while governed by the ether force. Let us call this broader space Cosmos, to distinguish it from our observable Universe.

In this scenario, our observable Universe would have been originated by a Big Crunch, similar in a sense to a WFC at a cosmic range, of part of the fluid which fills the Cosmos (this would be natural if we would assume invariance

\(^{38}\) Einstein’s hope was in fact to eventually move everything to the left term and explain nature in terms of geometry.

\(^{39}\) There are reasons to believe they will in the near future [28].
of scale in the equation for the ether force). The following Big Bang would have created the present structure of our observable Universe, which would be expanding, driven by a runaway solution, against a relative void outside. This outside void would be a much thinner version of the ether that fills our observable Universe.

The probable fate of the observable Universe in this scenario would be to get mixed again with the rest of the Cosmic fluid, like a Supernova sending its matter to mix with the galactic clouds of gas, which eventually collapse in different stars (Big Crunches in our case) in an infinite cycle. Notice that there is not any singularity, just very dense concentrations of fluid. The only condition needed to warrant this infinite cyclical behaviour, apart from appropriate boundary conditions for the Cosmos, is that (some) Big Crunches should be able to reverse complex atomic structures and return the matter to a plasma state like the one that existed in the first minutes of our Universe. We know that this is true over a certain density threshold.

This scenario would also avoid a foreseeable criticism to our model: how do the departures from cosmological homogeneity emerge in a theory which is not fundamentally indeterministic? In the traditional inflation framework, the quantum indeterminacy is invoked to provide the large-scale inhomogeneities. In a deterministic theory we cannot start with a perfect spherical model, since even if the model is unstable under small perturbations, a seed must be nevertheless supplied. The Big Bang must have then started from a relatively inhomogeneous collapsed state. Most of the inhomogeneity would have been swept by inflation. The overall acceleration and angular speed, relative to the neighbouring fluid, of the blob which gave birth to our Universe is quite irrelevant, since inertial effects on the blob depend on the density of the fluid around the blob, which is supposed to be very tiny (compared to the background ether inside the blob) due to the dragging effect of the Big Crunch runaway collapse.

Notice also that within this picture the initial state of the observable Universe is not deductible from (1), because \( < \rho >, < v > \) and \( < a > \), in particular, are the result of the previous collapse, and the Big Crunches are as stochastic as any WFC. Fundamental parameters in effective theories should be traced back to this initial conditions plus any fundamental constant appearing in (1). In particular, the exact values of \( c, \hbar \) and \( G \) probably do not have any particular meaning\(^{40}\). As Ellis remarks [59], one runs into major problems in distinguishing boundary conditions from physical laws. What appears to be an inviolable physical law may just be a consequence of the particular boundary conditions that happen to hold in this particular Universe.

VIII. CONCLUSIONS

In this section we summarize the assumptions we have made during our discussion of the classical Euclidean approach and the SFM. Then we also summarize the main consequences. We then compare the complexities of this approach versus the orthodox one (the Standard Model). Considering all this we finally provide a (subjective) answer to the entitling question of this paper.

A. Assumptions

These are the assumption we have made for constructing the alternative framework (in parentheses the corresponding assumption under the Standard Model (SM)):

1. Principles:

- The fundamental space is Euclidean, homogeneous and isotropic, and the time is absolute (SM: the fundamental space-time is Riemannian)
- The fundamental Lagrangian does not depend on relative speeds (SM: Lorentz invariance as a given metaprinciple)

\(^{40}\) Other than the restrictions based on the anthropic principle. Presumably many Big Bangs do not have the right initial conditions so that life can emerge.
2. Initial data and conditions on the equations:

- The space is filled with a fluid in a turbulent thermal state (SM: The fundamental laws are indeterministic)
- There are stable and metastable vortices as solutions (SM: Point-like particles exist)
- Spin is a property that characterises vortex solutions (SM: Spin is an internal property of particles)
- The forces between stable and metastable structures are spin-dependent (SM: The postulate of the quantum collapse)
- Inertial mass is a property derived by the interaction of vortex solutions with the thermal background (SM: Inertial mass is an internal property of particles)
- The average increase of tangential speed of the ether around a vortex is proportional to the square root of the inertial mass of this vortex (SM: The Einstein equations)
- The runaway solutions implicit in the fundamental Lagrangian can be implosive (SM: The postulate of the quantum collapse)
- At macroscopic ranges the thermal background is homogeneous and isotropic (SM: The energy-momentum classical conservation laws)
- The runaway solutions implicit in the fundamental Lagrangian can be explosive (SM: Dark energy and inflation)

3. Pending issues:

- All phenomena are supposed to be derived from the dynamics of a fluid (SM: A grand unification is supposed for the Electroweak and Chromodynamic forces. Gravity should be included. The particles are treated apart)
- The fauna of particles should emerge from the characterisation of these stable solutions (SM: A mathematical structure to be discovered is expected to provide a reason for the known hierarchies of fundamental particles.)
- $c$ is the sound speed of waves on the thermal background and can in principle be obtained from other data (SM: $c$ is a fundamental constant)

So a model for (1) will need to match all these conditions. Is it possible? Is it reasonable? Clearly the answer to that questions still needs a lot of effort, but in our opinion the picture does not look as daunting as the string approach.

Notice, furthermore, that if a model can be found that meets all these criteria, then most of the assumptions become predictions, which results in an axiomatic system much simpler than the Standard Model.

B. Consequences

Now assuming such a model can be built, there are some consequences of a classical Euclidean TOE and of the SFM in terms of the qualitative predictions on the structure of particles and space, Quantum Theory, Special Relativity, General Relativity, cosmology, and the four standard forces.

1. Basics

- It explains particles as short-lived metastable states that result from WFC.
- Virtual particles have a natural explanation. They only differ from real particles in the parameters describing the surrounding ether.
- Energy and momentum are not conserved.
2. Quantum Theory

- It explains the quantum void as a stochastic background in the sense of SED.
- As in SED, quantum uncertainty emerges from the stochastic nature of the background void. This eliminates all the paradoxes related to the indeterminism.
- The Feynman-Fivel-Pearle assumption of gravity as the source of WFC [3, 4] is partially justified in some way: the ether force, of which gravity is a long-range manifestation, is the origin of the dragging and collapse of the inertial system on which the wave travels.
- The typical energies $dE$ that can be subtracted from the void depend on the typical time of return $dt$ that we consider. This is related to the thermodynamic properties of the void, depending on its density (of order $\hbar$, according to SED).
- All quantum events, real and virtual, are driven by runaway solutions.
- WFC is explained dynamically as a superluminal phenomenon.
- One of the main characteristics of General Relativity is that acceleration causes acceleration or put in another words, acceleration drags the inertial systems. That is the result that led Einstein to General Relativity in the first place. This behaviour is inherited from the ether force. The WFC would be a phenomenon parallel to the gravity-induced dragging of inertial systems, although in the WFC-dragging the spin would play a major role.
- The quantum vacuum does not gravitate, as gravity operates in a simplified background that includes the ZPF. In particular, gravity is an inertial force, an inertia does not exist without a supporting inertial system, which is the ZPF itself.

3. Special Relativity

- Lorentz invariance is an emergent phenomenon
- The speed of light is not a fundamental constant but the sound speed of phonons traveling on the ether.

4. General Relativity and inertia

- It explains inertia as a stochastic interaction with the void, in the limit of a homogeneous background.
- Mach’s principle (Mach0\textsuperscript{41}) is explained in the Spin Force model. From several points of view, the SFM can be considered more Machian than General Relativity. For instance, the Mach2 principle reads An isolated body in otherwise empty space has no inertia [44]. Both Newtonian and Einsteinian gravity fail at satisfying this principle. The SFM, on the other hand, predicts this to be true (this is relevant even when the direct experiment is probably impossible). This is because inertia is an effect of the ether in equilibrium with matter. A void space implies no matter and no ether, and then no inertia. A piece of matter that could\textsuperscript{42} somehow escape our Universe could have any acceleration relatively to other neighbouring Universes while travelling on really void space.

Mach3 principle, Local inertial frames are affected by the cosmic motion and distribution of matter, is fulfilled by General Relativity and the SFM.

Mach7 principle, If you take away all matter, there is no more space is false in General Relativity and in Newtonian gravity. In the SFM is true, however, if space is understood in the sense of the effective Minkowskian space provided by the background ether. The explanation is the same as in Mach2.

From this small survey we can conclude that the SFM is more Machian than any other theory, including General Relativity. Of course, this is just a notational observation. Scientifically, it is only important whether the experimental principle Mach0 is predicted or not.

\textsuperscript{41} See subsection IV B.
\textsuperscript{42} It could not escape in fact: it would evaporate in a sort of micro-Big Bang if it is extracted from the ether bath.
• It explains gravity as a long distance inertial effect of the model. In this limit, it reproduces General Relativity.

• Gravity does not need to be quantised.

5. Cosmology

• Cosmological runaway solutions are permitted, which includes inflation and dark energy.

• Our observable Universe is enclosed in a wider Cosmos.

6. The four forces

In the classical approach the four interactions have a different relationship from that in the unification extensions of the Standard Model. We have seen than the geometrodynamics of the Standard Model is replaced with three different interactions: an Euclidean gravity in the macroscopic range, spin-driven inertia (encompassing quantum collapse, in the thermal range) and quintessence (in the cosmological range), all of them deriving from the fundamental ether force in certain limits.

The role of the three remaining interactions of the Standard Model, that is Electromagnetism, the Weak force and the Strong force, is more opened. We should note that once a model provides spin and Lorentz invariance, then certain restrictions appear on the field equations. Spin 1 bosons follow Maxwell or Proca equations (also, spin 1/2 fermions are bound to Dirac equations)[60]. Then, simple bosons (unstructured phonons) on the Spin Force Model, if they exist, are forced to follow Maxwell equations in the macroscopic range. Electric charge, then, seems to be linked to the capability of certain fermion vortex fields at emitting and absorbing unstructured phonons.

We need to invoke complex bosons, with an internal vortex structure (and then massive) to account for the nuclear forces. How many of these bosons there are, if any, is hard to tell without a detailed study of a particular form of (1). But some qualitative consequences can be sorted. First, the Electroweak unification looks quite unnatural in this framework. Second, Chromodynamics with massless gluons does not seem compatible with the framework. If the Spin Force Model is to accommodate Chromodynamics, then the gluon should have a small mass.

It is also remarkable, when comparing to the Grand Unification models, that the Higgs boson does not find any place within the SFM. The origin of mass, in fact, is originated by the inertial interaction, which is an effect that lays at the same fundamental level than particles.

C. The complexity of the Standard Model vs the classical Euclidean approach

The Standard Model is based on a set of assumptions underlying the four pillars (mainly, Lorentz invariance and \( c \) invariance, the Principle of Equivalence, the space-time as a geometry and its geometrodynamics, the absoluteness of space when acceleration is considered and relativeness when speed is considered, the quantum collapse, the indeterminacy and the need of a chooser, the point-like particles, duality and renormalisation, the populations of particles, its internal characteristics, their 3 non-gravitational interactions). All these assumptions have parallel assumptions in our proposed framework, as we have detailed in subsection VIII A. We have seen that in this framework, though, the assumptions seem less arbitrary, as they fit naturally in the model based on fluid dynamics.

But apart from these collection of assumptions, we need fixes in the Standard Model for the internal inconsistencies generated by these assumptions, which we have analysed in the previous sections:

• Special Relativity is threatened by the Scharnhorst effect and situations involving negative energies. The minimal cure is to degrade \( c \) from a fundamental constant to a sound speed, which anyway opens a breech in the philosophical basis of Special Relativity.

• The quantum gravity deadlock

• The quantum void does not gravitate

• The measurement axiom

• The renormalisation anomaly

• Dark energy
In the SFM, on the other hand, these are naturally explained, although such a conclusion has obviously an influence from subjective considerations.

**D. Is the classical Euclidean approach reasonable?**

Is then the search for a classical Euclidean TOE reasonable? Its mathematics could be certainly less analytic than what we are used to in theoretical physics, as specialists in fluid dynamics know and suffer, but should Occam’s razor rely on this factor or on the complexity of the axioms? We have always weighted favourably the simplicity of the equations and their analytical solutions because analytical results were, until recently, the main source of knowledge on our systems of equations. But that is a circumstantial fact and attaching ourselves to this restriction may have led us to an overwhelming complexity in the underlying axioms. A high price to pay for analytical simplicity, indeed. Today, however, in the age of computing, the complexity of the equations is not a point to consider heavily, as we can always get numerical solutions. Instead, we should start looking for a simplicity of assumptions, even when they lead us to non-linear equations hard to attack analytically.

In this sense, a classical Euclidean TOE is reasonable, because it can be simpler than the Standard Model, whose underlying axioms have entered a dead path. The interpretational paradigm of the XXth century physics suffers from a deadlock that already lasts 70 years. The suggested outcomes that do not deviate from the paradigm are obtrusively complex. Paraphrasing Bell, the interpretational paradigm of the XXth century physics bears the seed of its own destruction. On the other hand, one can imagine an outcome for the deadlock within the simple interpretational paradigms of XIXth century physics and fluid mechanics if one assumes three basic ideas:

- The Universe is filled with a stochastic fluid background (ether)
- The interaction of the fluid is mainly driven by its relative acceleration, that is, we need to assume a dynamics of acceleration (an ether force)
- The dynamics is divergenceless and creates vortices

Is then a classical TOE reasonable? It certainly seems so.

**APPENDIX A: A SIMPLE TOY MODEL**

One of the most obvious and simplest models for (1) to try first is

\[ L(x, t) = \partial_i F(x, t) \partial_i F(x, t) - \partial_t F(x, t) \partial_t F(x, t) \]  

(A1)

where

\[ F(x, t) = \rho(x, t) a(x, t) \]  

(A2)

and the Einstein summation rule applies (i=1,2,3). Therefore we have a simple wave equation for the force \( F \).

**APPENDIX B: TOROIDAL VORTICES AS THE ORIGIN FOR SPIN?**

If we assimilate fermions to vortices, the simplest assumption is to model them as toroidal vortices. This might provide a dynamical origin for the spin. Apart from the standard angular speed axial vector \( \omega \) describing the rotation of the vortex from an external point of view, we need an additional scalar to account for the internal rotation on the toroidal axis.

Now we postulate that stable vortex configurations are characterised by a fixed azimuthal-toroidal speed ratio. For spin 1/2 fundamental fermions, for instance,

\[ \frac{\omega_\rho}{\omega_t} = 2 \]  

(B1)
where $\omega_\phi$ represents the angular speed of the vortex around its azimuthal axis and $\omega_t$ represents the internal toroidal angular speed.

For such a vortex, the Dirac equation is approximately valid on the macroscopic range. The Dirac equation is derived by the only assumptions of a spin 1/2 particle plus Lorentz invariance (transformations under the Lorentz group) [60], which is a good approximation on the macroscopic range.

APPENDIX C: EXPERIMENTAL PREDICTIONS

The classical Euclidean approaches, and the SFM in particular, can be tested through some basic predictions. Here we will list a collection of predictions from the SFM, although some of them are traceable to the classical approach. Unfortunately, the predictions can only be qualitative given the preliminary state of the model. However, some of the qualitative predictions could be used to falsify the framework.

1. Implications on cosmology

Currently, cosmological models are confronted with the observations on the weights of different sources of energy in the framework of the Friedmann-Lemaître model [28]:

$$\Omega_{M0} + \Omega_{R0} + \Omega_{\Lambda0} + \Omega_{K0} = 1 \quad (C1)$$

The qualitative model of section VII implies that $\Omega_{K0} = 0$, since the underlying theory is Euclidean. Also, the model predicts that $\Omega_{\Lambda0} \neq 0$ in general (see VII G 5)

These values are currently the best fits of astronomical observations, so this result cannot be considered a prediction. Anyway, more precise observations could change that picture and rule out the model proposed in section VII. At present, a $\Omega_{\Lambda0} = 0$ is two or three standard deviations from the best fit [28].

The precise values of the weights depend on the form of (1) and on the initial conditions at our particular Big Bang, so we cannot provide a prediction for the ratios on the rest of weights.

2. Increased $c$ in a bath of rotating cylinders

a. The experimental set

Imagine a long cylinder (the longer the better in order to suppress boundary effects) containing a bunch of smaller cylinders. The smaller cylinders should be able to rotate at different speeds. The space not occupied by the smaller cylinders should be void, both to avoid air turbulence and to permit the measurement of the speed of light in vacuum. In particular a tiny space should be left in the middle of the device, so that light can travel along it. We will call container the big cylinder and rotators the smaller ones. The central corridor for the light will be called cannon.

At one end of the cannon we place a laser. Light will propagate from the laser to the other end of the cannon, where a mirror reflects it. An interference pattern should pop up. The mirror will allow light out to study the interference.

First we will measure the interference pattern with the rotators stopped. Then we will accelerate them progressively (in different senses, to keep the global angular momentum null) while watching any change in the pattern of interference.

b. Theoretical predictions

The rotators, when spinning, will create an acceleration field on them, which will create a spatial gradient on the probability of collapses of virtual particles. Closer to the rotators, the collapse probability will be greater. The

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43 Nonetheless, as mentioned in subsection VII G 6, there is no reason to be dogmatic about whether the Cosmos is spatially open or closed. The latter option would imply a static space curvature, but that would presumably happen on a spatial scale much larger than the distances in our observable Universe, so we can consider the curvature to be approximately null.
thermodynamics will tend to rebalance the density of the ether by transferring ether from the collapse regions, close to the internal rotators, to the axis of the cannons. An equilibrium will be achieved, with a stabilised gradient of ether density: below the cosmic average on the axis of the cannon and above average in the vicinity of the rotators.

The variation in ether density will cause a variation (increase) in speed of light, which would be measurable if intense enough.

This effect is similar to gravity, although gravity emerges from the stochastic microscopical rotation of the ether around a body. Here there is a macroscopic rotation of the ether.

3. Masses of fermionic and bosonic fields

As explained in subsection VIII.B.6, all fermionic fields are bound to have a mass within the SFM. Also, all non-trivial bosonic fields (Electromagnetism) must be derived from massive bosons. This means, in particular, that both neutrinos and gluons should have a mass.

4. Other differences with Grand Unification models

The most trivial consequence of the classical approach is that gravity cannot be unified with the quantum forces, as they have a different origin. The SFM also misses to find an explanation for a Electroweak unification (this is commented in the conclusions). We do not still know whether this is fatal for the SFM. Finally, the Higgs boson does not find a place in the SFM (see also the conclusions).

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