Is Nature OO?

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Contents

1 Introduction **1**

2 What do we mean by *doing physics?* **1**

3 The Hilbert Space Formalism (HSF) **2**
- 3.1 The Schrodinger equation 2
- 3.2 Definition of the HSF 3
- 3.3 So what is the idea for ψ? Probability of what? 4
- 3.4 What is Quantum Mechanics? 6

4 DSAT: Detector-Source Apparatus Theory **7**
- 4.1 DSAT, detector and click(event)-source definitions 7
- 4.2 A no-go for corpuscles in microphysics? 7
- 4.3 Bohm-Aspect setup 8
- 4.4 Bell reasoning 8
- 4.5 The HSF at work and the DSAT point of view 9
- 4.6 The QM point of view 10
- 4.7 A remark 11

5 We are Object Oriented! **11**
- 5.1 The two slits experiment 11
- 5.2 MachZender (and delayed choice) experiments 14
- 5.3 Corpuscles? at what cost? 14

6 A pure *click-ology*? No **15**
- 6.1 The Missing or In-Between Apparatuses; the MA or IBA . . . 16
- 6.2 What is the mathematics for the MA? 17
- 6.3 The mathematics for the MA of a click-transformation experiment 17
- 6.4 What is high energy or particle physics? 19
- 6.5 What is the *Standard Model*, the *Higgs*? 20

7 Restoring *OO* in microphysics **21**

8 Gravity, General Relativity and the Grail of Unification **21**
- 8.1 The right question: what are the apparatuses in GR? 23
- 8.2 Relativism with DSAT and the TEA 25

8.3 A key experiment related to gravity in microphysics 27

9 What are apparatuses made of? The true fundamental question 27
9.1 QM textbooks? 27
9.2 Bohm-model, Consistent Histories? 28
9.3 DSAT? 29
9.4 *aparticles* 30
9.5 Pairs of (emitter,receiver)? 30

10 Relationship with software 31

11 Conclusions 32
11.1 Summary of the overall argumentation 32
11.2 Is nature OO? 33
11.3 Yes, we can! 33
11.4 No mathematics, only ideas 34

1 Introduction

We want to ask some questions

- What exists *out there*?
- What does *doing physics* mean?
- What are the *axiomatic ideas for microphysics*?
- What is a *particle*?
- What is an *apparatus made of*?

We want to show that Quantum Mechanics textbooks(even mine) have not, in general, answered these kind of questions whereas they should!

We adopt a new point of view for microphysics by introducing the *Detector-Source ApparatusTheory* (DSAT) and the idea of a *Missing Apparatus* (MA) or *In-Between Apparatus*(IBA) that together restore, through a *redefinition of the meaning of an object* (RMO), an intuitive ontology to deal with this kind of physics.

Through a review of what it means to *observe* and what *relativism* means in Special and General Relativity (SR and GR), we also address the problem of finding *common mathematics* for GR and QM.

Finally, with our new way of thinking, we address the *measurement problem* in QM and propose two possible approaches.

2 What do we mean by ***doing physics?***

Physics consists of three parts:

Ideas about nature

Mathematics

Experiments

This means

Clear ideas about something in nature, something *out there*.

A clear mapping of these ideas with mathematical symbols.

A good matching of experimental results or observations (the data) with what is derived from the mathematics.

A good theory must have all three.

We have the deep conviction that if we do not have all three, especially the right ideas, we are not doing good physics or even physics at all! This could be represented with the *semantic* equation

$$\text{doing-physics} = (\text{ideas, mathematics, experiments})$$

Mathematics is the logical manipulation of propositions made with symbols. One set of propositions, the axioms, is more *fundamental* than the others. The axioms are considered de facto to be true and are, by construction and definition not provable since that is the meaning of the word axiom!

Regarding the ideas for physics it appears that we have a similar kind of process. Among all ideas some seem to be more fundamental than others, for example the ideas of space and time. We are going to say such ideas are *axiomatic*.

It is interesting to question what the axiomatic ideas are in todays physics. For example, we are going to see that the idea of *corpuscle*, defined as a little object *out there* bearing properties of its own and *flying around*, is far from being such an obvious axiomatic idea as it may seem to some!

It is interesting to note that this kind of reductive process seems to apply in experimental physics too. Some experiments, such as the *two slits* one, reveal, so sharply, a peculiar feature of nature that they seem to be axiomatic too!

3 The Hilbert Space Formalism (HSF)

3.1 The Schrodinger equation

Before the mid 1920s we had very good theories dealing with the meso-scales and macro-scales *out there*: classical mechanics, Maxwell theory, General

Relativity. In particular, in these theories, fundamental ideas did not pose problems. They were the ideas of solid body, space, time, and field. These ideas were nicely symbolized by using differential calculus. Moreover, we had an impressive match with experiments. However, things collapsed around 1925 with micro-scale physics. One key experimental fact was the observation of the spectrum of emitted light from an illuminated hydrogen gas that appeared to be discrete! A key theoretical fact was the discovery by Schrodinger of an equation able to predict this spectrum

$$-\frac{\hbar^2}{2m}\nabla^2\psi + V\psi = E\psi$$

This equation (the *time independent* one) operates on a field ψ, has the symbol E representing Energy as a parameter and a *potential field* V as a constraint. A wonderful feature of this equation is that for some particular potentials it has solutions for ψ only if E is in a discrete spectrum. In the the case of a $1/r$ potential(Coulomb), this spectrum matches the observed one of the illuminated hydrogen gas. This is brilliant (no pun intended). Especially knowing that the Maxwell theory, based on the idea of corpuscles flying around in a field mapped on space-time, was not able to predict the observed spectrum. The straightforward calculations can be found in many books.

This amazing equation seems to solve the question of microphysics, but a *little detail* prevents that – we have no clear idea how to attach meaning to the field ψ!

3.2 Definition of the HSF

The Schrodinger equation leads to new mathematics that we call the Hilbert Space Formalism (HSF). It is the mathematics used in microphysics today. The HSF is based on a Hilbert vector space using complex numbers, equipped with an inner product to get real numbers from vectors, operators acting on a vector, a whole body of logic to analyze the spectrum of operators, a way to decompose a vector (a $|\psi\rangle$ or ψ for short) into the basis of an operator, etc... In these notes we are not going to question this mathematical formalism but we will question the ideas of the physics attached to it – for example, the idea attached to the ψ of the Schrodinger equation which is itself part of the HSF.

3.3 So what is the idea for ψ? Probability of what?

What is ψ for?

A textbook answer is that ψ is used to calculate probabilities.

Fine, but the probability of what?

It would be natural to say that the axiomatic ideas for microphysics are space, time and corpuscles able to *fly around* and that ψ is used to calculate the probability that a corpuscle *be* at a given position, with the randomness having its origin in some unknown effect to be discovered(or maybe including an axiomatic idea of randomness).

In general, experts, teachers and textbooks discard this view, this interpretation, by saying that ψ is used to calculate the probability that the corpuscle *be found* at a given position. This is a subtle difference, but an essential one. In particular this *be found* assumes de facto an apparatus logic in the foundations, in the axiomatic ideas. This *be found*, and the fundamental change of semantics attached to it, has its origin in a piece of mathematics in the HSF called the **Heisenberg inequality** and an interpretation of this inequality called the **Heisenberg Uncertainty Principle (HUP)**. We are definitely not going to argue about this *principle* here, but a key feature of the HUP is to say that we can no longer attach both the properties of position and speed (momentum in fact) to a corpuscle. With the consequence that the idea of trajectory no longer makes sense in microphysics, and so the idea of *flying around out there* makes no sense either!

In order to keep the connection to nature, textbooks fall back on an *axiomatic measurement logic* by attaching position or momentum to the result of a measurement process on a *tiny something* that we are going to call *particle* from now on rather than *corpuscle*. We reserve the term *corpuscle* for a *tiny object* having a trajectory as in classical mechanics or Maxwell theory. We may write the definitions

$$\text{corpuscle} \overset{def}{=} \text{tiny object with trajectory}$$

$$\text{particle} \overset{def}{=} \text{tiny object without trajectory}$$

A key point is that a *particle be found* assumes that there are *tiny objects out there* beside the axiomatic apparatus needed to attach ψ to the idea of *be found*. It is here that we start to have problem of interpretation because if ψ is dedicated to a *be found*, there remains nothing in the formalism to symbolize a *tiny something*! In particular, since there are no more trajectories, there are no $X, Y, Z(t)$ symbols to represent a *tiny object out there*. So with these ideas attached to the Hilbert Space Formalism, we are driven to a strange interpretation in which some axiomatic ideas (*tiny object* or *particle*) have no direct mapping symbols in the formalism. **Very weird**.

Moreover, the symbols of space and time, t and x, appear both in $\psi(t, x)$ and in the partial derivatives of the Schrodinger equation. A three dimensional uniform and constant metric is also hidden in the Laplacian ∇^2 of the equation (through a δ_{ij}). So we must conclude that a *found position* has to be understood from an apparatus immersed in a Euclidean space-time. This induces a more acute problem of interpretation since we have to speak of a *tiny object out there* not represented in the formalism, having no trajectory of its own, and that cannot be said to be *here*, but is nevertheless in a *here* when measured because of the Euclidean *here* defined by the apparatus! **Very, very weird**.

To emphasize the point we could mention the *spin*. If we put an illuminated hydrogen gas in a magnet we observe a change in the emitted spectrum. It appears that the HSF has the *spinor* operator piece of mathematics that brings the necessary degrees of freedom to model the modified spectrum. So we have a good match of the mathematics with an experimental result - fine! However, things go wrong when looking at the ideas presented in textbooks to justify the usage of the spinor mathematics. A spinor is a mathematical object related to rotation in a Euclidean three dimensional space and textbooks attach a *spin* property to their *particle* (spin 1/2 of the electron). How can we attach to the *tiny object* a property related to rotation in the Euclidean space of the apparatus which is the only space at hand in this interpretation? How can we attach the idea of meso-scale rotation to something that cannot be said to be *here*? How can we attach a geometric idea to a *tiny object* that cannot be said to *be* in space? Most textbooks evade the issue by saying that spin is a *pure Quantum Mechanics effect* which obviously explains nothing! Worse, before reaching this conclusion some dare to use the analogy of the classical spinning top in order to give an *intuitive feeling* to what the *spin*

of a *particle* is. **A disaster!** (A classical spinning top is an object having a spatial structure that rotates *out there*).

If there is no $X, Y, Z(t)$ in the formalism, and no more symbols to represent the *particle* directly, it would be much more consistent to say that there are no particles at all and then say that ψ is used to calculate the probability that a cell at a given position in a measuring apparatus has to register(click). This is much more convincing since the HSF has symbols to describe a measuring device (the operators) and also has symbols to describe a *source apparatus* (the vectors). *Source* is interpreted here as the source of the click events in the sense that, if the source apparatus is not there, then we never observe the clicks associated with the cells.

It is this *no particle* idea that we would like to develop in these notes to see if we can have a more consistent approach to microphysics. More consistent at the level of the mathematics and experiments, but also of the ideas.

3.4 What is Quantum Mechanics?

A textbook about microphysics that uses the HSF is said to be about **Quantum Mechanics** (QM in short). As just discussed, a particle vocabulary is still heavily used in these QM books. The words atom, electron, particle, etc... often appear in the introduction as if taken for granted, without any kind of definition. To help the argumentation of these notes, we are going to rely on this usage of a particle vocabulary to define *Quantum Mechanics*. In fact few books come with a definition of what QM is. For us, QM is the area of science dealing with microphysics based on the mathematics of the HSF but *still associated* with a particle vocabulary.

Having the conviction that this excess vocabulary is the source of the intuitive discomfort that many people have with *QM* (including me), we are going to see if it is possible to use the HSF while avoiding this particle vocabulary and thereby obtain a clear understanding of the science of microphysics.

4 DSAT: Detector-Source Apparatus Theory

4.1 DSAT, detector and click(event)-source definitions

DSAT, for Detector-Source Apparatus Theory, is defined as an interpretation of the HSF formalism based solely on the two axiomatic ideas of apparatuses and events(clicks) appearing in them.

Experimental microphysics shows that we can classify apparatuses in two categories, the *detectors* and the *click-sources*. We define a *detector* as an apparatus in which clicks appear. For the moment the clicks are zero dimensional (instantaneous) events appearing in the detectors. Some apparatuses are such that, if they are not present, no clicks appear in a detector apparatus. We define a click-source apparatus as such an apparatus. In a complex detector (some made of many devices) clicks often appear in a pattern that characterizes the click-source (for example an *electromagnetic shower* click pattern).

It is important, in fact fundamental, to note that the definitions above do not use the words corpuscle and particle at all. We consider that these definitions are good foundations because they do not pose a problem of realism for us. At first glance, DSAT looks like, let us say, some kind of *clickology*, but we are going to see that it is more than that.

4.2 A no-go for corpuscles in microphysics?

To define an apparatus, we could have said that they are made of an aggregate of corpuscles, that a click-source is a device that emits corpuscles and that a detector is a device that reacts by producing a click when impacted by a corpuscle. *Corpuscle* would then have been a universal axiomatic idea. It is very natural to attempt to define apparatuses and the whole of microphysics in this way, but it appears that one part of this kind of theory ..... does not work!

Some reasoning of John Bell, tested in *Bohm-Aspect* kind of experiments, is said to rule out the idea that a click is produced by a corpuscle emitted from the source. For clarity of the overall argumentation, we must explain, with our words, the outline of a Bohm-Aspect type experiment and the Bell reasoning.

4.3 Bohm-Aspect setup

We can imagine an experimental setup composed of three apparatuses, a click-source and two detectors placed remotely from the click-source by having the three devices aligned along the same axis (say z in this case). Each detector is such that it defines an oriented axis in a plane perpendicular to z so that *+click* can appear in the forward direction of this axis and *-click* can appear in the backward direction of the axis.

For a particular kind of click-source *actually found* in nature, we can observe *time coincident* pairs of clicks in both detectors. The pairs are of four kinds: $(+,+)$, $(+,-)$, $(-,+)$, $(-,-)$. We can count the number of pairs with the same sign

$$N_{same} = N_{++} + N_{--}$$

and with the opposite sign

$$N_{opposite} = N_{+-} + N_{-+}$$

and then calculate the *correlation factor* C as

$$C = \frac{N_{same} - N_{opposite}}{N_{same} + N_{opposite}}$$

One macroscopic parameter of the setup we can play with, is the relative angle θ of the axes of the two detectors. Other macroscopic parameters are the two distances of each detector to the click-source, but strangely they do not appear in the reasoning. We can then do various data acquisitions (runs) by getting C for various θ and draw an experimental curve $C_{exp}(\theta)$. As the shape of this curve is not relevant for the argumentation, we are not going to show it here. It helps to concentrate on the essentials!

It is important, in fact fundamental, to note that in the description of the experiment we have not used the words corpuscle, particle and in particular have not used the phrase *pair of photons*.

4.4 Bell reasoning

It is at this point that Bell's reasoning comes into play. Bell claims that a large set of theories describing the experiment, and in particular the ones

based on corpuscles, must match some conditions, the Bell conditions (BC in short), and that when these conditions are met, then the $C_{theory\ under\ BC}(\theta)$ has some constraints. The passage from the Bell conditions to the constraints over $C(\theta)$ is the **Bell theorem**. A striking result is that these constraints are such that a $C_{theory\ under\ BC}(\theta)$, and then $C_{corpuscle\ theory}(\theta)$, *cannot reproduce* the $C_{exp}(\theta)$!

In Bohm-Aspect-Bell (BAB in short), it is not the fact that there are coincident clicks that poses a problem, but the fact that the amount of correlation for some θ cannot be explained by some theories, and in particular by the most intuitive theory that we can imagine at first, the one describing nature with corpuscles flying around and interacting locally with the detectors. Said simply, for some θs there is too much correlation for an intuitive corpuscle theory. With the BAB logic, it seems that we have a proof that this kind of theory cannot work and therefore that our intuition is baffled by experimental microphysics!

After the pioneer papers, a lot was written to criticize just about everything! In general, criticisms are of two kinds. First, some criticisms are centered around how the experiments are done. Second, other criticisms are centered around the fact that the Bell conditions cannot put aside all the corpuscle based theories. In these notes we are going to assume that *BAB is valid*[It is not so clear whether the Bell conditions cover the case of a theory based on corpuscles flying around in a space-time which is not *gently flat* at microscale, a space-time having some dynamics of its own that could be viewed as the origin of the *too much correlation*. We assume in these notes that this kind of theory is ruled out too], and in particular that the experimental data and the $C_{exp}(\theta)$ curve are valid.

4.5 The HSF at work and the DSAT point of view

This loss of the idea of corpuscle looks like the end of *doing microphysics*, but the situation is partially rescued because ..... it is possible to model this experiment with the Hilbert Space Formalism! If the click-source is modeled by a *vector of the HSF* and the detectors are modeled by *operators of the HSF*, the formalism makes it possible to calculate a $C_{HSF}(\theta)$ that matches the $C_{experiment}(\theta)$! Since the setup was presented by using a pure DSAT terminology, and we have defined DSAT as being associated with the HSF,

then we can write

$$C_{DSAT}(\theta) = C_{HSF}(\theta) = C_{experiment}(\theta)$$

and so we have restored clear ideas mapped to neat mathematics that recovers the data : *doing microphysics* is back for this experiment! Moreover, it is back in a way that reinforces a pure DSAT point of view since the Bell reasoning is said to eliminate, in this case, the word *corpuscle*.

4.6 The QM point of view

As QM is also attached to the HSF, we have

$$C_{QM}(\theta) = C_{HSF}(\theta) = C_{experiment}(\theta)$$

but what is striking is that in general, in QM, the experimental setup is presented by using the words *pair of photons* to qualify the *source*. As QM defenders also accept the *loss of corpuscles* coming from the Bell reasoning, we are driven into a strange microphysics in which on the one hand the *good old corpuscles* are said to be ruled out, but on the other hand the word *photon* is nevertheless used to describe the setup! **Very, very, weird. . . again**!

To qualify this strange *pair of photons source* that can produce, for some θ, an amount of correlation not reproducible by a corpuscle theory, the word *entanglement* was introduced (the source is often presented as a source of *pairs of entangled photons*). This new word obviously clarifies nothing, since we have no clear idea of the nature of the entity being qualified! For us, the questioning around this kind of experiment is not to qualify a source of *photons*, but to know if it still makes sense to use the word *photon* at all! QM defenders should first speak about an experimental setup with a *click-source* being able to produce particular coincident clicks, and then ask the question: does a *photon entity* make sense to explain them?

It is worth noting that the DSAT point of view transforms an uncomfortable feeling of weirdness coming from QM, to a healthy feeling of awe. The awe at finding in nature click-sources able to produce such $C_{experiment}(\theta)$ not explainable by a corpuscle theory!

4.7 A remark

It is also interesting to note that the BAB argumentation does not destroy the idea of apparatuses being, or not being, an aggregate of corpuscles! Strictly speaking BAB does not address this problem, it destroys the idea of corpuscles only for the *in between* apparatuses. Consequently, we start to realize that the nature of apparatuses is going to be a central question. This point is going to be explored later.

5 We are Object Oriented!

For us, being unable to decide on which foot to dance with the word *particle* in QM is what induces the huge discomfort that we have with this interpretation of the HSF for microphysics. The discomfort arises because the idea of property-bearing objects is something deeply rooted in the way we think: we, as human beings, are...**object oriented** (we are *OO*)!. A theory about nature that is unable to pinpoint its own objects cannot be a good theory for us. We claim that DSAT is better than QM, because DSAT clears the decks concerning the word *particle*.

And what if nature were not OO? If that were the case, we would be unable to find the right ideas for the *out there*, which would mean a true end to *doing physics* as defined earlier, but it seems that we still have some cards to play, so let us continue .....

5.1 The two slits experiment

The **two slits** is a canonical experiment used in QM textbooks to justify the HSF. This justification comes from the fact that the HSF contains a *vector addition* which represents very well what is observed. In general the two-slits is also presented as the canonical experiment showing that *microphysics is weird* because there is no way to answer the canonical question *through which slit does the particle pass?*. As we are going to see, a DSAT point view naturally removes any kind of weirdness here.

As in the Bohm-Aspect setup, it is important, in fact fundamental, to be careful about the words used to present the experiment. The setup is made of a click-source apparatus pointing in a direction z, a farther plane perpen-

dicular to z with two parallel slits (A and B) and a still farther plane detector also perpendicular to z. The four experimental situations

1. slit A opened, B closed
2. slit A closed, B opened
3. slit A opened, B opened
4. slit A closed, B closed

could be modeled with a $\sigma = 1, 2, 3, 4$ macroscopic parameter. In this reasoning, this $\sigma-$parameter is an equivalent of the θ macroscopic parameter of the Bohm-Aspect setup. For the first three cases, according to σ (and then for different runs labeled by σ), we observe three distributions of clicks: $D_{exp}(\sigma = 1)$, $D_{exp}(\sigma = 2)$, $D_{exp}(\sigma = 3)$. An interesting fact is that in the case $\sigma = 3$, the distribution of hits has an **interference pattern**, whilst each distribution $\sigma = 1, 2$ does not. So we have

$$D_{exp}(\sigma = 3) \neq D_{exp}(\sigma = 1) + D_{exp}(\sigma = 2)$$

What is nice is that we can model these three situations quite easily with the HSF by associating a ψ with each σ. A mathematical curiosity is that, apart from a normalization factor, we have

$$\psi(\sigma = 3) = \psi(\sigma = 1) + \psi(\sigma = 2)$$

and that $\psi(\sigma = 3)$ predicts the interference pattern. So far so good. We could have stopped the presentation of the two-slits here since the three ingredients of *doing physics* are here. Clear ideas (apparatuses, clicks), good mathematics (the ψs and the capability to add them) and a very good matching with experiment (in particular the prediction of an interference pattern).

An important and fundamental fact is that until now we have not used the word *particle*, nor the word *corpuscle*, and that so far the above two-slits presentation is clear. Now if we attempt to model this experiment with a corpuscle theory, we fall on a serious problem because a *standalone corpuscle flying around* theory would lead to

$$D_{corpuscle\ theory}(\sigma = 3) \neq D_{corpuscle\ theory}(\sigma = 1) + D_{corpuscle\ theory}(\sigma = 2)$$

which is not what is observed. In particular, a corpuscle theory would not lead to an interference pattern. So, as in BAB, we are driven to the conclusion that the idea of corpuscles is ruled out in this microphysics experiment. In fact, we could have used the two-slits as a corpuscle no-go argumentation instead of BAB, but BAB is more interesting since it eliminates more theories. It should be noted that it is not so much the fact that there is an interference pattern in $\sigma = 3$ which is important as the mere fact that $D_{exp}(\sigma = 3)$ is not the same as $D_{exp}(\sigma = 1) + D_{exp}(\sigma = 2)$. This non-equality alone is sufficient to rule out the idea of corpuscles

In QM textbooks or lectures, it is highly instructive to study the section on how the two-slits experiment is presented. Most of the time, it is presented in the first lecture by using the words *particle* or *electron* as if taken for granted. The *source* apparatus is presented de facto as a source ... of particles, themselves often presented as corpuscles (sometime even drawn on the blackboard!). This is wrong, and because of this usage of the wrong vocabulary so early, the poor student cannot avoid catching an intuitive discomfort right from the first lecture, a discomfort that leads in general to strong nausea by the end of the term! The two-slits is presented so early more to sell the HSF than anything else, in particular the *linearity of the algebra* - the fact that $\psi(\sigma = 1) + \psi(\sigma = 2)$ has a physical meaning[Students that feel comfortable are in general more mathematicians than physicists and do not run away (fast) because the HSF, with its linear algebra, is a nice piece of mathematics to play with. To be fair, we agree on that]. But the point with the two-slits experiment is not in the mathematics! It is in the fact that this experiment is a canonical one to question the usage of the words *particle* and *corpuscle* in microphysics.

We also see that a pure DSAT, a pure click-ological point of view, clarifies the question *through which slit does the particle pass?*. DSAT leads immediately to the conclusion that this question is not answerable because it is .... ill-defined! It is ill-defined because the word *particle* is ill-defined in this context. The DSAT point of view also transforms the sentence *microphysics is weird* to *microphysics is awesome*. It is awesome because we can find in nature, *out there*, click-sources able to produce an interference click pattern and we can model the experiment by using straight forward linear algebra. **Truly marvellous!**

The DSAT point of view makes it possible to raise an interesting question: what about the case *A closed and B closed* ($\sigma = 4$)? Our click-ological point of view does not rule out the possibility of actually observing clicks in the detector! Before saying that this is impossible, we must remember .... the tunnel effect!

5.2 MachZender (and delayed choice) experiments

We could also have mentioned the Mach-Zender *two arms interferometer* kind of experiment that would have drawn the same conclusions as for the Bohm-Aspect and two-slits ones. The macroscopic parameter to play with would have been the difference of length (δ) between the two arms. In such an experiment, various runs based on this this macroscopic parameter would have induced some $D_{exp}(\delta)$ experimental curve not reproducible with a theory of corpuscles flying around, but reproducible with the HSF.

Here too, we would have concluded that the question *through which arm did the photon pass?* is ill defined and then unanswerable because the word *photon* is improper in this context.

A QM point of view would have shown the same defects as for the two-slits : a too early and undue usage of the word *photon* and a focus on the mathematics. The conclusion would had been the same : the point is missed.

5.3 Corpuscles? at what cost?

It must be mentioned that some models exist which attempt to model the two-slits or the Bohm-Aspect results by keeping corpuscles. The Bohm model(hidden variables) is one of them (there are $X, Y, Z(t)$ with Bohm). Nevertheless all of them, at some point, have to introduce some weird ideas such as action at distance. Such ideas are definitely counter-intuitive and at some point not really OO. For example, action at distance implies that a corpuscle does not really bear properties in a standalone way since its behavior depends also on *the rest* (it is the so-called **Wholeness** idea).

6 A pure *click-ology*? No

Does the DSAT interpretation, because it is an interpretation, imply that microphysics is reduced to a pure click-ology? That is to say that nature is made of click-source and detector apparatuses, all modeled with the Hilbert space formalism for which the only goal is to calculate probability distributions of clicks? In fact, the answer is **no**. One particular set of experiments, involving *decay* processes, implies that we have to consider the existence of an extra entity in the whole story, the *in between*(IBA) or *missing* apparatuses(MA), which appears to be an active physical entity.

To describe a *decay experiment*, we first have to label a click-source. It appears that in nature apparatuses exist, or can be built, that produce different kinds of click patterns when the detector is placed very close to the click-source or even without any space between the two. These different patterns make it possible to classify the click-sources: electron-click-source, photon-click-source, muon-click-source, etc ... Note that here the words electron, photon, muon are introduced with a definition (through a physical procedure). Few books in microphysics do that. We are going to call this definition, which is based on experimental facts produced with a particular apparatus setup, a *definition setup*. We insist that these words are not, definitely not, introduced by describing some corpuscle entity *out there*. It is interesting to note that to define the words electron, photon, muon, etc .... it was necessary to introduce pairs(click-source, detector) of apparatuses. A click-source or a detector apparatus alone cannot do the job. This will be discussed again later.

Armed with this definition and classification of click-sources, we can observe that it is possible to find (or build) in nature the following setup. A click-source can produce a first kind of click pattern in its associated detector placed close to it, but can produce a different kind of pattern when the detector[for simplicity we assumed the same detector for the two patterns] is placed farther from it! Moreover, the pattern is not only changed by some geometrical factor (for example a different size of *electromagnetic shower* click pattern) but can also be transformed to a click pattern which is associated with another kind of click-source! A typical case is with a muon-click-source and an electron-click-source. If a detector is placed close to a muon-click-source, we observe a muon-click pattern but if the detector is

placed some meters farther away we no longer observe a muon-click pattern but an electron-click pattern!

So what?

A textbook explanation for this transformation is to say that a corpuscle (for example a muon) is flying around and that it transforms itself in mid-flight into something else (an electron and two neutrino corpuscles in case of the muon). Now if, because of BAB, we cannot keep the corpuscle idea, then we are compelled to conclude that besides the source and detector apparatuses there is, in between them, an extra entity that plays the active role of transforming the observed click patterns, and does this according to the relative position of the apparatuses at our human scale. To further analyze this *in between entity*, we have to find a name for it, and we have the right to name it because we have found experimental facts that reveal the existence of this entity. We have to take care in choosing the name. In particular the name must reflect the fact that we deal first with apparatuses, that apparatuses are axiomatic ideas. One name that we have found so far is the *Missing Apparatuses*, the MA in short. *In Between Apparatuses*, or IBA, could be a good name too.

6.1 The Missing or In-Between Apparatuses; the MA or IBA

This name has the huge advantage of using a set of words words that make clear sense to us. In particular this is much better than attempting to name the in-between entity by *quantum vacuum*, a name that uses the word *quantum* which has been so ill defined since 1925! We claim strongly that having identified the in-between entity as an active one by using the concepts of apparatuses and clicks, and having been able to name it with clear words is a huge conceptual step in the story of seeking the right ontology, the right objects, for microphysics. So to the question: is microphysics only a click-ology? We can now answer no, it is not. Microphysics must be viewed, because of decay-type experiments, as the study of apparatuses and of the outsider MA. We see also that *decay* is a highly misleading word since it relies on a particle idea. In the following text we are going to use *click-transformation* experiments instead.

The MA makes it possible to restore object orientation in microphysics. The MA is *something out there* that has properties of its own, and one of these properties is to transform click patterns. We also see that the MA is related to space defined through the relative position of apparatuses. Nevertheless, because of the click pattern transformation phenomenon, this space cannot be reduced only to geometry. It is more than geometry, and we can already conclude, without any mathematics, that this phenomenon clearly rules out any theory such as the special or general relativity, that attempts to model space (space-time in fact) between apparatuses by pure geometry alone!

6.2 What is the mathematics for the MA?

In the HSF, between the ψ of the click-source and the operator for the detector, there is an extra entity called the **Hamiltonian operator**. By using the time-dependent Schrodinger equation, the Hamiltonian operator transforms (evolves) the ψ. By doing a spectral decomposition of the evolved-ψ in terms of the local ψs of the detector attached to each outcome (cell), we can calculate the observed probability distribution of the firing events (the clicks). The Hamiltonian is clearly describing something in between the click-source and the detector apparatuses. Therefore it is natural to attach it, in our click-ology interpretation, to our MA. We might, therefore, called them *time-evolution apparatuses* instead(TEA). So each of the essential components of the HSF now receives its interpretation. We claim that these interpretations are based on better grounded ideas than the ideas found in QM (as defined earlier).

6.3 The mathematics for the MA of a click-transformation experiment

A simple Hamiltonian, such as the one describing the *harmonic oscillator* in QM, cannot model the transformation of click patterns. We need more sophisticated mathematics for that, and it appears that this mathematics already exists! It is nothing more than the mathematics of a *Quantum Field Theory* (QFT) and in particular the mathematics of QED(Quantum Electrodynamics) for the microphysics of electric-charge-click-sources. However, the QFTs suffer the same problems as QM at the level of the ideas that prevent a clear understanding of them. Mainly, it is that the QFTs still make heavy use of a particle vocabulary.

This vocabulary is visually reinforced by the intensive usage of the Feynman diagrams. A Feynman diagram is a nice trick for doing a perturbative calculation, but it is a huge intuitive and ontological trap from the very moment that the branches are attached to the idea of particle, since the word *particle* remains suspicious. Moreover, the QFTs introduce new words such as *virtual*, *quantum field* and the winner, *quantum vacuum*, that lead straight to the trap. The word *virtual* qualifies a particle attached to a branch of a Feynman diagram, but it is definitely not clear whether the *virtual particle* is something *out there* or not! If *quantum vacuum* is associated with *no particle*, and that particle is suspicious, then quantum vacuum is suspicious too. The best that we can do here is to say that *quantum vacuum* is the name of the mathematics symbol $|0\rangle$ found in the mathematics of a QFT, that is all. No clear idea can be associated to these two words. The same for *quantum field*; here too the best solution is to say that it is the name of an operator in the mathematics of a QFT. About *quantum vacuum* - if people attempt with these words to qualify the in-between apparatuses (as for example the *in between* of the two plates of a Casimir setup), we claim that the MA or IBA or TEA terminology is superior since it is much better defined.

This being said, a strong point with QFTs, and especially QED, is that their mathematics is very impressive in giving the right probability distributions, and especially the ones of click-transformation experiments. So we are perhaps in a situation where we have found the right mathematics but not yet the right ideas for them. Now let us see if we can restate QFTs with our click-ology ideas. If we look closely, the relationship of a QFT to experimental physics is established only via an input and an output *state*. In general the word *state* is defined by using a particle terminology, for example an input or an output state with an electron and a positron in it with their own $4-$momentum. In the formalism, it is modeled with symbols such as $|e^-, e^+\rangle$. Now if BAB is right, we can no longer retain such an idea since the idea of a particle is no longer relevant. Instead, we have to rethink the symbols above as modeling some apparatus able to produce a click pattern characterizing the association of an electron-click-source and a positron-click-source as defined previously through their definition-apparatus setup. Note that the click-source apparatus could be something very complex. It could be a full accelerator setup! For example the LEP machine in the 1980s for the symbols $|e^-, e^+\rangle$, or the LHC for the symbols $|p, p\rangle$.

The final state, which is modeled with the same kind of symbols, has to be conceived as something attached to a click pattern in a whole detector such as the ALEPH detector during the LEP era or the ATLAS detector at the LHC. In the formalism, to pass from an input state to an output state, there are a lot of in between operations and symbols that appear. What is the ontologic status of these in-between mathematics symbols? We are going to associate all of them as a model of the MA or IBA or TEA, which is something that exists for us and is very well defined as an object for us to work with (so unlike a *quantum vacuum*).

Is there some specific set of symbols that maps to the MA? In fact yes, we already have that. In a QFT everything is encrypted in the **Lagrangian**. It is from this entity that in-between manipulations are derived and that final probability distributions are calculated. So the Lagrangian can be seen as the piece of mathematics representing the MA. We must point out that the symbols for the MA cannot be $|0\rangle$, since $|0\rangle$ does not bear any transformational property.

This being said, we have now a better understanding of the meaning of the mathematics of a QFT and what QED is about. Moreover, the complexity of the mathematics attached to the MA reinforces the idea that this entity is far from being a *gentle space-time continuum* as described by the two relativities (Special and General), and various other space-time oriented theories.

In general we remain amazed at the complexity of the mathematics dealing with microphysics (and representing the MA for us). This algebraic inflation, originating from the introduction of the **i** of complex numbers by Schrodinger in his time-dependent equation, culminates in the SUSY (supersymmetric) mathematics where we end up manipulating extra dimensions made of Grassmann numbers. (I wonder if SUSY defenders really believe that there are extra dimensions made of non-commuting numbers *out there*?)

6.4 What is high energy or particle physics?

We can now have a better understanding of the part of science called High Energy Physics (HEP) or .... particle physics! Experimental HEP is nothing more than the construction of detectors and accelerators seen as click-source apparatuses, the classification of click patterns, the classification of natural

click-sources and the study of the click pattern transformations.

The theoretical aspect of HEP consists of finding the right QFT with the right Lagrangian that encodes all possible click pattern transformations found so far and makes possible the calculation of the right probability distributions of clicks in detectors.

There is a lot to be done and someone can spend a whole research career in HEP science!

6.5 What is the *Standard Model*, the *Higgs*?

The *Standard Model of particle physics* (!) can be defined now as the best Lagrangian discovered so far that encodes all known click-sources and observed click patterns.

An interesting point in the QFTs is that a *Lagrangian logic* of its own appears in them. If we take a Lagrangian, it may be deduced from another Lagrangian with less symbols, in particular by applying transformations justified by mathematical symmetry criteria. The Lagrangian of the Standard Model is such a *less symbols* Lagrangian. To model correctly all the *weak decay* click patterns, the *reduction of symbols* procedure requires also the introduction of a *Higgs* term that can be related to a click pattern of its own, but a click pattern not yet seen in any experiment!

Finding a *Higgs click pattern* is the whole point of *seeking the Higgs* at the LHC. In particular *seeking the Higgs* cannot be *looking for a new little thing flying around*. The *Higgs* is going to be a new click pattern never seen before in any experiment, a pattern that will guarantee the mathematical consistency of the *best Lagrangian discovered so far*, a Lagrangian that should be interpreted as describing ... **time-evolution apparatuses**!

Does the Higgs term explain or solve everything at the conceptual level? In fact no, far from it! The Higgs term does not solve the integration of gravity in microphysics and it does not address, as BAB does, more fundamental issues concerning our understanding of microphysics.

7 Restoring *OO* in microphysics

We have seen that we can restore object orientation, and then good intuition, when dealing with microphysics. A first step is to get rid of the words corpuscle, particle and probably wave since nothing in our apparatuses measures or detects waves. Restoring OO could be done by the drastic rethinking, revisiting, of all the vocabulary used so far when dealing with microphysics. If some words are to be retained (such as electron, photon, atom,. . .) they must be carefully defined, or redefined, by using a set of axiomatic words (apparatus, click, time-evolution apparatus) that make sense for us. We claim in these notes that this is possible by restating the Hilbert Space Formalism as a click-ology completed with the TEA entity.

After having helped to recover some intuitive comfort in microphysics, we are going to see that this click-ological point of view can also help in one of the outstanding problems in todays physics; the problem of the unification of meso-macro-physics with microphysics.

8 Gravity, General Relativity and the Grail of Unification

The mathematics of the QFTs is the best candidate we have for microphysics. This mathematics makes it possible to recover all click probability distributions observed so far, and this, sometimes, with astoundingly accurate precision.

Nevertheless, gravity still eludes QFTs. Here we use *gravity* as a word originating in our every day experience in the meso-scale and, as such, does not pose a problem to our intuition. The best mathematics we have for this phenomenon observed at meso-scale and macro-scale, is the mathematics of General Relativity (GR in short). GR models this phenomenon as a curvature property of a Riemann continuum in which physical quantities are mapped on tensors. The main idea of GR is that gravity can be explained as an effect of space-time which is seen as an entity having a dynamics of its own. **Awesome!** With GR, space-time truly becomes an object with properties. GR is OO and space-time is one of its objects.

For meso-scales and macro-scales, GR theory is a brilliant example of *doing physics* as defined at the beginning of these notes. First, we have clear and elegant ideas; there are bodies ($X^\mu(s)$ in the mathematics) and fields *out there* embedded in a space-time which is an object of its own. Second, we have good mathematics, such as tensors and Riemann geometry, with a nice mapping of ideas to mathematics symbols; in particular space-time is mapped to a metric tensor field. Third, we have a good match with experiments and observations in the meso-macro scale domains. Defenders of GR mention a match up to 10^{-14} precision for the period of pulsar PSR 1913 + 16.

However, GR does not cover a good part of microphysics and in particular the click pattern transformations. GR is not a theory of microphysics. For example, it cannot explain the discrete spectrum of an illuminated hydrogen gas. For almost a century, physicists have been grappling with a difficult problem: we have a good set of mathematics for meso-macro scales and another set of good mathematics for microphysics but each has a logic of its own and we have not yet found some appealing common foundation mathematics to bring them under one common banner! Being able to do that is the challenge of the unification of GR and QM.

It is interesting to note that most unification attempts are done at the mathematical level where theoreticians attempt to bring under the same algebra the mathematics of the HSF and the mathematics of GR. For us it is not so surprising that these attempts at *unification by mathematics* failed so far. It seems that we forget that we are dealing with physics, and that a part of physics is ideas about what is *out there*. We don't see how we can unify at the level of the mathematics if we have not unified at the level of the ideas! If the problem has resisted solution for so long it is probably because we have not yet put the finger on the right set of ideas that would lead to a common underpinning mathematics for micro-meso-macro scales. Manipulating mathematics symbols having no mapping to an idea about something in nature is not doing physics!

As an example we can have a quick look at String Theory. What is String Theory? What is it about? Is it the science of one dimensional clicks? Do string theoreticians expect to see one day or another spaghetti clicks in a detector? Is String Theory only a mathematical trick to have more degrees of

freedom for the mathematics between the input and output states in order to fulfill the goal of calculating the probability distributions of zero-dimensional clicks? If the idea of zero dimensional objects is already ruled out by BAB, does it make sense to look for a microphysics based on objects of one, or even more, dimensions? What is sure is that if BAB is right, it would be highly surprising that a String Theory for microphysics turned out to be right!

This is making an important point about doing theoretical physics - it should be done bottom-to-top and not top-to-bottom! The understanding of String Theory will follow from an understanding of QM first and *not* the other way around!

8.1 The right question: what are the apparatuses in GR?

Could DSAT and the TEA help in going farther on this problem of unification? We can easily answer *yes*, simply by asking the question: what are the apparatuses in Special Relativity (SR) and GR? When reading Einstein, for example, the response to this question is quite simple; the apparatuses in SR and GR are .... sticks and clocks! SR and GR are based on the idea of a space-time continuum that assumes that, whatever the geometric scale, we can assign a coordinate 4-tuple (x, y, z, t) to all events and also to all space-time points. The assignment of coordinates done by one observer defines a coordinate frame. A frame is nothing more than the piece of mathematics representing a measurement apparatus in SR and GR. Moreover, these theories assume that we can assign two coordinate 4-tuples to one and the same event, in particular from two frames representing two *observers* in motion relative to each other. This kind of double assignment of 4-tuples to a same event is at the core of the encoding of relativism in SR and GR.

Having two 4-tuples, we pass from one to another with a *transformation*. In SR, it is the Lorentz transformation (LT) that represents observers in a uniform movement relative to each other. In GR, it is a general $r^{\mu}(x_0, x_1, x_2, x_3)$ transformation representing any kind of relative movement. By using tensors, the SR and GR formalisms make it possible to write an expression describing a physical law in such a way that the expression stays the same, has same form, after transformation. This constancy of form represents, in the mathematics, the idea of relativism that says that the laws of physics

should look the same whatever we observe the *out there*.

This is great, but the absolute coordinate assignment is ... a myth! We cannot build a detector covering all space-time for all scales, that is too idealistic. At micro-scale, we cannot use a stick to do measurements within a presumed *atom* object.

Moreover, the idea of a double assignment of 4-tuples to a same event does not hold either at micro-scale. Supposing we keep the idea that light is made of hypothetical photon objects, most of the time a measurement on one photon, for example done with a photomultiplier (PM), is said to destroy the photon. So, in such a theory *with photons*, we may assign a 4-tuple to a photon in the frame defined by the PM, but we can no longer associate a 4-tuple to the same photon from another moving PM since the photon object .... no longer exists!

This loss of double assignment is much more striking with an apparatus-centered point of view. In this case an event is a click which is, by definition, attached to a cell of a detector, so a click cannot be attached to two detectors, whether they are in movement or not relative to each other. The loss of multiple 4-tuple assignments is natural here. DSAT comes straight in with the right point of view and the consequences are drastic.

Since the *observation* (therefore a coordinate assignment) of a *flash of light* (instantaneous event) by two different *observers* (frames) in movement relative to each other (for example, one observer in a train and the other on the platform) is the starting point of Einstein's reasoning that leads to SR and then GR, it must be concluded that if, at micro-scale, we can no longer do this *observation* (4-tuple assignment), then it is the whole SR and GR that collapse like houses of cards at this scale.

The loss of double assignment destroys the way that relativism is encoded in *frame based theories*. For example, there is no reason for the mathematics of micro-scale to be *Lorentz covariant* anymore. If the LT makes no sense, the idea of *constancy of speed of light* at micro-scale is highly questionable because the LT was introduced to encode this constancy in the formalism. Such questioning about light concurs with the BAB argumentation that tells us that the word *photon* cannot be associated with a corpuscle *out there*: how

can we speak about the speed of something, if there is no .... *something*!?

The word *light* should be associated (as should *gravity*) with a meso-scale phenomenon. At this scale, within the Maxwell theory, we can associate a speed with this phenomenon which is modeled with waves. With a meso-macro scale theory based on multiple 4-tuple assignments to a single *flash of light* instantaneous event and the axiomatic idea that the *speed of light* is constant for all coordinate frames, we can build SR and GR. At micro-scale, the best that we can do is to associate with this *light* phenomenon the word *photon* defined by a pair of (click-source, detector), but the connection of this pair to the word *light* of meso-macro scale is now far from being ... luminous! One idea to achieve this association would be to define the word *lamp* as some kind of aggregation of photon-click-sources. So a *lamp* would be a *source of light*. The justification of such an aggregation brings us to the question of the constitution of apparatuses, a point which is going to be discussed later.

We also start to see how some unifying mathematics could operate; by keeping a frame logic for meso-scales and macro-scales (and so keeping SR and GR here), but by being able to evolve this mathematics to a logic not based on frames at micro-scale.

At this point an important question arises: if we discard frames, and therefore SR and GR for micro-scale, do we lose completely the idea of relativism at this scale?

8.2 Relativism with DSAT and the TEA

The idea of relativism is that physics laws should be expressed in the same manner whatever the way we observe nature. This sounds like a great idea and it would be a pity to lose it.

As seen above, in SR and GR this idea is mapped in the covariance of tensors that makes it possible to have a constancy in the form of formulas representing physical laws. The idea of relativism in SR and GR is then attached to a very peculiar way to *observe*. The idea of *observation* is attached to the fact of being able to assign coordinate 4-tuples to everything (then define a *frame* identified with the *observer*) and to the fact of being able to assign

two 4-tuples to the same event. Looked at from this point of view, this is a very particular manner of expressing relativism which comes from a too idealistic way of *observing*.

Now if we can no longer keep the frame logic for microphysics, what happens to the idea of relativism? Is it possible to define it without frames? It appears that we can do so quite easily with an apparatus-centered point of view. In DSAT, it is sufficient to state:

> Whatever the apparatuses layout, the way to calculate
> the click probability distributions must be the same.

This is straightforward, simple. We call the above statement the **Apparatuses Relativism Principle (ARP)**. How could it be represented in the mathematics? In fact it appears that the HSF already does that! Whatever the apparatuses setup is, we attach a ψ to a click-source apparatus and an operator to a detector-apparatus, and we have the same mathematical mechanism to get the probability distribution. We have to evolve the ψ, then decompose the evolved ψ to the operator local ψs attached to each possible detector outcome, and then take the square modulus of each term of the decomposition to get the probability distribution (Borns recipe). We already have a mathematical transcription of the idea of relativism in terms of apparatuses and clicks for microphysics! Moreover, we see that this way of dealing with relativism is much more physical than that of SR and GR, because it deals with the idea of *observation* in a much more accurate and physical way than what is done with sticks and clocks in SR and GR.

In fact, we may even say that Quantum Mechanics, if understood as a clickology, is already much more relativistic than the two relativities themselves! (at this point Einstein definitely turns over in his grave!)

It is interesting to note that in various unification attempts, theoreticians still keep the whole-coordinate-assignment idea and stay with the mathematics of tensors (extended with spinors) for microphysics. This may make sense from a mathematics point of view but it does not appear to be well-grounded from the point of view of microphysics. If we have to seek a new mathematics it should be a mathematics that keeps or restores the *multiple coordinate assignment of everything* for meso-macro scales, but goes to a DSAT+TEA+ARP+HSF logic for micro scales.

8.3 A key experiment related to gravity in microphysics

To make progress on gravity at micro-scale knowing that there are, because of BAB, huge questionings about the idea of objects at this scale, we have to do experiments that pose the right questions. Probably the best one that we can imagine would be a Bohm-Aspect setup with a gravity component, for example by introducing a *massive object* close to the *line of flight* (!) between the click-source and one of the detectors. So we have an experimental setup with the three cases:

1. no massive object on either arm.
2. one massive object close to one arm.
3. one massive object close to each arm.

If we label the three setups with $\sigma = 1, 2, 3$, then we could get runs $C_{exp}(\theta, \sigma = 1, 2, 3)$. What would the experimental curves be? Do we have a theory that could model this to give a $C_{some\ theory}(\theta, \sigma)$ to compare with $C_{exp}(\theta, \sigma)$? Moreover, an ideal situation would be massive objects able to induce a gravity effect interpretable with GR, then interpretable as a space-time effect. For example, some ..... black holes would be nice! (Micro-macro experimental physics at last!). Here we would truly mix gravity with questions about microphysics. We would learn a lot about gravity in microphysics here!

This kind of Bohm-Aspect-Einstein setup would be the most interesting since it would be related to the Bell reasoning. Something similar done with a variant of the two-slits or Mach-Zender setups by putting, or not, massive objects close to their *lines of flight* would be very interesting too.

9 What are apparatuses made of? The true fundamental question

9.1 QM textbooks?

With QM textbooks, we cannot answer this question because the word *particle* is not mapped to a direct mathematics symbol as a trajectory, and therefore we have nothing to recover a $XYZ_{body}(t)$ describing a body at our scale: we cannot build something from...nothing!

In QM textbooks, this question is related to subjects such as the *measurement problem*, the *quantum to classical transition* and the *decoherence*. A lot is written about them, but we don't quite see how physicists can make progress without some reliable micro-entity to build on!

For example, for us *decoherence* is, first of all, a mathematical manipulation within the HSF that shows that a *density matrix* (a version of ψ) can evolve to become diagonal. Fine, so what? If the density matrix is still not mapped to an ontological entity we have made no progress!

9.2 Bohm-model, Consistent Histories?

We may look for other interpretations that explicitly restore *particle* as an axiomatic idea, because with the idea of particle, and equipped with an aggregation mechanism, it is possible to recover bodies (a $XYZ(t)$ in the mathematics). However, we have seen already that attempting to keep particles along with the HSF leads in general to the introduction of additional weird ideas. In the Bohm model, in which there is a $XYZ(t)$, the weirdness is due to action at a distance.

Another candidate model is the *Consistent Histories*(CH in short). At proposed, CH contains *particle* as an axiomatic idea. The compatibility with the HSF is restored at the cost of axiomatic constraints in the method of calculating probabilities over possible *histories*. In CH, the pruning of *branches* makes it possible to recover physical bodies and *us*, as human beings[In CH, we are IGUSes! IGUS for Information Gathering and Utilizing System. In this respect, "We are OO thinkers!", looks, for us, a more relevant statement to start with]. This seems appealing, but looking closer it is still weird and the weirdness is related to these axiomatic constraints. From what we understand (?), there are objects that can have a property (position) in a first set of histories, but may not have this property (i.e. no position but momentum) in another set of histories said to be *not consistent* with the first set. The constraints allow one to avoid the assignment of a joint probability to sets that are not compatible (in particular not to assign a probability to *position and momentum*). So the constraints are related to the fact that *out there* there are objects for which we can no longer say whether they have a property or not! If this is the case, then it is here that our intuition rebels because this is definitely .... anti OO! In OO, an object has a property or

it does not. If we look for an OO interpretation of the HSF, CH is not the right horse to back and so on for other interpretations!

9.3 DSAT?

In DSAT the situation is de facto clean! The question *what is a click-source or detector apparatus made of?* is simply a bad question in DSAT. It is a bad question because apparatuses belong to the axiomatic ideas and as such they cannot be built from more basic ideas. We may think that apparatuses can be built back from the TEA, but this is not possible since the TEA is deduced from apparatuses. So within DSAT+TEA the question is ill-defined. We claim that being able to recognize this is *progress* compared to QM textbooks because QM textbooks cannot clearly state whether the question is ill-defined or not within their axiomatic ideas. Logically, a question can have an answer, but it may also be ill-defined in such a way that no answer is possible, and being able to see that a question is ill-defined is progress!

Nevertheless, we now come across another problem which is our DSAT restating of the *measurement problem* in QM. Agreed, by recovering understandable ideas at all stages in DSAT, we now have a very consistent approach to deal with microphysics, but this situation is not satisfactory (which is not, for us, the same as uncomfortable) because all our intuition tells us that an apparatus is made of something. We can take a hammer and smash an apparatus to pieces. What is then the status of the pieces? At the very moment when they cease to be a detector, do they belong to the TEA? Are they new click-source apparatuses that *do nothing*? Despite the fact that a theory based on the axiomatic ideas of the 4-tuple(detector,click,click-source,TEA) is highly consistent, it is still frustrating because it is not intuitively satisfactory at the level of the status of the apparatuses. All our intuition tells us that the apparatuses cannot be axiomatic ideas. This leads us to a rephrasing of the *measurement problem* in DSAT in which we state it as

> The *measurement problem* is the dissatisfaction we have that the microphysics of today leads us toward a consistent model (DSAT) in which apparatuses are axiomatic ideas, while our intuition tells us that they are not!

We see that this problem can be rephrased in a more OO way and therefore more comprensible way that allows us to ask the right questions. In particular, a straightforward one is: can we build more OO axiomatic ideas so that these new axiomatic objects can recover the (detector,click,click-source,TEA) of our click-ology?

9.4 *aparticles*

Noticing that the BAB argumentation (if granted) rules out corpuscles only for the *in between* apparatuses, one way to build more OO axiomatic ideas would be to introduce some corpuscles or particles as an axiomatic idea but dedicated to build *apparatuses only*. If we name this kind of corpuscle *aparticle* (for apparatus particle, or a particle that can be aggregated), the axiomatic ideas would be: aparticle and the TEA. Then the click-source and detector apparatuses would be made by an aggregation of aparticles. We could perhaps even restore an (emitter, propagation, impact) logic by saying that inside a click-source, an aparticle *does something* to the TEA, that this TEA modification is seen as a propagation at our scale up to the detector in which an aparticle reacts producing a click, with the mathematics describing what happens between the emission and the impact being the HSF.

Here is an idea; what if our brand new aparticle were nothing more than the ... *good old atom*?! If so, this *atom* should be equipped with some special property so that it can be seen, from a DSAT point of view, as an axiomatic idea to build back an apparatus.

9.5 Pairs of (emitter,receiver)?

Let us consider another idea. We have also seen that a *particle* could be defined by a 2-tuple (click-source, detector) in DSAT. A click-source without a corresponding detector is nothing, and a detector without its click-source is nothing either. So would it be possible to push the idea further and say that the *out there* is constituted by elementary pairs of (click-source, detector) or (emitter, receiver) and that these are the fundamental building blocks of everything? Assuming that a gathering of micro-pairs is possible, we would be able to recover a meso-pair(click-source, detector), but would also recover

the idea of being able to smash it into pieces.

To build a consistent model of elementary pairs, we would have to find some dynamics for these elementary pairs; at least some kind of crystalization dynamics to recover our scale (click-source,detector) and some kind of *soup dynamics* to recover the TEA from special states of micro-pairs.

10 Relationship with software

OO is terminology coming from software and it is not a coincidence that it is used here. We can have a detailed view of how data is treated by thinking a little about software for HEP experiments. This makes us aware that the primary input of *all that* is nothing more than a bunch of clicks appearing in detectors if the right conditions are met, and in particular if we have, at last, built the right 27 km long accelerator! Software in HEP makes us realize that trajectories and particles are secondary entities that are *recovered back* in a step of data treatment called *reconstruction*, a step which is targeted to build back the *final state*, the one after the *interaction* (dangerous vocabulary). Here we see that particles and trajectories are clearly something introduced by us, humans, when treating data.

To treat data, we need to write software and to do that we need some programming language. For a long time HEP computer programs were done by using procedural languages such as FORTRAN, but the 1990s saw the migration to object oriented (OO) programming. This kind of language puts a gun in ones back and compels us to think hard to know *what are the classes*, what could be considered as objects defined as standalone entities bearing their own properties. This questioning applied to HEP data treatment runs into questioning about a longstanding discomfort with QM. This questioning leads to the conviction that one key ingredient to understand microphysics (the missing link!) is the recognition that our way of thinking is naturally strongly OO, that we are *OO thinkers*. From here it is quite easy to reach the conclusion that perhaps the number one issue with the QM interpretation problem is that we have missed some key objects or key classes in the whole story.

11 Conclusions

11.1 Summary of the overall argumentation

After having defined what *doing physics* meant for us, we decided to examine the situation in microphysics. By granting the Bohm-Aspect experiment results and the Bell reasoning (BAB), we acknowledged that the concept of *corpuscle flying around* is hardly tenable for microphysics. We have seen that Quantum Mechanics (QM), defined as the Hilbert Space Formalism (HSF) attached to a particle vocabulary is intuitively misleading. We have seen that reinterpreting the HSF in terms of detector apparatuses, clicks in detectors and click-source apparatuses is a much more natural interpretation, especially if we have in mind how data is treated in experiments. We have named this interpretation the DSAT interpretation. This is a more natural interpretation because it is object oriented (OO) and OO is a natural driving paradigm for us. By using the three OO concepts: detector apparatus, click, click-source apparatus, and a reinterpretation of *decay* experiments we have revealed the existence of the in-between apparatuses(IBA) entity or time-evolution apparatuses (TEA) entity, defining it in a very clear way for us humans. We reached the conclusion that the TEA is an active entity having the capability to transform click patterns.

We decided that the mathematics of Quantum Field Theory (QFT) is the right one to describe the TEA, but we rejected any particle vocabulary attached to a QFT. Because of click pattern transformation, we saw that the TEA cannot be reduced to a space-time geometry, concluding that all theories, such as General Relativity (GR), which are based only on a space-time geometry for the *in between* entity cannot be good for microphysics.

We saw that the problem of unification of Quantum Mechanics and General Relativity, if taken only at the level of the mathematics, is doomed, and that it has, first, to be solved at the level of the ideas. We saw that SR and GR are based on a too idealistic conception of a measuring apparatus. We saw that the reconsideration of the idea of apparatus at all scales could lead to the right underpinning mathematics able to recover the HSF at micro scale and a Riemann geometry for meso-scales and macro-scales. Along the way, we stated an apparatus based relativism principle (the ARP).

We ended by rephrasing the problem of measurement in QM as the question *what is an apparatus made of?* and saw that it is an ill-defined question in DSAT. To overcome the frustration of not being able to *smash apparatuses*, we mentioned two ways to build models with axiomatic ideas that can recover those of DSAT, the first based on the *aparticle* idea and the second based on the idea of elementary micro-pairs(emitter, receiver).

11.2 Is nature OO?

So, to the question **Is nature OO?**, we can answer that for meso-scales and macro-scales the answer is **yes**. For microphysics, it looks like we have to yield some ground, but we believe that the answer is not yet **no**; a click-ological point of view is a card still to be played. What is sure is that, if nature is truly not OO at this scale, *doing physics* will become a weird pair (mathematics, experiments) activity, with no clear meaning for us because it is no longer grounded on .... reliable ideas!

11.3 Yes, we can!

About the famous quote of R.Feynman:

> I think I can safely say that nobody understands Quantum Mechanics

we say:

> if Quantum Mechanics is understood as the Hilbert Space Formalism attached to a particle vocabulary, then yes, we agree, we really don't see how someone can have a full understanding of Quantum Mechanics.

Now to the question:

Can we understand microphysics?

We say: yes, we can!

By using a click-ology and *time-evolution apparatuses* we can restore an Object Oriented point of view which, associated to the Hilbert Space Formalism, makes it possible to still understand this kind of physics.

11.4 No mathematics, only ideas

Some may note that there is no new mathematics in these notes. This was done deliberately because of the deep conviction that the number one problem in todays physics is more around the ideas than around the complicated mathematics. We hope that the chain of reasoning and ideas found in these notes may help those who have intuitive discomfort with microphysics. What is sure is that we, with his new DSAT, sleep much better now!