J. R. Croca

Dialogues on the New Physics

Complexity and Nonlinearity in Nature

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Cambridge Scholars Publishing

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This work is dedicated:

– To the young, generous and enterprising spirits, freed from dogmatic, obscure and conservative prejudices.

– To all those who recognize the profound interdependence between the complex entities in which the human being is included, and for that reason give priority to cooperation rather than aggression.

These are, in fact, the builders of the true progress of mankind.

To my granddaughter Teresa

J. R. Croca

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Finally, I would like to take this opportunity to publicly express once again all my recognition to Maria Odete for her ever-present and loving support in this difficult saga of the demand for truth.

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The author also wants to thank the kind and enthusiastic cooperation of the translator Jose Almeida.

I also would like to thank Gill Pavey of Wordhouse Writing Services for the efficient English proofreading of the manuscript.

INTRODUCTORY NOTE

The book that is now presented to the reader is the continuation of the previous Dialogues – *Dialogues on Quantum Physics, from Paradoxes to Nonlinearity*.[1]

The first version of the Dialogues was mainly intended to present to the general public, not only a more simplified version from the formal point of view of the ideas contained in *Towards a Nonlinear Quantum Physics*[2] but also to develop with a little more detail certain historical and epistemological aspects related to the foundations of quantum physics.

Like the first volume, this second volume of *Dialogues – Dialogues on the New Physics, Complexity and Nonlinearity* – aims to bring to the general public in a relatively accessible way, even those people without great mathematical preparation, the ideas contained in the book *Eurhythmic Physics or Hyperphysics, the Unification of Physics*.[3] In this work, a proposal for a global and unifying view of physics is presented.

It's a new way of looking at nature, the physis, based on the organizational genetic principle of eurhythmy. In this perspective, traditional physics, quantum physics, relativistic physics and classical physics can be seen as a particular cases of the new relational physics of the complex and nonlinear. In addition, the new physics or eurhythmic physics also aims to build a bridge between those commonly called hard or exact sciences and the sciences that treat highly complex systems. From these, we can refer to the human and social sciences – psychology, sociology, economics, etc.

In these sciences, which deal essentially with complex systems, the whole is generally quite different from the sum of its constituent parts. Under these conditions, these systems are generally not susceptible to an adequate treatment within the traditional simplistic, linear and Cartesian conceptual framework.

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[1] Croca, J. R. and Moreira, R. N. (2014). *Dialogues on Quantum Physics, from Paradoxes to Nonlinearity.* Cambridge, UK: Cambridge International Science Publishing.

[2] Croca, J. R. (2002). *Towards a Nonlinear Quantum Physics.* Singapore: World Scientific Publishing.

[3] Croca, J. R. (2015). *Eurhythmic Physics or Hyperphysics: the Unification of Physics.* Berlin, Germany: Lambert Academic Publishing.

In the Guise of an Introduction

The new version of the Dialogues, which I now have the opportunity and the honour to present to the reader enlightened and motivated by matters of science and knowledge in general, corresponds to the continuation of the fruitful and interesting discussion meetings on the foundations of the new physics which I've carefully recorded over time. Once again, I begin by asking the reader's indulgence for my rather crude and little refined prose. As I mentioned in the first version of the Dialogues, I don't have a great literary background because I'm an engineer.

Due to the needs of my profession I've been more in contact with the practical applications of science. However, not for a moment have I lost interest in the meaning and origin of the practical rules that we use in solving the real problems that arise in our day-to-day lives. Moreover, I'm convinced that this natural tendency to look for the origin or the meaning of things and not to content myself with the uncritical use of a set of recipes, of practical rules, was a precise and important reason for my professional and economic successes.

The first version of the Dialogues, which I was pleased to present, corresponds to the discussions around the foundations of quantum physics, in its traditional indeterministic or bohrean interpretation and in its causal and nonlinear formulation. Now, this new version of the Dialogues corresponds, first of all, to the discussions of the School of Lisbon on the extension and generalization of nonlinear quantum physics to the known physics giving rise to the new physics, or eurhythmic physics. This is, in my humble opinion, a revolutionary proposal – a new scientific paradigm – in other words, a new way of looking at nature.

As in the first version, these Dialogues correspond to the systematic narration of the interesting and stimulating journeys of discussion we had in various places and that I was careful enough to register, and now, once again, I am transferring to writing so the reader can also benefit from them.

The characters involved in this new narrative are the same, as the discussion group is essentially the same. However, I have to say that I feel extremely happy for having the opportunity to add the presence of a woman to our initial group. Contrary to a general believe, especially in certain masculine sectors, I am of the opinion that women always had and still continue to play an extremely important role in the progress of humanity.

To confirm this just think, for example, about agriculture. This invention, which is mainly due to women, was undoubtedly one of the most important discoveries made by humankind. Without this step there would be no progress at all. To this feminine element of our group I've attributed the name of Iris for it's mainly related to light, that element that has played and continues to play a fundamental role not only in physics itself but also in the evolution of humanity.

The first version of the Dialogues didn't include women for the obvious reason that there were no women in the discussion group about the foundations of quantum physics. Now, since the Dialogues are a narrative as faithful as possible to what actually happened, there was no reason to falsify it by introducing a woman into it in a perfectly arbitrary and unfounded way.

Only for information to the reader unfamiliar with the first version of the Dialogues, I will briefly mention that the names of the interveners have been Latinised and chosen in a way that seek to translate their attitude towards science and the world as much as possible. From these names I will only mention that of my great friend Argus, whom I ascribe this denomination for being related to this mythological ship which demanded knowledge across unknown universes in an initial instance and, at a later stage, wisdom.

The name I've chosen for myself is Liberius, as I consider myself as a lover of liberty, especially the one that's most difficult to achieve, which is freedom of thought. This is, because right from birth we are formatted by all possible means in a given pattern of thinking. Therefore to depart – even if briefly – from this pattern, this conceptual imprisonment, constitutes in my opinion a truly heroic achievement.

Liberius

Science until the Beginning of the Twenty-first Century

FIRST JOURNEY

We were in mid-September, at the beginning of the academic year, with people coming back from their holidays, some better or worse prepared to tackle the systematic hard work of everyday life again. Following the wishes expressed by the members of our research group, the Lisbon School of Eurhythmic Physics, we would finally continue our discussions around the possibility of elaborating a global interrelational new physics, of the complex and nonlinear. This new physics – more general – where emergency finds its natural place, would have the capacity to integrate the known physics as a particular case, at least with regards to its applications.

As you must understand, I was very excited not just for having the chance to see my dear friends again after a longer absence than I had wished for, but also for the opportunity to resume our interesting and stimulating discussions.

The meeting had been scheduled for Wednesday at about 8.00 p.m. at the Fábrica Braço de Prata. This building, next to the port area of Lisbon is – so to speak – the heiress, the continuation of the Eterno Retorno (*Eternal Return)* bookstore that is currently closed. It's a very spacious place constituting one of the most interesting places of the capital, especially for those who are interested in avant-garde culture in its most varied aspects. In addition to a bookstore and a bar, there are several rooms that can be used for lectures, meetings, concerts, film projections, exhibitions and other cultural activities.

Once arrived, I sat down at the bar and had a beer while I waited for the rest of the group. Soon after Argus arrived, accompanied by Fabrus. They sat at my table and asked for tea, as usual. Promptly, we started the conversation about the holidays with Argus saying that he had spent a part of his vacation at the thermal baths because it was a very quiet place and therefore lent itself wonderfully to the act of thinking. So much so, that when he went on vacation, he'd always take those more difficult problems with him to study which required a much greater effort and dedication. Fabrus was telling how much he had enjoyed himself sailing his yacht when Iris, Amadeus and Lucius arrived. What a feast! Everyone talking at the same time. When things calmed down a little more and the holiday talk lost its initial impetus, we began, as expected, to talk about science.

Following my request to the group to systematize the discussion, Argus began:

Before we begin presenting a proposal for a new physics, for a new way of looking at nature, the physis, it might be convenient to say a few words about what has been, in essence, our science, that is, the traditional science.
Traditional science, also called modern science by many, can be said to have had its beginnings in the seventeenth century, mainly with that great man by the name of Galileo. Naturally, as we all know too well, there was a whole plethora of precursors, of which I shall merely mention Nicholas of Cusa, Copernicus and Maestlin, the mentor of Kepler. For this great achievement, Galileo had to proceed with the unification of physics. Thus, he assumed on the one hand that both the supralunar and sublunar worlds had the same ontological nature and, on the other hand, he had yet to drastically simplify the problems to be dealt with.
Since we have already mentioned its ontological unification in previous discussions, now I will only mention the method, the simplification process he used in solving the problems, namely with regard to the movement of projectiles which is the basis of mechanics. It's worth noting in passing that at the time of Galileo the artillery was in full development. On the other hand, it could be seen that Aristotle's description of the movement of bodies was completely inadequate. As we know, the movement of a projectile fired by a cannon is not composed of linear segments, one inclined and one vertical, as Aristotelian physics intended and as this scheme seeks to indicate (Figure 1-1).

On the paper tablecloth, Argus drew the scheme I am reproducing as faithfully as I possibly can:

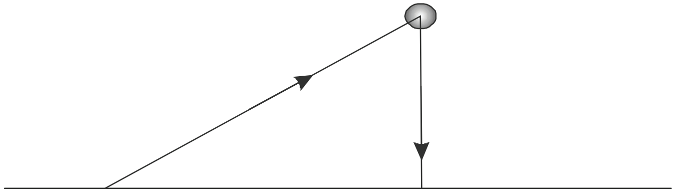

Figure 1-1: Movement of a projectile according to Aristotelian physics.

Argus continued: "Actually, the projectile motion is approximately parabolic, as anyone can observe."

At this point, Lucius decided to intervene.

Indeed, since the motion of projectiles fired by the cannons could be easily observed at the time, it would be very difficult to accept the explanation given by Aristotelian physics and its medieval variants. No one saw a violent inclined linear movement, resulting from an eventual *impetus*, which would be gradually lost, followed by a vertical drop, for the body to follow its 'natural' movement back to Earth. In fact, what was observed was a continuous movement, without any interruption, approximately parabolic, as Argus said.

Argus responded.

Thank you, Lucius, for your clarification! However, it should be borne in mind that it took about two thousand years after Aristotle to solve this problem of projectile motion. To solve it, Galileo had to invent a whole new process, a new way of looking at the world.
It is this process, this radical and fruitful method initiated by Galileo that I want to talk to you about. Since the projectile motion is very complex, Galileo will assume that this complex movement ultimately results from the composition of two more simple and perfectly independent movements: a vertical movement and a horizontal one, being that the complex motion of the projectile results from the simple sum of these two elementary motions. Under these conditions, he will study each one of these movements in a completely independent way. Let us then consider the vertical motion: In this motion, the projectile begins to rise, losing its speed progressively until it reaches a maximum height where the speed is null. Once it has reached this point of maximum height, it then starts to descend until it reaches the ground with a speed equal to that of the launch.
Now let's look at what happens to the horizontal movement: In this case the motion is very simple, always uniform, and naturally starts and ends at the same time as the vertical motion.
So, as can be seen, each part of the problem to be studied – the projectile motion – is of relatively much simpler treatment and its solution almost direct. The more complex total motion to which the body is subject to is then the simple sum of the two movements. In the sketch I am doing here, you can see how to proceed (Figure 1-2).

Argus, who we know is very talented in drawing, moved to the paper tablecloth once again to draw the sketch that I now reproduce as faithfully as I possibly can:

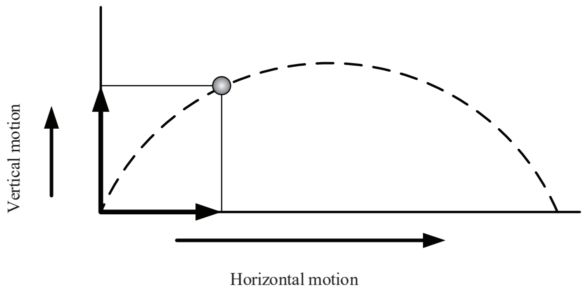

Figure 1-2: Movement of the projectile as a result of two influences.

Argus continued:

So, as you can see, the final motion of the projectile results from the sum of the two motions: the speed of the vertical motion is higher at the beginning and decreases gradually until it reaches the zero value. When the vertical speed of the projectile is zero, the projectile has reached the maximum height, as we know. In the next instant it begins to fall, with an initial speed equal to zero that progressively increases until it reaches the starting value. The horizontal speed of the projectile is constant and lasts the same time as the vertical motion of rise and fall. Note that in this figure only the position of the projectile, on the dotted line, is represented at every instant.

On the other hand, the observation of the relative motion, associated with his way of seeing the world, led Giordano Bruno to the conclusion that the movements of the various bodies could be taken as independent and therefore the process of linear independence was applicable. Thus, the speed for example, of one boat relative to another would be given by the simple difference of their velocities relative to the port, or, for example, in relation to the river banks.

In any case, this process of linearization or independence of the constituent parts of a whole, initiated by Galileo, received a more complete and more general theorization at the hands of Descartes, this great man of thinking. This great thinker will generalize the process initiated by Galileo and make it the lever, the key, in short, the ‘method’ to unveil the secrets of nature. This method, also known as Cartesian or linear – as already mentioned in our previous discussions – basically consists of the following:

When we have a difficult problem to solve we begin in the first instance by decomposing it, for example into two distinct parts. Next, we will try to solve each of the parts separately. If the solution of these two parts still proves to be difficult, we proceed to a new division and so on until each of the parts can be solved. The final solution will then be the simple sum of the parts. In this process of describing natural phenomena, studying the whole or its constituent parts is exactly the same thing. It's implicitly assumed that the different parts that constitute the whole when in reciprocal interaction do not change. That is to say, whatever the combination, the parts remain perfectly unchanged, thus always maintaining their own identity. Ultimately, as it can be seen, it is a question of assuming total independence between the constituent elements of the whole. Therefore, when in interaction − if we can truly designate this type of composition or combination as an interaction − the constituent elements always maintain their identity without suffering any modification, no matter how small.

From this linear principle of perfect independence and permanence of physical systems, naturally results the principle of action–reaction. This principle states that when an action is exercised on a body, it responds with an equal action in the opposite direction in order to preserve its own identity.

At this moment, Iris, who until now had been very attentively listening to Argus, said, "Argus, I don't quite understand this relationship between the action–reaction principle and the linear principle of total independence of physical systems. Can you explain this subject a little more?"

"With pleasure!" replied Argus, continuing:

In fact, the statement of this principle is the third postulate of Newtonian mechanics. Its form, as enunciated by Newton in his book *Philosophiae Naturalis Principia Mathematica*,[4] is the following:

To every action corresponds always an opposite reaction of equal intensity: or the mutual actions of two bodies upon each other are always equal in magnitude and directed in opposite directions.

[4] Newton, I. (1687). *Philosophiae Naturalis Principia Mathematica.* London, UK.

Another way of enunciating this principle consists of saying: when a force acts on a given body, this responds with equal force of opposite direction.

In the end, what this statement intends to say is that a body – a given physical system – seeks to maintain, above all, its total independence. In these conditions, in order not to lose its identity and to remain as such, it responds to the action exercised on it with an equal force with opposite direction in order to neutralize it. As we will see later on, this principle is only a very particular case of the application of a much more general statement which is the principle of eurhythmy.

In any case, the importance of this linear Cartesian method was clearly assumed by Newton in his *Principia*. Besides postulating the principle of action–reaction as the basis of his mechanics, he also postulates the principle of linear superposition. The principle of addition or linear superposition of forces serves to obtain the force resulting from the action of various forces applied to a physical system. This principle of addition constitutes, as we know, one of the important pillars upon which the whole of Newton's theory rests.

At this point, Fabrus entered the discussion.

At this point, I think it's worth mentioning that the principle of independence of forces, and their addition, is clearly assumed in the so-called parallelogram of forces. This gives nothing but the practical form of determining the resulting force from the action of several independent forces applied on a given point.

Let's consider, for example, the case of a boat in a canal being pulled with a tow rope from the two banks, as seen in this drawing.

With the help of Argus, he drew Figure 1-3, which I am reproducing below.

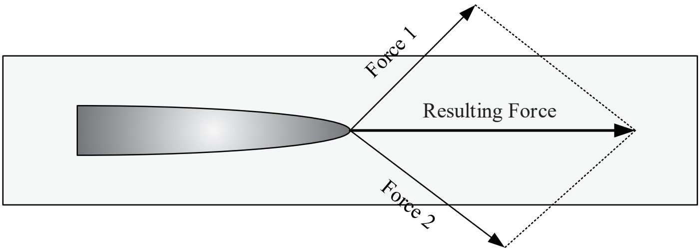

Figure 1-3: Parallelogram of the composition of forces.

Fabrus continued:

The resulting force, that is, the total force pulling the boat along the canal is the linear composition of the two forces considered as independent.
It should be considered, though, that this simple and extremely elegant formalization that students of classical mechanics learn to combine forces and velocities, the so-called vector calculus, only appeared much later in the late nineteenth century, mainly due to the work of Gibbs and Heaviside. I would also like to draw your attention to the fact that, even though vector calculus was not available, the study of mechanics didn't stop its development and application mainly due to the work of Lagrange, the great physicist-mathematician.

After a pause, Argus resumed.

It seems to me that it's still convenient to add to this beautiful explanation given by Fabrus on the parallelogram of forces, the so-called conservation laws of physics, namely the law of conservation of linear momentum proposed by Descartes, the law of conservation of kinetic and potential energy developed by Leibniz and the other conservation laws which have much to do with this principle of linear independence.
On the other hand, also as an implicit consequence of this method we have the fundamental notion, in the traditional physics, of the infinite referential both in space and time. Likewise, the so-called laws of nature, namely the second 'law' which tells us that force is

> proportional to acceleration, the 'law' of universal attraction and others, are assumed to be valid forever and ever, whatever the region of space.

Once again, Iris entered the discussion. "I don't quite understand the notion of 'referential' which seems so be so important after all! I wonder, Argus, if you could explain the subject more clearly ..."

Amadeus and Lucius acknowledged Iris's question, and I, truth be told, also joined forces with them because I think the matter needed to be better clarified.

"My fault!" admitted Argus, "I apologize! You are quite right, a notion as important as that of a referential deserves a deeper explanation."

> Although the origins of this concept can be attributed, among others, to Galileo and Descartes, it was mostly Newton in his book the *Principia*, which I have already mentioned, who postulates the existence of an absolute referential where the laws of physics would be valid. This referential then assumes a primordial status because it would then be some kind of 'stage' where matter would perform its role according to the immutable laws of nature. Eternal laws which Newton, eventually by divine inspiration, had discovered himself. This stage, this absolute referential would be naturally infinite in space as well as in time. In this context, the concept of absolute referential will from then on be one of the fundamental elements upon which classical physics is based and also, implicitly, relativity. In perfect analogy with the concept of absolute referential, others − as many as we like − are conceived as infinite secondary references. These secondary referentials are naturally in true motion relative to the absolute referential and in relative motion with themselves.
>
> Naturally, as you can observe, this attitude – unfortunately very much in vogue – of pretending to know the immutable laws of nature, is nothing more than an infinite arrogance, a sad apanage of many human beings. They naively believe they are the keepers of the truth – not of a sketch, a clue, a part of the truth as it would be expected, but of the ultimate and absolute truth!
>
> By now, an interesting story has occurred to me, which illustrates how vain these human pretensions are about the possibility of the dogmatic and absolute knowledge.

After a pause, Argus asked, "do any of you know the story from the Sufi about the *village of the blind people*?"

Only Iris knew the story, but still joined the others encouraging Argus to retell it.

He resumed:

> The Sufis are a mystical group of very remote origins, presently associated with the Muslim culture, who have a very particular way of expressing their ideas through small but significant stories.
>
> This story goes something like this: In times long gone there was a remote village where all its inhabitants were blind. These people lived their life quietly. However, this village had yet another very important and rather rare feature: all the inhabitants appreciated knowledge.
>
> One day they became aware that an elephant would pass near their village. As they had heard vague references to this fabulous animal it was no surprise that they all got very excited! Everyone wanted to 'see' the animal! However, the elephant would pass near the village but not close enough that everyone could go and see it. So, they assembled in council and appointed three of the wisest men among them to go and observe the elephant.
>
> However, as they appreciated scientific knowledge and method, they took care to establish a protocol of observation. So, to avoid any possibility of mutual influence among the observers, they stipulated that each one should make his observation in a perfectly independent manner.
>
> This salutary attitude used by the scientific method is very important. It's mainly aimed at avoiding that an experimental result which was only obtained by a certain research group is taken as a scientific fact. This is so for two main reasons:
>
> 1) The researcher or researchers carried out the experiment in good faith but possibly may have been mistaken. A perfectly natural situation that occurs very frequently given the great complexity of experimental systems. In this case, researchers may have made mistakes involuntarily and take one or more artefacts produced by the experimental device as trustworthy results.
>
> 2) The other reason corresponds, of course, to the worst of possibilities. In this case, the researcher or the group of researchers involved in the realisation of the experience want, at all costs, to present a certain type of result to justify the large investments

involved in the experiment. In these conditions, as the history of science very well illustrates, they adapt or sometimes go even further by eventually forging the experimental results they want to achieve. From these realities, results this salutary criterion of scientific validation:

For a scientific experiment to be considered trustworthy it must have been carried out in different laboratories and also by independent researchers. It's only when the results obtained by the various sources coincide that the experimental results can then be considered credible.

And so it was! According to the established experimental protocol, the three wise men set out for their mission and each one did the study of the animal in the best way he could. On their return, the whole village got together to hear the wise men talk about the elephant.

The first one, very excited, took the floor and said:

'You cannot imagine how wonderful this animal called elephant is. To tell you the truth, I don't even have words capable of describing such an animal. Just for you to have a rough idea, think for example that the elephant is some kind of snake – very flexible, or even a very thick rope from a ship'.

This wise man had palpated the elephant's trunk.

The second wise man stood up and said aloud:

'You're completely wrong! The elephant is not a snake! Not even a rope! What he most resembles will be, at best, a leaf of cabbage, long and thin.' This man had palpated the elephant's ear.

Totally exalted, the third wise man stands up and says:

'What snake! What cabbage leaf! The elephant is a dignified, noble animal with a rugged appearance in all similar to the strong, sturdy trunk of an oak tree.'

This man had touched the elephant's leg.

All the wise men were right! Partially, we must say, because they only knew a portion of the elephant. Yet they were all deeply deluded when they confused their share of knowledge with reality. The elephant was, without a shadow of a doubt, a much richer and more complex entity than they thought.

Therefore, as I told you, this story seeks to illustrate in a very human way our limitations in the face of such an incommensurable, vast and multifaceted reality.

"This story from the village of the blind is beautiful and instructive", said Amadeus. He added:

> We must always be aware of our blindness. We must be aware that in any historical era the human being is always naturally limited, whether it's by the experimental instruments he has access to or by the mental tools he uses.
> Just to give you a little idea, imagine what biology was before the discovery and use of the microscope. The notions of microorganism, cell and gene, so fundamental in modern biology, were then meaningless.
> That's why I say and repeat: blind are we, always, when faced with the immeasurable wealth and complexity of our Mother Nature!

Argus replied:

> I completely agree with you Amadeus! In fact, to claim possession of the eternal laws, the universal laws that govern, that rule nature, is a true madness. A complete lack of sense of proportions. The best we can aspire to is to be able to establish some principles, as general as possible, that allow us to describe and systematize the information we have in a given historical period. Meanwhile, we must be aware that when conditions change, and the experimental and conceptual universe widens, then possibly the principles set previously will no longer be very adequate to describe what is observed.
> A consequence of this euphoria about the Cartesian method for the resolution of problems, undoubtedly extraordinarily simple and fruitful, was the fact that it was accepted, almost by the entire scientific community, as the true, the one, in short, 'the method'.
> Naturally, as expected, there were some exceptions to this way of thinking. From these we should highlight the great figure of Leibnitz, followed by Huygens, Bernoulli and other researchers linked in general to the physics of waves. The painstaking work made by this sector of thinkers later gave rise to the field theories. However, all these developments were somehow integrated into the prevailing mechanistic paradigm, where, as we know, the simplistic, Cartesian, linear superposition principle reigned omnipresent and omnipotent.
> In any case, even in the so-called non-exact sciences such as sociology, economics and others, where we constantly come across complexity and nonlinearity, this method of perfect Cartesian linear independence was explicitly assumed as the model, 'the method' to

follow. Of course, in the case of these sciences, the result, as we can see, has been at the very least disastrous.
We must also consider that due to the inherent complexity and nonlinearity of natural phenomena, even in the so-called exact sciences, here and there, there were discrepancies in the application of the method. These discrepancies have been somewhat cleverly disguised, concealed by the introduction of supplementary *ad hoc* hypotheses which we know all too well and are suitably called attrition, friction, noise and so on. Thus, by the convenient introduction of these additional hypotheses, the natural complexity of physical phenomena is subject to a forced, or in certain cases, even abusive linearization, I must say in all truth.

At this point Argus paused to take a sip of tea then continued:

It's curious to note that yesterday as today, the human being, possibly due to his fragility and insecurity before the becoming, has always sought to hold to false certainties, to alleged immutable laws that govern nature, anywhere, always and forever. In this particular case, man believed, especially because of the great success of the classical physics, that he had finally discovered the truth, the method, the key that would allow him to have access to all knowledge. Of course, this comfortable attitude of believing that one possesses the truth, more characteristic of the dogmatic or religious way of thinking, goes against the true spirit of science. Science, in its essence, consists of a permanent demand for knowledge, ultimately to attain wisdom.
However, with the advent of the twentieth century, things start to get seriously complicated. This idyllic panorama, where the simplistic method of Cartesian independence reigned omnipresent and omnipotent, begins to show gaps. These difficulties are mainly due to the fact that since the third quarter of the nineteenth century, there has been an incredible advance in the production of scientific instruments.
Just to give you an idea of this enormous progress, it's enough to remember that when Galileo wanted to know if the speed of propagation of light was finite or infinite, he used his finger as a wrist watch to determine the time interval that light took in its path from the observer to a mountain just a few kilometres away and from the mountain back to the observer. Thus, by evaluating the number of pulsations between the emission of the light pulse and its reception

and knowing the distance travelled on the round trip, he could calculate the speed of light.
If we are generous with Galileo we may admit that he could, with this measurement process, estimate time intervals in the range of a tenth of a second. As we now know, light travels at about three hundred thousand kilometres (300,000 km) per second. So, in a tenth of a second the light would travel about thirty thousand kilometres (30,000 km). If Galileo could do the experiment under conditions such that the distance travelled by the light was greater or equal to that distance, thirty thousand kilometres, it was probable that he could eventually measure something.
I want to draw your attention here to the great difficulty he would have in achieving such a feat, since, as we know, the distance from Lisbon to Sydney in Australia is less than 19,000 km.
Thus, since the distance he used was of only a few kilometres, its measurements were, as expected, totally inconclusive.
At the threshold of the twentieth century, as I have mentioned already, due to the great development in the techniques of making scientific instruments, particularly in the field of optics, the interferometer appeared. Interferometers are devices that allow the comparison of the time interval between two complete oscillations of incident waves. As the duration of a full oscillation is what, in scientific language, we call the period of the wave, this extraordinary apparatus allows us to evaluate variations of time that ultimately are fractions of the period of the luminous wave being used. Since the period of the yellow light is in the order of twenty femtoseconds, this means that with these optical instruments it's possible to evaluate time intervals in the order of the femtosecond. A femtosecond being, as we know, equal to 1/1000 000 000 000 000 = 10^{-15}s. If we compare the accuracy of the measurements using the interferometer with those performed by Galileo, which were on the order of the tenth of a second (0.1 = 10^{-1}s), we find that there is an abysmal difference between them.

At this point Amadeus interrupted the conversation by saying "Argus, I don't quite understand how a device, however precise it may be, can measure such small time intervals. More so as we're talking about technology from the late nineteenth century. After all, how do these fantastic gadgets work?"

Fabrus, who was in high spirits said:

Well, Argus, if you'll excuse me, I'd like to explain the operation of the interferometer, because, as you know, I had the opportunity to assemble and use these instruments at the optics classes I gave at the Faculty.
I think that the best thing to do will be to present an apparatus which was simultaneously proposed by two physicists and, as result, bears their names. It's the interferometer of Mach and Zehnder, being that the basic operation of all the interferometers of this type follows a process in every way similar to this.
This apparatus is composed of a stable light source and a set of mirrors supported on a base with a high degree of stability. If the stability of the optical platform, where the mirrors and other optical devices are supported is not good, nothing can be observed due to the tremor of the fringes that appear and disappear in a perfectly random manner. In the drawing I'm going to do, for the sake of simplification, only the mirrors and the light emitting source will be indicated.

And so, aided by Argus, he began to draw the diagram I reproduce below:

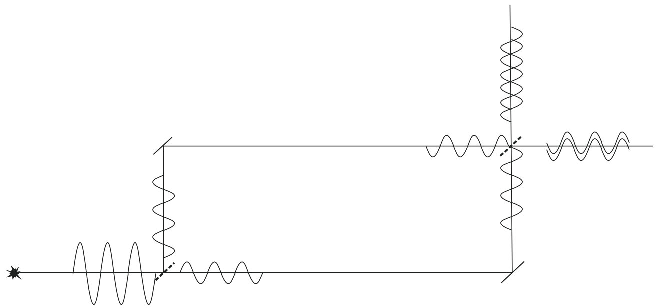

Figure 1-4: Mach-Zehnder interferometer with approximately equal paths.

After drawing the figure, Fabrus continued:

As you can see, the light wave emitted by the source arrives at a half-silvered mirror, represented as dotted lines. As we know, a half-silvered mirror is only partially mirrored so that one part of the light is reflected and the other is transmitted. In this case, the reflection and transmission coefficients are the same. This means that in practice half the light is reflected and the other half is transmitted.

Thus, the wave, the luminous impulse, when reaching the half-silvered mirror is partially reflected and transmitted as shown in the figure. If the upper route is equal to the lower one, after reflecting in two full mirrors, the two impulses arrive at the same time to the second half-silvered mirror as indicated in the figure. In this case, we can see the horizontal waves continue without any deviation and, on the contrary, the vertical waves are in phase opposition. In these circumstances, since the waves are in phase opposition, nothing is observed in the vertical output due to the destructive interference of the waves.

In the horizontal exit the waves are in phase and therefore they will come out reinforced. In conclusion, when the optical path (that is, the path travelled by light) is equal in both paths, nothing can be observed above because all the light exits horizontally. Under these conditions the interferometer behaves simply as a light transmitter.

Suppose now that we're going to increase the optical path of the upper arm of the interferometer with the aid of mirrors, as shown in this figure (Figure 1-5).

He started to draw a new diagram:

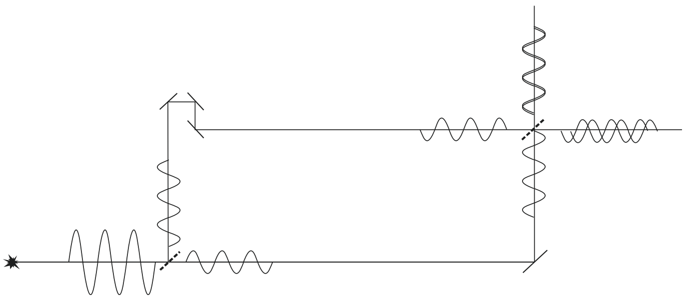

Figure 1-5: Mach-Zehnder interferometer with different paths.

In this case, as you can see, the luminous impulses that follow through the upper path arrive at the second half-silvered mirror with a delay in relation to the ones going on the lower path. This way the waves will overlap at the outputs of the interferometer more or less out of phase depending on the difference between the optical paths.

However, I must say in full truth, that in this type of interferometer, due to the great speed of light the time lag between the two paths is not generally achieved by the process indicated in the figure above,

which was presented here for illustrative purposes only. In practice, what we do is to connect the total mirror of the lower path to a piezoelectric system that causes slight changes in the optical path in the order of the fraction of the wavelength of light.
Keeping in mind these considerations, let us then observe what happens at the outputs of the interferometer:
Equal optical path. In this case, in the horizontal output the two waves arrive in phase. In the vertical output the waves are in phase opposition. For this reason, due to the destructive interference, the total wave resulting from the composition of the two waves comes null, and consequently nothing can be observed. Thus, the interferometer behaves globally as a simple light transmitter.
As the difference between the paths increases the waves in the horizontal output begin to overlap in phase but only partially.
This lag will increase until it reaches the maximum value when the waves are in phase opposition. In this case, due to the destructive interference the waves will completely be annulled and nothing, or no light, is observed on the horizontal output.
Under these conditions, and for this optical path difference, the waves will overlap in phase at the vertical output. Thus, for these experimental conditions the interferometer behaves as a pure reflecting mirror.
By measuring the amount of light coming from the two outputs of the interferometer we can evaluate the degree of superposition of the light waves and determine times that are fractions of the period of the incident waves.
Here is the important fact!

He paused, then continued:

Since the period of visible light is located in the band of the femtosecond (10^{-15}s), by accurately measuring the light coming from the two outputs of the interferometer, we are able to measure times that are fractions of the period of the light being used. So, by this extremely simple process, at least from the conceptual point of view, because in reality things are extremely complicated, we have the possibility of determining time intervals in the order of the fraction of the femtosecond.
Just to finish this topic, I would like to point out that today, mainly due to the use of optical fibre and other electronic devices, these

devices are extremely reliable and have a great practical application especially in the field of telecommunications.

After a pause, Argus spoke again.

Thank you, Fabrus, for the excellent explanation of how the interferometers work. Correct and at the same time so simple considering the complexity of the subject.
However, there is a fundamental point that although you mentioned in passing, I'd like to emphasize now. As we have already said in previous conversations, the accuracy of a measure ultimately results from the devices being used. More precisely of the element, the physical standard we use for comparison. The measure is no more than a comparison with this same pattern from which we will eventually evaluate fractions. For example, if we use a ruler graduated in centimetres the predicted accuracy of the measurement will be of the order of this pattern distance. Under these conditions we can then measure with the accuracy of the fraction of a centimetre. If, on the contrary, it's a watch in seconds, the accuracy of the measurement will obviously be in the order of the fraction of this pattern time. Thus, we can determine, i.e. measure, fractions of the second. What is really important about the measurements made with the interferometers is that, because of their very particular design, as Fabrus explained very well, they use the period of the light being used as a time pattern, i.e. the time between two consecutive maximum values of the light wave. Knowing that this period, this time interval, is in the order of the femtosecond, it follows that the accuracy of the measurements performed with the interferometers is in the order of the fraction of the femtosecond.

At this point Amadeus, feeling exuberant, said, "I finally understood! I understood not only how time measurements can be made with this great precision, or should I say, fantastic accuracy, but even more so, I have now truly understood what it means to measure."

After this outburst from Amadeus, Argus spoke again:

As I was saying, at the end of the nineteenth century there was a tremendous advance in the techniques of making scientific instruments. Of these, I have already mentioned the interferometer that allows us to determine very small time intervals. On the other hand, this exploding technological development also increased, in a totally unpredictable way, our ability to probe nature at a very small scale. This progress is mainly related to the experiments related to the discovery of X-rays, radioactivity and spectography.

The interferometer, given its great precision, allows us to study how the speed of light varies. Basically, the question was whether Galileo's principle of velocity addition was adequate for describing the behaviour of light.

Needless to say, everyone at that time believed in the universal validity of the law of linear independence of addition of velocities. Consequently, when the results of an interferometric experiment performed by Michelson and Morley were known, there was a great panic in the scientific community. Indeed, experience showed that the supposedly universal law of velocity addition could not describe the result of the experiments. One of its consequences was that the speed of light would be independent from the speed of the source. This means the speed of light measured by an observer is the same whether the source approaches or departs from the region where the measurement was being made. According to the principle of addition of velocities, when the light source approaches, the measured speed should be equal to the speed of light C plus the speed of the source ($V = C + V_{\text{source}}$) and therefore we would obtain a speed higher than C. On the contrary, when the emitting source departs, we would obtain a lower speed. This speed would then be equal to the speed of light less the speed of the source ($V = C - V_{\text{source}}$). As I said, in order to understand the results of the experiment it was necessary to assume that the speed of light did not depend on the speed of the source, which was against what people had believed until then.

However, given these results, that were a clear manifestation of the limits of the simplistic linear Cartesian approximation in the description of natural phenomena, what should be done?

Argus, at this point, took a dramatic break and resumed the speech a few moments later:

Was it recognized that one was dealing with complex and nonlinear phenomena where the reciprocal interaction between physical entities and the medium should be taken into account?

Was it admitted that the simplistic linear approximation of the independence of physical systems was no longer adequate to describe the experimental results?

In the face of such results, was it assumed that it was necessary to radically change our way of looking at nature?
Clearly not! As expected people were imbued, or should I say completely formatted in the traditional Cartesian way of thinking. Thus, as predicted, they would seek to explain the negative results of the Michelson and Morley experience within the Cartesian linear paradigm.
It should be noted that I have purposely used the term 'negative results' used in much of the scientific literature to reinforce its unexpected character. Of course, the result of the experience is only unexpected if we blindly believe that the 'laws of nature' are absolute, and not just simple and limited human constructs that, sooner or later, according to experimental conditions, will inevitably show their limits of adequacy in the description of natural phenomena.
Indeed, I must tell you that throughout this process, what we should be most surprised to see is that the law of addition of velocities, such a simple rule, can be successfully applied − i.e. it can be adequate in so many physical situations.
As we well know, Einstein, himself immersed in the Cartesian linear paradigm, will by all means seek to conceal the complexity of the process where the reciprocal interactions can no longer be neglected, because systems can no longer be considered as totally independent. Thus, to 'explain' the result of the experience he postulates the invariance of the speed of light. In this way, he created a dogma in physics that has been going on for more than a century. This dogma consists of proclaiming that the speed of light is always the same regardless of the speed of the emitting source or of the observer, and more so, that in the said vacuum, which only exists in our mind, the speed of light is c = 300,000 km/s, this being the maximum possible speed that any physical entity can achieve.
The rejection of the complex nature and the reciprocal interaction between light − those particles, those complex physical entities called photons − and the medium, will have disastrous consequences in the understanding of natural phenomena, thus dragging us on to the so-called paradoxes of relativity.
On the other hand, in the field of microphysics, i.e. on the quantum scale of describing natural phenomena, things were not well known either. At this scale of observation and description of natural phenomena, the problem of wave–particle dualism imposed itself. It is not known how, but quantum entities sometimes present

undulatory aspects, and some others corpuscular. This means that the quantum entities have a very strange behaviour that goes away from everything that was predictable – now they behave like waves, later on they behave as corpuscles (particles).

In the previous Dialogues we had the opportunity to talk at length about this subject of the wave–particle dualism, so I will not dwell on the subject now. I will merely say that we are faced with a complex phenomenon that is typically nonlinear. In these conditions, to obtain a more adequate description of the phenomena, it's necessary to abandon the linear Cartesian methodology and adopt, from the outset, an essentially complex and nonlinear treatment. We also know that Niels Bohr, instead of facing the situation as Einstein did, tried to hide the intrinsically nonlinear nature of quantum phenomena in his well-known principle of complementarity. This path leads directly to the postulate of the reduction or collapse of the wave function and thus constructs a supposed linear theory to treat quantum phenomena. This theory is linear throughout its domain except in the act of measurement, where the nonlinear and complex nature of quantum phenomena is introduced 'on the sly'. From this basic inconsistency, from this refusal to accept the complex nature of natural phenomena, were derived the quantum paradoxes which we have talk about so much, mainly a consequence of quantum indeterminism.

At this point, Fabrus, who was showing some signs of dissatisfaction, said:

I think, Argus, that you're not doing justice to Niels Bohr, especially when you compare him with Einstein.

It's true that he sought to explain the quantum phenomena in a linear perspective. However, I think that in his time it was not possible to do any better. On the other hand, it's also understandable that early twentieth-century thinkers, completely immersed in the Cartesian linear method, sought to explain the new phenomena in these terms. How could it be otherwise?

Niels Bohr, with the help of his School, the Copenhagen School, did quite a lot by succeeding in building a theory that was extremely coherent and endowed with an almost insurmountable predictive capacity up to the present. I know you agree with me that the fundamental characteristic of any scientific theory worthy of this name is its ability to predict and act in our day-to-day lives. That is

to say, the possibility of increasing our capacity for concrete intervention in the world.
On the other hand, as I have said several times, particularly in the previous Dialogues, Einstein's 'theory' doesn't have by far the same concrete capacity to act in the world. At most, and being generous, we can only point out a few concrete applications that have resulted from it. And even these can be perfectly achieved using another methodology.

Smiling, Argus replied:

I completely agree with you, Fabrus! In fact, Niels Bohr despite being influenced by the Cartesian method did a lot and did it well. As you very well said, Bohrean quantum mechanics is, beyond any doubt, a great theory. However, as with any human construction, sooner or later it will show its limits of adequacy in the explanation of natural phenomena. And, as you well know, this moment has already arrived. Of course, I don't intend in any way to belittle the value and importance of quantum mechanics. In the same way, it would be perfectly grotesque to attempt to minimize the importance of Newtonian mechanics. Both were and still are great human theoretical constructs.
It's perfectly understandable that the thinkers and scientists of the early twentieth century, completely immersed in the simplistic method of Cartesian linear independence, could not proceed otherwise. So, they tried to impose, at all costs, this method onto the study of new phenomena in both the domain of the microphysics and of the high speeds.
Now that we are more distant in time about a century later, we can have a clearer view of what twentieth-century physics really was. At the core, physics of the last century corresponds, in its genesis, to an attempt to force linearization on complex, interrelated and essentially nonlinear phenomena.
These facts lead us to the conclusion that it becomes necessary to develop a whole new and better way of looking at the physis, i.e. nature.
This new way, this new process of looking at nature will finally allow us to unify the known physics. This new global and unified physics called eurhythmic physics or hyperphysics, assumes as a starting point that the natural phenomena that we intend to describe either on the quantum scale or in the domain of the high speeds, near

the speed of light, require a global approach based on the organizational principle of eurhythmy due to the significative permanent and complex reciprocal interaction between physical entities.

At this point, we all looked at Argus with redoubled interest. The word eurhythmy had aroused great curiosity among us, and so we wanted him to continue. However, because of the late hour, and since so many of us were away from home, we decided to end our meeting but not without taking care to schedule our next journey.

SECOND JOURNEY

The venue booked for this meeting was Iris's house. It's a beautiful space in the outskirts of Lisbon. Iris had prepared for us a fine lunch, which was an honour we enjoyed. After lunch, as it was a beautiful day we went out to the garden and since we were all very motivated, we immediately started our cherished discussions.

In my role as narrator, I encouraged Argus to proceed with the clarification of the concept that had been left suspended from our last meeting, which was, as you may remember, the principle of eurhythmy.

Argus, who like all of us was in very high spirits, began by saying:

> In our last meeting I mentioned a fundamental principle that, due to its characteristics, allows us to organize, to unify all of our physics in a much more global perspective, also making it possible to obtain numerical predictions. As we know, the ability to draw up quantitative predictions is a fundamental condition in any theory of nature worthy of that name. This basic principle, as I've mentioned, is called the principle of eurhythmy. The name of this organizational principle, which allows for the mathematization of physics, written in the Greek alphabet has this form:
>
> Argus wrote the word eurhythmy in Greek on a piece of paper.

ευριτμια

> He continued:
>
> This word results from the composition of two terms: *eu* and *rhythmy*. The term *eu* can mean: the good, the right, the adequate, etc. whereas the element *rhythmy* has a correspondence with the path, the course, the harmonic movement, the rhythm and so on.
> So, the conjunction of the two terms, giving rise to the word eurhythmy, may, among others, have the following meanings:
> the harmonic becoming
> the good way

the good rhythm
the right path
the right way
the right route
the way of harmony
the true path
the path leading to persistence
the course of adaptation
the course of evolution
etc.

Of course, as you must understand, the path/ course/way/route, as you prefer, the becoming of a complex physical system is neither good nor bad in itself. There is no moral consideration being made here. What this principle establishes in fact is that in its course, in its becoming, the complex entity that is the physical system must ‘opt’, on average, for interacting in a reciprocal way with the medium in which it is inserted so that it can persist or survive. Of course, to do so it must adapt itself to a greater or lesser degree. In other words, it follows an evolutionary process. If it doesn’t follow this eurhythmic becoming, the complex physical system in its multiple reciprocal interactions with the medium will eventually perish, by disappearing as such – i.e. by de-emerging.

At this point Argus paused dramatically, then continued:

From the physical point of view this principle of stochastic nature tells us that a complex system, in its reciprocal interaction with the medium of which it is a part, just as we are part of the society in which we live but at the same time we keep our relative identity, must ‘choose’ on average, among the many possibilities, the path that best ensures survival. Deep down, everything happens as if the complex physical beings were endowed with a certain degree, although rudimentary, of consciousness that leads them to choose among the multiple possible options, those that seem better to them. If on average the options the complex physical system take are bad, from the point of view of its existence, it naturally ends up de-emerging, losing in this case its identity.

Amadeus, as always very interested in more transcendent matters, said, “Argus, I think this principle of eurhythmy is very interesting all the more because it seems to me that it's deeply connected with this complex problem called free will, which has given rise to so much controversy over the centuries." He paused. "Is free will a basic characteristic of nature, which begins to manifest itself right at a very elementary level?"

Argus became somewhat embarrassed then replied:

> Amadeus, the question you have formulated is extremely interesting, and, as you well say, it has been much discussed over the millennia by the most brilliant minds. However, as a physicist, I mean, as the natural philosopher I consider myself to be, I don't even dare to elaborate on such a difficult subject. From a predictive perspective, at the level of our present knowledge, everything happens as if the complex physical entity, no matter how rudimentary, is endowed with a certain degree of free will. Thus, and at the level of our present knowledge, the complex physical entity seems free, or at least it seems to have a certain degree of freedom in behaving as if choosing the path to follow. However, and this point is extremely important, nothing guarantees us that at a deeper level of knowledge such seemingly free choice does not ultimately result from a natural sequence of much more subtle causes and effects leading ultimately and necessarily to the chosen path.
> By the way, in order to better illustrate this question, I shall now give a concrete example of the application of the principle of eurhythmy, that takes place in our daily lives. Moreover, this example has the added advantage of helping to intuit its deeper meaning.

"Let us suppose we're in a vast field in the Alentejo" he said, and he showed us a drawing he had brought with him which I reproduce here (Figure 2-1).

At the beginning

Figure 2-1: A flock of sheep is set free in a field.

In this big field in the Alentejo we released a huge flock of sheep in an area where the pasture is not very good. Somewhere, far away at the opposite end of the field lies an area where pasture is really good.

Argus paused and turned to us all, who are following him with curiosity, and asked, “What do you think will happen? What predictions can you make about the sheep’s behaviour?” He paused again, but before anyone could even answer he continued:

I think everyone agrees that the answer to this question will be something like what is shown in the following figure:

Some time later

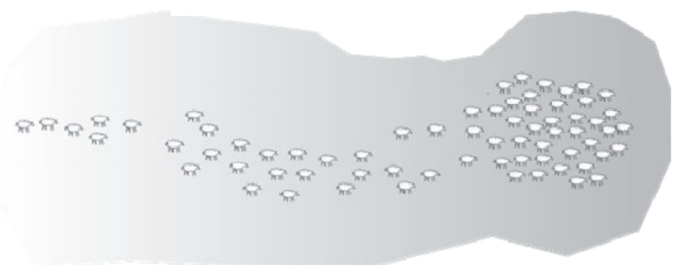

Figure 2-2: After some time the sheep move to the most favourable area of the field.

That is, the sheep will progressively and naturally move to the area of the field where the pasture is richer and more abundant. Under these conditions, after a certain period of time nearly all the sheep are located in the region where the pasture is better, as shown in this drawing.

He showed us the drawing, which I reproduce here as Figure 2-3.

As equilibrium is reached

Figure 2-3: After some time, equilibrium is reached.

As you can see, after a certain time some sort of equilibrium is achieved. In this situation, nearly all the sheep are located in the region of better pasture.

As one can conclude, it's possible to predict with some degree of certainty the average behaviour of the sheep, described precisely by the principle of eurhythmy. This means the sheep will move, on average, to the areas of the field where their intensity is the greatest, where the pasture is better and more abundant, in order to increase their capability to survive.

Of course, it will not be possible to predict the behaviour of a single element. In fact, a sheep may decide to move to the most inadequate areas of the field and eventually stay there. However, if that is the choice of that sheep its chances of survival are seriously reduced.

So, in this interrelational physics of the complex and nonlinear, in eurhythmic physics, it's not possible to predict the behaviour of an individual element. What can be predicted is only the average tendency, i.e. the global movement. Therefore, there is no determinism in the Laplacian sense of the term, where from the laws that would hypothetically govern nature, it would be possible to predict with absolute exactness the future either of a singular element or of multiple elements, since they are considered as perfectly independent. In this new perspective of eurhythmic physics, there is only one causality and never a strict determinism. However, any phenomenon always has an origin – a cause – and therefore there is no supernatural effect here, that is, no miracle. It's always about natural phenomena, i.e. specific behaviours from nature.

Therefore, and returning to the question from Amadeus, I would say that absolute determinism and absolute free will are extreme ideal concepts that in reality have no existence at all. What really exists is a certain capacity of choice, a certain degree of free will, bigger or smaller, but in any case, never absolute. Likewise, absolute determinism makes no sense either, at least in this way of thinking, since there is no perfect separation between the being and the medium. A complex entity is necessarily interrelational. Consequently, it does not exist outside a very specific context. The bigger its global theta wave, that is, the greater its degree of coherence, the greater will be its interacting region.

Therefore, it is concluded that any decision we make, however simple it may seem, always results from a consideration, a use of reason, so that we can persist in a given interrelational context. If our global theta wave, our sphere of interaction, our degree of coherence is small, probably our decisions will only be suited to our persistence or survival in a very brief becoming.

At this point, Amadeus intervened: "Argus, I don't understand your last statement. Could you please clarify what you just said?" We all agreed with Amadeus and looked questioningly at Argus.

Well, to clarify what I've just said, I think the best way forward is to use a real story by way of a metaphor.

This story which unfortunately, like so many others of the same genre, is true, consists essentially of the following:

In a certain agricultural region there was a great flood that left the peasants in the greatest misery. To minimize the effects of such a natural disaster, the international commission dedicated to these causes sent aid in the form of high-quality seed potatoes for them to sow in order to rebuild their farming activity.

The peasants, of course, were very happy with the gift. However, since they were very short of food, they decided to eat the special seed potatoes sent by the international community.

Once the potatoes were eaten, they were once again in the darkest misery but now with no chance of surviving in their beloved homeland!

Argus paused, then continued.

A first analysis of this decision-making process could hastily lead to the conclusion, I would say, that the decision to eat the potatoes was not rational, was not eurhythmic.
Nothing could be more wrong! The peasants' decision was, in fact, eurhythmic, rational. Since they were hungry and had the potatoes at their disposal, they decided to eat them.
The inconvenience of this decision was that they didn't realize that once they had eaten the special seed potatoes, they would be left with nothing and therefore would continue to starve.
Deep down, from an interrelational approach point of view, everything happens as if their universe of decision was very small. Or, in other words, their theta wave, their sensory range was very small. In these circumstances, they had no prospect of seeing or foreseeing any further in the future. So, under these conditions, given that they were hungry, the simplest and most immediate decision would naturally be to eat the potatoes.
However, if their degree of coherence were greater, their overall theta wave would be greater and therefore their sensory range had been much higher, implying, of course, a far greater predictive capacity. In these conditions, having an extremely wide sensory range, when faced with a decision-making moment, they would naturally have a much greater universe of possible paths. Thus, in the face of this greater possibility of choice, through the use of reason and in accordance with the principle of eurhythmy, they would take the decision or decisions that would maximize, on average, their ability to survive.
In this case, having a much more extensive sensory range, what would these peasants do?
Since they were very hungry it seems that a possible decision would be, for example: to eat some of the potatoes, say, 80%; the remaining 20% would be sown.
Given that their land was extremely fertile, especially after having benefited from the flood, the resulting crop would surely be very abundant. In this case, their survival would be assured not only in the immediate future but also in a more distant time.

Fabrus broke in.

By the way, I'd like to add that the same smallness of *sensorium* affects many people who present themselves in the media with great fanfare, as if they were the vanguard of humanity. It's mainly the people connected with capital!
Their activities, instead of being based on cooperation, on the pursuit of general well-being, are, on the contrary, dictated by an atrocious selfishness. Thus, they try by all possible means to dominate, crush and humiliate everybody else but them. As they have a diminutive theta wave, a coherence wave, they only care about the immediate. They forget or even despise the effects that their actions may have on the longer term. So, it's no wonder that the results of their pernicious activities are, if let alone, disastrous!

After a pause, Lucius said:

I see, Argus, these examples of the sheep grazing in a field in the Alentejo and of the peasants, as very interesting and suggestive. However, if you'll allow me, I'd like to ask you if there are no other situations that can also illustrate intuitively and more scientifically, if possible, this principle of eurhythmy which seems to be so important.

'I think you're right, Lucius!' replied Argus, and continuing, he said:

In fact, these examples of the sheep and the shepherds serve only as an illustration of the enormous adequacy of the principle of eurhythmy in the understanding of natural phenomena. They also have the advantage of showing that science, from the so-called hard to the natural and social sciences, is unique.
They are just different aspects, different processes to apprehend the same reality. However, as one may infer, they will hardly be capable of a relatively rigorous quantitative mathematical formulation, at least in the stage of development in which this discipline is at present.
Fortunately, there are other very old examples in the history of science which not only illustrate very well the adequacy of the principle of eurhythmy in the explanation of natural phenomena, but have the additional advantage of being subject to a mathematical formulation.

After pausing, Argus continued:

As we know, man has always been intrigued by the nature of light, i.e. with luminous phenomena, namely this complex phenomenon which is the reflection of light. From an early age the human being saw his image reflected by the surface of water at rest. On the other hand, we also know that the Egyptian ladies, in addition to the surface of the water at rest, wore instruments like polished metal surfaces, where they could observe when attempting to beautify themselves. The Romans developed and greatly improved the technique of producing these observation instruments by developing a specific alloy. This special alloy, consisting mainly of copper and tin, was called *speculum*. Hence, by extension, the word mirror (*speculum*) has come to designate these optical devices used to show images.

This natural luminous phenomenon was then regarded as something mysterious of a half-magical nature. Anyway, and this is the real issue, no one could explain, let alone even quantify, this strange phenomenon called reflection of light.

Heron of Alexandria, one of the natural philosophers, who worked in the Museum at the beginning of our era, had the intellectual courage to face this complex problem.

Heron considered that the reflection of light occurs when a luminous object, either because it has its own light or because it receives it from another light source, emits light that reaches the reflecting surface which in turn directs light to the observer. Thus, to study this phenomenon, it’s enough to consider one single luminous point of the object in question, for he thought that an image can be understood as a combination of many points. This luminous point S, belonging to the object, emits rays of light in all directions as indicated in the following drawing (Figure 2-4). In this drawing we see only two of the many possible rays emitted by point S.

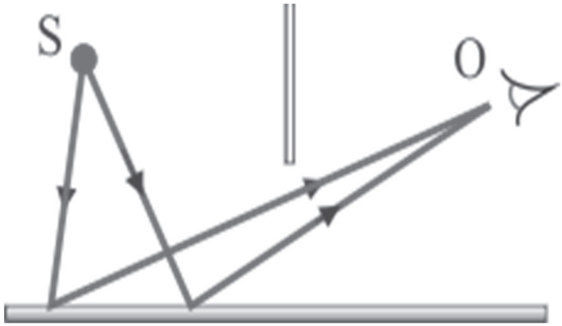

Figure 2-4: A luminous point emits a ray of light which passes the mirror and hits the observer.

These rays of light, emitted by the point S, arrive at the mirror on their path from where they are reflected and then eventually reach the observer O. In the drawing, for reasons of simplification already mentioned, only two of the possible optical paths are drawn. As can be surmised, many other routes will, in principle, be possible. However, and here is where the great contribution of Heron of Alexandria resides, he assumes that from of all possible paths, the ray of light will follow the shortest one. This hypothesis, as you might guess, is called the ***principle of the shortest path***.

From the principle of the shortest path, and by simple geometric considerations, Heron was able to derive the law of reflection of light. This law tells us that the angle of incidence, θ_i, is equal to the angle of reflection θ_r. That is, it obtains the equality $\theta_i = \theta_r$, known as the law of the reflection of light.

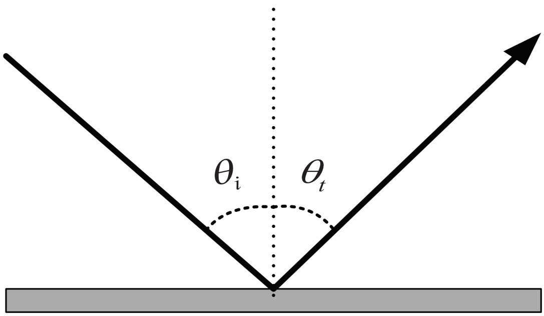

Figure 2-5: Reflection of light.

About one thousand and five hundred years later, in 1662, Pierre de Fermat sought to theoretically derive the empirical law of Snell which describes the propagation of light in two different optical means. For this he followed a process somewhat similar to that of Heron of Alexandria. Fermat considered that the ray of light, as it is emitted by the luminous point S propagating in the medium of incidence, for example air, will penetrate into the second medium made up of water and will subsequently reach the observer ‘O’ as can be seen in this figure where only five of the possible paths are represented.

Argus then drew Figure 2-6 on a piece of paper.

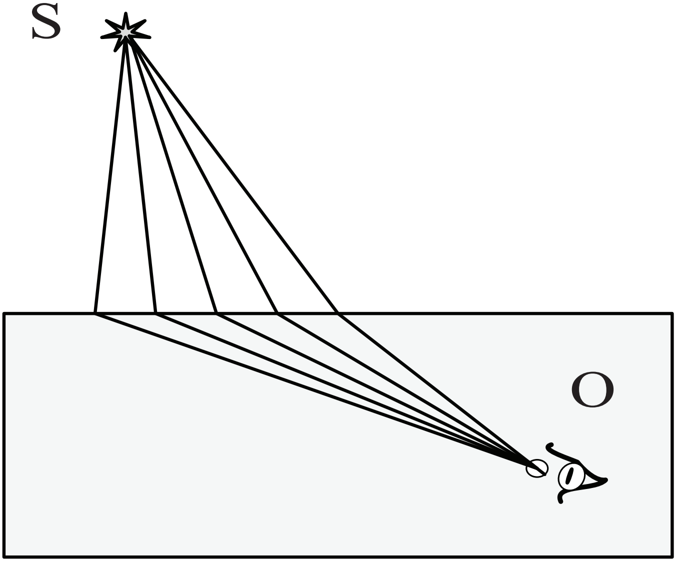

Figure 2-6: Fermat's principle of the minimum time.

Now, we know that in each optical medium light has a different velocity. In air its speed is about 300,000 km/s while in water it has a lower speed. From all possible paths to go from object point S to observer O, Fermat says that light follows such a path so the total time taken is the minimum. That is to say, that the global path of light, in different optical media, is described by the ***principle of minimum time***.

From this principle and by mathematical considerations, Fermat was able to derive the law of the transmission of light in different optical media.

Fabrus decided to intervene, saying:

As you may have guessed, Heron of Alexandria's principle of the shortest path is merely a particular case of Fermat's principle of minimum time.

In reflection, light always follows the same optical medium, so it always has the same velocity. Thus, if the whole course is done at

the same speed, it follows that the course that takes the shortest possible time is the shortest distance also.
Under these conditions, Fermat's principle of the minimum time is only a simple case of the principle of eurhythmy.

Fabrus stopped as if he was passing the topic to Argus, who replied.

As you can see, in this situation the light, the photons, behave as if they have a certain degree of intelligence, albeit very rudimentary. Their way of acting, their way of interacting is somewhat similar to some human behaviour.
To better understand what is at stake, I will refer to a very common example.
Let's suppose that on a beautiful summer morning we meet in the centre of Lisbon – in Chiado – and we intend to go to the beach in Caparica. To do this, we use a car that is parked nearby in the Camões Square, as our means of transport.
What route should we follow?
The shortest route from Largo do Chiado to Caparica, is surely to go by the Ponte 25 de Abril bridge.
Another alternative route, much longer, is to follow the Vasco da Gama Bridge.
So, everything would lead one to believe that the chosen path would be the shortest by the Ponte 25 de Abril bridge.
However, on the radio we heard that there is now a giant traffic jam on the way to this bridge. This is mainly due to the time of year, because everyone wants to go to the beach, and to make matters even worse, an accident occurred on the bridge.
In these conditions, in view of the present circumstances, we chose the longest path via the Vasco da Gama Bridge as our route. This choice, this decision, was dictated by common sense. If we had followed the shortest route by the Ponte 25 de Abril bridge, we would take a long time to reach the beach, whereas by the longest route, we can travel much faster and therefore arrive at the beach in good time. Although in this case the total distance is much longer, as we can move faster, the total time of the trip is much shorter. So, we too, under these circumstances, adroitly follow the principle of minimum time. I mean, we follow a eurhythmic path! In this case, we can say that our proceeding, our human behaviour, is, under certain circumstances, described by the principle of eurhythmy.

At this point Amadeus said, "It's extraordinary! It seems that light is also endowed with a certain degree of intelligence by proceeding in a manner similar to human beings. Who would say?" All of us looked at Amadeus in silence, agreeing with his words. After a few moments, Argus continued:

> Now, and returning to the subject, I would like to add that Fermat's principle of least time was followed by other principles of the same nature. Of these we shall refer to Maupertuis's principle in 1744, Lagrange's in 1788 and Hamilton's, all known as the principles of least action. It has been shown that, from the formal point of view, classical mechanics could be derived from these extreme principles. Naturally, as you have probably already noticed, all these principles are merely particular formulations of the more general principle of eurhythmy.
>
> However, the history of the principle eurhythmy can be said to have begun in the first quarter of the twentieth century, with the great French physicist, whom we have mentioned several times before – Louis de Broglie.
>
> In order to explain in causal terms the so-called quantum mystery, the problem of wave–particle dualism that has arisen in the realm of microphysics, this thinker proposed a totally radical approach. It was a question of breaking, for the first time, with the domination of the omnipotent and omnipresent Cartesian linear method where the action is proportional to the reaction. Thus, he proposed the principle of *guidage* that allows us to understand in an easy and intuitive way the wave–particle dualism. This principle, which de Broglie proposed for quantum physics, is the first version of the principle of eurhythmy.
>
> In fact, truth be told, initially the principle of eurhythmy began by constituting a generalization of the principle of *guidage* that was later extended from quantum physics to all the physics.
>
> Although it derives from physics, and in particular, from the formal and conceptual problems of quantum physics, the principle of eurhythmy is, however, generalizable to other sciences, so that its quantum formulation appears as a simple particular case.
>
> Formulated in a more general way this principle says:
>
> Any relatively stable entity is a complex system of interrelationships.
>
> In this way, and in general, an entity is defined as the emergence of a highly organized relational structure. This complex system of

reciprocal interactions with the medium tends, on average, to maximize its capacity of persistence.
Under these conditions, the principle of eurhythmy is understood as a genetic principle. More than stability and persistence, it seeks to capture the becoming and genesis of entities, understanding them as organized systems that only persist in constant interaction with the surrounding medium and in permanent reorganization.
The opposite of the principle of eurhythmy would be the disorganization, that is, the evolution of a system into a zone of destructive interactions in which the physical entity, the relatively organized form, would de-emerge and annihilate itself. This situation occurs frequently. It happens, however, that the de-emergence of complex systems is always accompanied by the emergence of other, new systems.
Thus, taken in this general formulation, the principle of eurhythmy is, in fact, a constitutive principle and not a mere reflective principle. Under these conditions, the principle of eurhythmy is thus understood as a constitutive process of physis of nature.

After this long speech, Argus took a few breaths before continuing. “The precise formulation of the principle of eurhythmy in the field of physics will be given later on when we talk about the basic principles of the new physics, of eurhythmic physics.”

At this point Lucius decided to intervene. “From what I’ve heard in our discussion today and in the previous one, it seems to me that one can conclude there are no absolute and definitive theories and therefore we must try to always go further.”

“Of course!” Argus replied.

As we have seen, the belief shared by most scientists at the beginning of the last century that they knew the laws that governed natural phenomena was totally unfounded. However, and from what we see, it seems that the vast majority of physicists have not learned this lesson. On the contrary, in the course of the twentieth century we have witnessed the establishment of two so-called absolute dogmas: one in relativity, the other in quantum mechanics.
In relativity, this is the establishment of the dogma of the speed of light. This dogma, as you know, states that the maximum speed that a physical system can attain is 300,000 km/s, that is, the speed of

light in an ideal medium, physically non-existent and designated by vacuum.
In quantum mechanics the pretension goes even further, for it has established a much stronger dogma. The dogma instituted by relativity is somewhat milder in that it has only a character of a strictly physical nature. In quantum mechanics, on the contrary, the dogma consists of fixing, expressed mathematically, the limits to human knowledge. This dogma states that there is an insurmountable limit to our predictive capacity, given precisely by Heisenberg's relations.
In the previous Dialogues, we saw how vain this assertion is, for presently, in the field of state-of-the-art technology, there is a whole range of concrete instruments that work beyond the limits imposed by Heisenberg's relations.

"You are quite right, Argus!" said Lucius, "in quantum physics, as you rightly said, this dogma of the absolute incapacity of the human being to know, to foresee beyond the limits imposed by Heisenberg's relations, has clearly been shown to be false. This confirms your idea, and I think we all share it too, that there really are no absolute and definitive theories."

"I wonder, how could it be otherwise?" exclaimed Argus.

Since physical theories are mere human constructs, and what's more constructed in a given historical time, in a given experimental and conceptual context, they will necessarily have to be limited. As human progress advances, new experimental evidence is emerging giving rise to new problems. In these conditions, it's not surprising to note that to resolve these new challenges, possibly the processes known until then may not be adequate. To face these new problems, these new challenges, it will be necessary to look at nature with other 'eyes' in order to be able to 'see'.

Argus looked at us for a moment before continuing.

A passage from *Mysterious Island*,[5] has just occurred to me – a book by Jules Verne, that great science fiction writer, who I think most of you will know. This passage from the book illustrates this point in a particularly interesting way.
Let us briefly see what this story is about, adapted to our context:

[5] Verne, J. (1847) *Mysterious Island*. Paris: Hetzel.

A group of people, travelling in a hot air balloon, are wrecked at night in an unknown place. As soon as morning broke, they had to make plans in order to survive in this lost place. So, to find out if they had landed on a continent or an island, they climbed a high mountain. Once at the summit, they found that they were on a lost island somewhere in the Pacific Ocean.

As they were coming down, the expedition leader occasionally picked up small stones from the ground. This operation was repeated with relative frequency, so much so one of the members of the group, a stout sailor, started to look uneasily at the expedition leader. He did not understand the reason why he was so worried about the stones that stood in his way. Could it be that knowing himself lost on an unknown island would have led him to lose his mind?

When they reached the temporary camp by the sea, they gathered to work out plans to survive on the island where they had crashed.

The leader of the expedition then took out the stones he had picked from his pocket. Picking up a yellow one he said, ‘As you can see, this stone is pyrite. Very good quality pyrite ... from this mineral we can extract sulphur.’ Taking another whitish stone with a salty look he exclaimed, ‘And, this one is saltpetre, almost pure potassium nitrate! As there are many trees on the island, we can use them to make coal. So, we have all the ingredients to make gunpowder. Once we have gunpowder, we will have better ability to defend against the possible beasts that may exist on the island.’

Picking up another small grey stone he had brought, he said, ‘This pebble is hematite. From it we can extract iron.’

He went on to state the characteristics of the other stones he had picked up and of their relationship with the plans to survive on the desert island.

As you can see, for our honourable sailor, what the leader of the group had picked up from the ground were stones, mere stones. This is because he did not have the knowledge necessary to know how to distinguish the stones and to know their usefulness. Therefore, he did not look with the eyes of ‘seeing’. For the expedition leader, who had some knowledge about geology, and therefore had eyes to ‘see’, those simple stones of innocuous appearance represented something very important: the survival of the group on that lost island. This happened because, as we have seen, he had eyes to see beyond appearances. This ability to see resulted, as you may have understood, from his scientific knowledge.

At this point, Iris took the floor. "Argus, I really liked the story you told us, especially since I had read the book when I was very young. But being honest with you, although I quite liked the book, I had not fully understood the meaning of this passage. What further confirms the idea that in order to 'see' with the 'eyes' of the mind, one must be duly prepared?"

Fabrus, following on Iris's words, said:

In fact, to 'see' in the sense of understanding it becomes necessary to 'look' at the world in a very particular way. This other way of 'seeing' the world results mainly from our knowledge. This knowledge in turn results from our education and this, of course, is part of the social and cultural context which we live in.
It's evident that the sailor did not have enough knowledge of mineralogy to distinguish the various stones and therefore to know their characteristics and eventual utility. So, for him and for anyone else in his condition they were stones, mere stones and nothing more.
However, we must not forget that practice and experimentation are also very important for the progress of knowledge. Sometimes the advancement of knowledge results, in a given time, more from practice or from technique, rather than from theory itself.
Let's take, for example, the case of the steam engine whose discovery and development led to a radical change in man's ability to act in nature. Forgetting the contributions of Heron of Alexandria, who invented the *aeolipile*, the first known steam engine, this important invention was initially a result of a series of rather nebulous theories about the so-called vacuum force that began to develop in the time of Galileo.
Anyway – and here is the point I want to make – in this case of the steam engine its development was mainly due to the action of practical men unfamiliar with the theory. When the theory of thermal machines, thermodynamics, was elaborated in the mid-nineteenth century, locomotives and other steam engines were already in full use in our day-to-day lives. Therefore, in this particular case, we have an extremely important example where praxis was far ahead of the theory.

Of course, Fabrus is absolutely right! Argus said, and continued.

When it comes to scientific progress, sometimes it's the practice that goes ahead, as the example of the thermal machine presented by

Fabrus very well illustrates, in others it's the theory. For the sake of clarity on this matter, let us consider the following fictional hypothesis:
Suppose we meet in the time of Pharaoh Ramses II. And, here, our friend Lucius is named the all-powerful Minister of the Pharaoh. As this Pharaoh devoted much of his life to military campaigns, he was particularly interested in how he would communicate with his armies. Thus, Minister Lucius was commissioned by the Pharaoh to develop an efficient communications system. To carry this project forward he had almost infinite funds.

Pausing, Argus turned to Lucius and asked, "What would you, Lucius, do then to carry the Pharaoh's project forward?" Lucius, somewhat perplexed and looking at Argus and indeed all of us, after a few moments said:

Given that we were around the thirteenth century before our era, I think what we could do with the knowledge available in this remote time, would be for example:

1. Set up schools of couriers, on foot or on horseback.
2. Establish a network of horse stations.
3. Develop of facilities to produce fast horses suitable for the terrain.
4. Create and select birds for the transport of messages, such as carrier pigeons and other suitable birds.
5. Develop a network of communication stations for birds.
6. Create a network of communications towers by light signals.
7. Set up schools to prepare operators for communications by light signals and by birds.
8. Create cryptography schools to develop systems and teach coding and decoding of messages.

Maybe I could do other things, in those backward times, but at the moment I cannot think of anything else.

Addressing Argus, he asked, "What do you think?"

Argus replied, "I think you've got most of the processes available at the time." With a smile, he commented, "What a fine minister you would make, Lucius!"

"Now I'd like to ask you if, instead of being in the time of Pharaoh Ramses II, we met in the time of Alexander of Macedonia and likewise he appointed you as his Communications Minister. What would you do about nine hundred years later?"

We all looked at Lucius. After thinking for some time, he said, "I suppose I'd do precisely the same thing as in the time of Ramses II. I think that at this time, in the fourth century before our era, nothing else really more significant could be done."

"And now, suppose we meet in the time of Julius Caesar" said Argus, "What would you do in the same situation?"

After a moment, Lucius said, "Well, I think now that we are almost at the beginning of our era, I would do precisely the same, since science and technology in this particular domain of communications had hardly changed."

"Now suppose, Lucius, that we are almost in our time, in the 1800s, in the days of Napoleon Bonaparte. What would you do?" Argus asked.

After thinking for some time, Lucius said:

> I think that although we were at the beginning of the nineteenth century, little more could be done than in the time of Ramses II. Despite the interval between Pharaoh Ramses II and Napoleon, about three thousand years, the science and technology known back then did not, it seems to me, do much more. Therefore, no matter how much effort and capital they employed, very little would be there to be done.

"Precisely – I am of the same opinion!" said Argus. He continued:

> Suppose now that we are in the second quarter of the nineteenth century. At this point something very important occurred in the field of the study of light, and electrical and magnetic phenomena. By the way, I would like to add that this revolution, this abrupt change, occurred both in the realm of pure theory and in technology.
> Inspired by the propagation of electricity in conductive wires and the operation of the electromagnet, Samuel Morse developed the first prototype of the telegraph in 1835. With this innovative wired system, it was possible to communicate, almost instantaneously, at nearly the speed of light, at any distance, as long as its network – cables, stations and operators – was connected. The main drawback of this communication system is that it's only possible to establish contacts between fixed points connected by electrically conducting metallic wires.

The next step, the development of the so-called wireless telegraphy, resulted from the culmination of theoretical studies on the electrical and luminous phenomena that led, as we have seen in previous Dialogues, to the emergence of the electromagnetic field theory with Maxwell.

The adequacy of this theory in the description of natural phenomena had a brilliant experimental confirmation when Hertz, with his careful and intelligent experiments, showed in 1888 that the electromagnetic waves predicted by Maxwell's theory were more than mere mathematical abstractions and therefore had a real physical existence. Inspired by these works, Marconi was able, in 1899, to make the first wireless transmission across the English Channel. From that moment, radio communication was open. This Earth-scale communication process can be considered as virtually instantaneous.

This process of propagating electromagnetic waves allowing the sending of sound messages and video has made it possible to communicate in virtually no time with anyone, anywhere in the world.

And to conclude, we can infer from what has been said, that certain technological advances only become possible when one 'sees' the world with other 'eyes'. Naturally, until about 1800, studies on light, electricity and magnetism that culminated in Maxwell's electromagnetic theory were not yet developed, so it was not even possible to conceive of the existence of technological devices that would allow communication at a planetary level, almost instantaneous, either wired or wireless.

However, let's not forget that the development of the electromagnetic field theory was only possible because there was a whole range of concrete experiences that allowed it to unfold. In turn, the development of the theory will lead to 'seeing' nature with other 'eyes' making possible new technological advances that were totally inconceivable until then.

Fabrus turned to Amadeus "Now that we are on a series of examples, and to reinforce the importance of this subject, I would also like to present another hypothetical situation", he said. "Suppose, Amadeus, that we find ourselves in Napoleon's time and someone asks you if it will be possible to see the heart of a person beating, without having to resort to an operation. What response would you give, naturally attending to the knowledge of that time?"

Amadeus thought for a while and then replied: "Well, in view of what was then known, I would say that such an observation was not possible at all. Only by resorting to an operation designed to open the patient's chest, or should we say, the victim's chest, could one observe a human heart beating."

At this point Iris, very excitedly commented, "Of course, with the knowledge and technology available at that time, it was not possible to perform such a feat. However, today, thanks to the modern techniques of medical imaging, we can perfectly see the heart of a human being beating, without the need to do an operation. I myself had the opportunity to see, not the heart, but a baby in the mother's womb".

Fabrus continued, "This indirect observation of the interior of the human body was made possible by the development of X-rays by Röntgen at the end of the nineteenth century and other techniques of medical imaging that were developed throughout the twentieth century. I am very glad to say that these techniques are still in full development today."

We all looked at each other. Argus spoke again:

> From what we've seen, we can conclude that each historical epoch is characterized by a relatively well-founded science. Although not totally coherent, and with inconsistencies here and there, what this science does, as we've seen, is to give the human being an ability to look at the world in a certain way. In turn, this view of the world, this science in its multiple variants, from physics to mathematics, biology, psychology, linguistics, economics, etc., allows the human being to interact with the surrounding medium of which it's also a part, so that it can survive in an ever-better way.
>
> On the other hand, we also know that this relatively coherent view of the world given by the science of a given time period necessarily contains its limits. But these limits, which always exist in each historical period, are not absolute limits as it has been repeatedly defended by many people until this day, even by high-minded thinkers. As the history of science has systematically taught us, these pseudo-limits are being continually overcome.
>
> The open contact with nature through praxis, including the fundamental and technological experimentation combined with the analysis of our processes and conceptual instruments, may, due to this natural evolutionary pressure, lead us to question the foundations of the known science and to try to understand the world

in another way. In times between transitions science, in its more general sense that we have been assuming, constitutes a relatively monolithic edifice. However, at times of change, this relatively well-structured building begins to be questioned and therefore fragmented. This degree of fragmentation can be such that it leads many researchers to think that it will not be possible to do otherwise, and therefore to reject the unity of science.

However, it seems to me that this attitude is nothing more than an escape, a dismissal of true scientific activity. This is because, in my understanding, science is a human activity destined above all to provide us with a way of looking and interacting with nature so that we can persist in a dignified way. Now, nature being one, it follows that the ultimate goal of science must be the search for unity.

We must always have the intellectual courage to dare to go further, for this is the true path of the human being in permanent becoming.

After uttering these words, Argus was silent. As it is late and many of us have commitments, we amicably ended this journey.

THE NEW PHYSICS

THIRD JOURNEY

Today's journey will take place at a famous place in Lisbon, the café *A Brasileira* in Chiado. This place of great tradition has a long and interesting history dating back at least to the beginning of the twentieth century. It's located in the heart of Lisbon, next to Camões Square, constituting one of the most pleasant places of the city, being almost permanently in celebration with many tourists, singers, players of the most diverse instruments and even dancers performing their street shows. The interior of the café has a very cosmopolitan atmosphere, where one can hear several languages simultaneously. The room below, in the basement, where our meeting will take place, has a much quieter atmosphere.

When I arrived Argus, who lives nearby, was already there along with Fabrus, both having tea. I sat down at the table and immediately we started the normal "coffee talk" about the weather and the calamitous state of the economy. I was already drinking my excellent coffee when Iris arrived, all smiling. Shortly after, Amadeus and Lucius arrived. After some time of conversation about the political situation and the economy, we started talking about science, mainly because of my insistence. Argus started the journey saying:

> In our previous journeys we've seen that traditional physics, i.e. classical physics including Newtonian mechanics, electromagnetism, thermodynamics and modern physics, i.e. relativity and quantum mechanics, are all based on the linear Cartesian method, where the whole is equal to the sum of the parts and the reaction is assumed to be proportional to the action. We also mentioned that these sciences had already reached their maximum explanatory and predictive capacity of nature.
>
> The limits of classical physics, as we have seen, were reached at the end of the nineteenth century, giving rise to the appearance of relativity and quantum mechanics.
>
> The limits of relativity were reached when superluminal velocities were observed, which we will have the opportunity to discuss in more detail in the coming journeys.
>
> The limits of quantum mechanics were equally reached, as we have already seen in the earlier Dialogues, when it was found that it was possible, both conceptually and experimentally, to go far beyond the

limits imposed by Heisenberg's relations. On the other hand, recent sophisticated experiments, which we shall discuss later, have shown that subquantum waves are not mere probabilistic entities, but rather are endowed with real physical existence.
In these conditions, it becomes necessary to develop a whole new physics that allows us to overcome the difficulties we are immersed in. These difficulties are mainly due, as we have mentioned more than once, to the very basis of traditional physics founded on the Cartesian linear method.

He continued:

However, and I emphasize, once again, this does not mean that traditional science is not a good science! Of course, Newtonian mechanics is a great theory! So much so that even today it's used very efficiently in the study of many problems falling within its scale of adequacy. Among these problems I can mention, for example, the prediction of the positions of the planets of the solar system, the placement of satellites in orbit and so many others. Likewise, in our practical lives, there is also a vast field of applications.

Turning to Lucius, he asked, "What do you think, Lucius? What should we do if we want to build a bridge or design a house? What branch of science do you think should be used?"

"Assuming these are normal, typical bridges and buildings, I think that in order to elaborate the respective stability design projects one must use the old classical mechanics. Perhaps only in the case of extremely sophisticated structures will classical mechanics not suffice", said Lucius.

"Right! You said it very well" Argus replied, "And now suppose you mean to describe the emission of radiation from an atom when excited. For example, sodium when heated in a flame."

"In this case, classical mechanics certainly has no possibility of explaining this physical phenomenon. Under these conditions we will have to resort to quantum mechanics", Lucius said.

Argus continued:

It follows from here that classical physics is only suitable for the study of a certain family of problems. When it's intended to apply this theory outside its domain of adequacy, we face serious problems. In this case, the theory reveals itself to be totally incapable

of dealing with the problem. I'd even add, in certain cases the problems placed do not even make sense in their conceptual universe. As any theory, however sophisticated, is a mere human construction, it naturally has its limits.
In these circumstances, it seems to me that a reasonable conclusion will be, as we have already seen, that there are no absolutely true scientific theories.
So, contrary to what is promoted by the media, there are no totally true and immutable scientific theories. What actually do exist are more or less adequate theories for describing certain aspects of reality, only within its domain of application.

There was a pause, and Fabrus spoke:

I would like to draw your attention to another important problem: As we know, Copernicus, retaking the ideas of Aristarchus, proposed the heliocentric model. After numerous mishaps, with advances and retreats, this heliocentric model was accepted by almost the entire scientific community, especially after the publication of Newton's *Principia*. Of course, we also know there were quite significant pockets of resistance to these new ideas. To prove it, it's enough to mention that almost at the beginning of the nineteenth century there were still some Portuguese universities, linked to certain more retrograde religious sectors, where the geocentric model was still taught, assumed as the last and absolute truth.
However, we must remember that until the observations of the parallax of the stars by Bessel in 1838, some 300 years after Copernicus, there was no experimental evidence to show that the Earth moved. So, from the purely empirical point of view, both the heliocentric and the geocentric model were standing equal in regards to the prediction of the positions of the planets of the solar system.

"I totally agree with what you are saying, Fabrus!" said Argus.
In that sense, I would also like to point out, contrary to what is asserted and propagated by all means, this geocentric model, which places the Earth at the centre of the world, was, is and continues to be quite adequate to its scale of description of reality. Hence, this model, which from the kinematic point of view assumes the Earth as standing still, continues to be widely used in describing the great majority of the problems that now, at the dawn of the twenty-first century, are placed on humanity in its daily life.

Amadeus looked at Argus somewhat astonished and asked, "Are you really saying, Argus, that the geocentric concept, which has been so hard to combat (some have even been burned alive for denying it, such as Giordano Bruno), is still valid and therefore being used? Are you really saying that this outdated model is not wrong?"

"Note, Amadeus, that I've said adequate, not valid", replied Argus.

> To better illustrate this problem, let us consider, for example, a shepherd from the Alentejo, or from some other place. As he gets up very early at dawn, he takes his sheep to graze. In the evening, when he returns home, he leads the sheep to the sheepfold. If we ask this honoured shepherd whether it's the Sun or the Earth that is in motion, he will surely be quite perplexed by the question. Perhaps he will even look at us with some suspicion. This is because he sees the Sun rising at the breaking of dawn. As the day passes by, he observes the Sun occupying various positions in the sky, until, at sunset, it goes down on the horizon. What's more, on hot days our shepherd knows perfectly where the Sun is, in order to be able to take his sheep to rest under the holm oaks. Therefore, from a practical and concrete observational point of view, he has every reason to believe that it's the Sun that moves. All his life, all his activity is based precisely on the movement of the Sun. So, if this is the case, why are you asking him a question with such an obvious answer: to know if it's whether the Sun or the Earth that moves?
>
> I will say even more: for the great majority of our day-to-day problems the assumption that is the Sun that moves is the simplest. Even those who know that the Earth moves around the Sun, and this, in turn, moves in relation to the centre of our galaxy and around the centre of the cluster of galaxies, in their most common activities, and without saying it, implicitly start from the assumption that the Earth is standing still.
>
> So, I say it again, the geocentric theory, especially in its concrete practical aspects of a purely kinematic nature and at its scale of application, is not wrong! What is wrong is to say that it's the only and ultimate theory that the human being has constructed to explain the whole reality.

"Of course! I now understand the meaning of what you said Argus", said Amadeus. Argus replied, "The great merit of the thinkers of the sixteenth century was precisely to show that there was a whole new phenomenology that the geocentric model did not explain and therefore it was necessary to elaborate on a more general model."

After a pause, Fabrus took the floor:

> So, if from the empirical point of view, both the heliocentric and the geocentric model had the same predictive capacity, which criteria should lead us to prefer one theory over the other?
> A scientific theory worthy of that name naturally must have the capacity to predict the empirical phenomena at its scale of description. But more importantly, this theory has to offer us a broader view of the world allowing us to change our capacity to act in the world. In other words, it allows us to increase our ability to persist, to survive.
> In reality, the view of the world previously provided by geocentric and Aristotelian physics was exhausted. On the contrary, the heliocentric model permitting the ontological unification of the sublunary world with the celestial world enabled a new way of looking at nature that opened the door to the scientific revolution of the seventeenth century. In turn, this scientific revolution gave rise to the industrial revolution that radically altered our way of being in the world, thereby increasing our ability to survive as a species.

"I completely agree with you Fabrus", said Argus. "Ultimately, one of the criteria of adequacy of a scientific theory in the description of reality is its effectiveness. Under these conditions, we can never claim that a scientific theory is true. All we can say is that, at a given scale of description of reality, a theory is adequate."

We all looked at each other thoughtfully; we agreed with this last statement from Argus, so much so this was no more than a clear explanation of the multiple ideas implicit in our discussions. Argus continued.

> However, truth be told, this attitude causes a certain insecurity since it goes against the beautiful and alleged certainties established by science. As many of you must have heard already, the phrase generally used as the definitive argument is: 'it's proved by science, it's scientifically proven'. With this 'it's scientifically proven', we intend to present the absolute and ultimate argument. But now we're realizing that after all, even the so-called scientific truths, being mere human constructions, have also their inherent fragility.

After a reflexive pause, Argus spoke again.

I think it's time to start introducing new physics, the physics of the complex and the nonlinear, where emergence and de-emergence have their natural place.
In this new way of looking at the world, it's assumed from the beginning that the whole is more than the sum of its parts. On the other hand, it's also assumed that the action is, in general, not proportional to the reaction. That is, under certain conditions, a tiny action may give rise to a great reaction.
In order to better illustrate these concepts of the linear and nonlinear and the action–reaction I will show you some schemes that I presented in lectures I gave on the subject. Of course, as you must understand, these are mere metaphors, yet it seems to me they are very helpful when it comes to understanding the question.

Taking out a transparency from a folder he carried with him, he placed the following figure on the table (Figure 3-1) and continued.

Problem
How to take the sheep to the sheepfold?

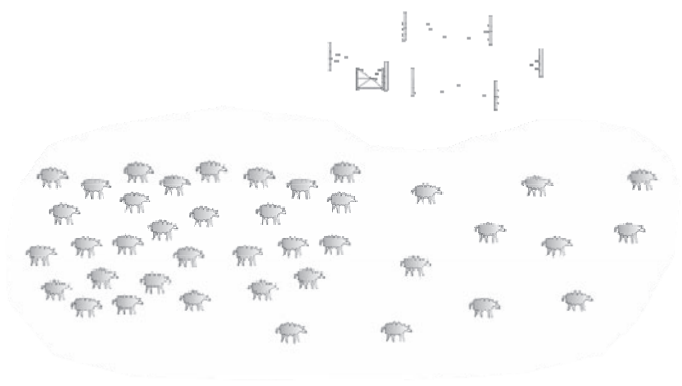

Figure 3-1: How do you take the sheep to the sheepfold?

This drawing seeks to represent a flock of sheep grazing quietly in the fields of the Alentejo. The problem is how to lead the sheep to the sheepfold. To solve this problem, to take the sheep to the sheepfold, two methods are suitable in principle:

1. The Cartesian linear method.
This process of looking at nature assumes the perfect and total independence between all the parts in question, that is, the sheep, the fold, the dog and the shepherd.
2. The eurhythmic, complex, interrelational and nonlinear method.
In this case, it's assumed that all the elements involved – sheep, dog, shepherd and fold – are reciprocally interconnected to a greater or lesser degree thus forming a unique whole.
Let us then begin with the traditional Cartesian method.
In this case, we assume that the whole is equal to the sum of the constituent parts. These parts remain perfectly independent, not suffering, any one of them, the slightest change whatever the type of interaction to which they are subjected. In this perspective, the flock of sheep is no more than a simple combinatorial of parts, being these parts naturally, the sheep, completely independent from each other. On the other hand, it's also assumed that the action is equal to the reaction.
So, in this conceptual universe of perfect independence between the parts that make up the whole, in this case the herd and the other elements, all that is to be done is indicated in this drawing, Figure 3-2.

Classic Cartesian Method
Linear (hard line)
Action = Reaction

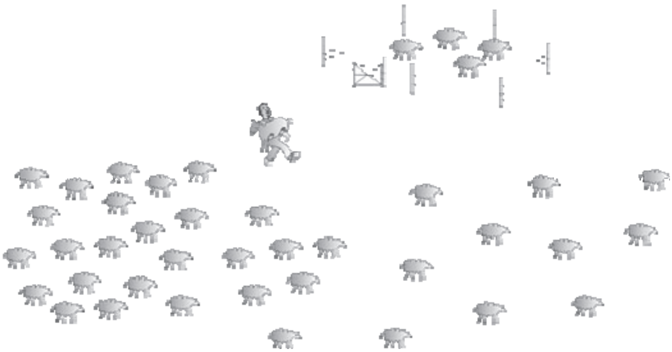

Figure 3-2: Linear method.

Argus continued:
As can be seen, since there is no interdependent relationship between the parts, all one can do is to take the sheep one by one to the sheepfold.

"I would like to add the care you must take in closing the sheepfold door whenever a sheep is transported, or you'll let her get away!" said Fabrus, smiling. It was a contagious smile that extended to all of us. After this little diversion, Argus continued:

As can be seen, the total labour expended to solve the problem, that is, to take the sheep to the sheepfold, will, of course, be the sum of the individual work necessary to transport each one of them. The more sheep the herd has, the more work it will take to put them inside the sheepfold.
Let us now see the same problem in the light of the eurhythmic perspective where it's assumed that, in general, the whole is much more than the sum of the parts and that a very small action can, in appropriate circumstances, give rise to a great reaction.
This process is indicated in this drawing, Figure 3-3.

Non-Linear Method
Action ≠ Reaction

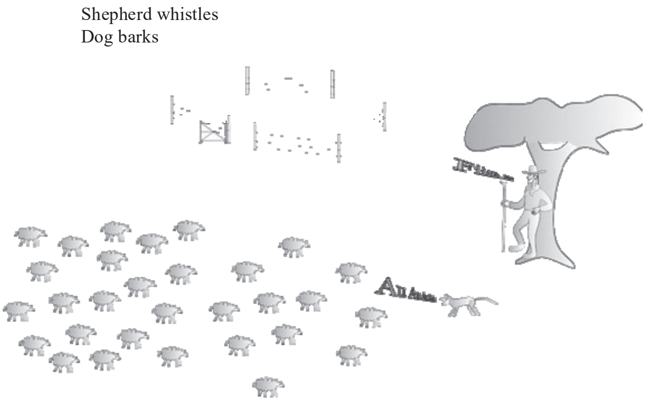

Figure 3-3: Nonlinear method and a small action.

In this way of looking at nature, it's assumed that the flock of sheep, the shepherd, the dog, the sheepfold and the pasture field constitute an interrelated whole. These parts of the whole are in reciprocal interaction, modifying the others and being modified themselves to a greater or lesser degree.

In the case indicated in the drawing, to solve the problem of putting the sheep inside the sheepfold, the Alentejan shepherd whistles in a very particular way. The well-trained dog understands the whistle and begins to bark too in its own way. At this point, the sheep understand that it's time to go home, as indicated in this final drawing, Figure 3-4.

Nonlinear Method
Action ≠ reaction

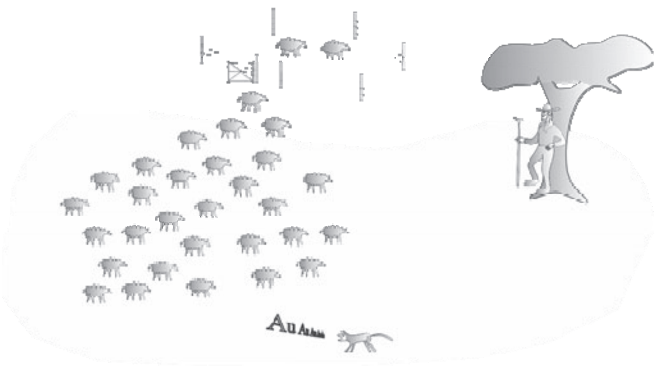

Figure 3-4: Nonlinear method where a small action can cause a great reaction

And so, progressively, the sheep begin to enter the fold, always stimulated by the watchdog. In this situation, a tiny action, the shepherd's whistle, unleashes a huge reaction: the movement of the sheep towards the sheepfold.

In the linear Cartesian process, the action, that is, the effort required to put the sheep in the fold is proportional to their number. On the contrary, in the nonlinear eurhythmic process, a small action, independent of the number of sheep, gives rise to the intended reaction which is to lead the sheep to the fold.

I think this example illustrates very well the importance and advantage of the nonlinear process over the Cartesian linear method.

Argus had just uttered these words when we realized that an old acquaintance of ours, Hilarius, had arrived without us having noticed him, and had been listening to our conversation for quite some time. As we have seen in earlier Dialogues, Hilarius, despite having a background in physics, is much more concerned with his career rather than with scientific truth. As unfortunately this has happened and continues to happen with many other 'scientists' of the same kind, he learned mainly by uncritically studying the manuals of physics that he now dogmatically teaches in his university classes. His main objective is not the scientific truth, which can and should contribute to the progress and evolution of humanity, but only his career progression and above all his apparent and immediate personal well-being.

With his usual arrogance and lack of tact he pulled a chair next to our table, sat down and said:

> I've been listening to you talk about the drawbacks of linear and the importance of nonlinear as if this was some novelty! Everyone who deals with practice is perfectly aware of nonlinear processes and knows that in reality there are no linear physical processes. It's well known that linear processes are outdated and out of fashion. So, where's the news? What is the alleged innovation you are talking about? Deep down, nothing new exists in what you are saying. You just repeat the known litany everyone is tired of knowing and nothing else!

We all looked at Hilarius – the careerist, the possessor of the certainties and absolute truths – I won't say we were surprised, because we had already known him for a long time, but we were rather perplexed.

As usual, Argus stared at Hilarius. He said, quietly:

> You're quite right, Hilarius! Everyone who deals with day-to-day practice implicitly knows that problems are always much more complex than they seem at first glance. Even in solving simple experimental physics problems such as the assembly of elementary linear electronic circuits, we must always be very attentive because, in general, if we follow only the theory, the system never works. This is because there are always anomalies, such as bad contacts, resistances, parasitic capacities, etc., etc. In short, there is always a large number of imponderable factors that prevent the circuit from functioning properly. A knowledgeable experimenter knows that he must develop a certain specific intuition, otherwise he cannot overcome these ever-present difficulties.

“However, I’d like to ask you Hilarius, if you believe in the validity of the ‘laws’ and principles of quantum mechanics?”

“Of course I do!” Hilarius replied pompously. “These laws, true and absolute, wonderfully govern all quantum phenomena. They represent the greatest, the last, the ultimate word about what humanity can achieve.”

Argus replied, “So, you also believe in the general validity of the simple vector calculus and in the generalized theory of quantum mechanics, the Hilbert space and consequently the principle of superposition?”

“Absolutely!” Hilarius answered, exuberantly.

“Likewise, I take it you believe in the absolute validity of the Schrödinger equation and the linear operators of quantum mechanics that allow us to make prediction of the measurements?”

“Yes, of course! More than that, the Schrödinger equation governs all quantum phenomena, allowing the determination of the spatial and time evolution of the state function. From it, from the generalized vector space and linear operators it’s possible to predict the result of all quantum measurements.”

Smiling, Argus exclaimed:

> Hilarius, I don’t quite understand your statements! On the one hand, you said that the linear method didn’t work and that everyone who values themselves knows this very well.
> On the other hand, you’ve just said that you absolutely believe in quantum mechanics, the ultimate, the last human theory, according to your words. However, quantum mechanics is, as you know, an essentially linear theory.
> Let’s see:
> - Linear is the fundamental equation of quantum mechanics, the Schrödinger equation!
> - Linear forms the quantum operators!
> - Linear is the Hilbert space, the generalized vector space of quantum mechanics!
> - Linear is the principle of superposition, which is nothing more than the Cartesian linear principle of addition!
> In short, the theory that you almost divinize, quantum mechanics, is, as we have just seen, fundamentally a linear theory!
> So, it seems to me that there’s a contradiction in what you said. More so, and please note, that this is not a small contradiction that can be removed with a few minor touches here and there, but rather a fundamental contradiction, something quite profound.

If, as you have said, the 'out-of-fashion' linear method is only credible and acceptable to fools, then, in the same way, quantum mechanics and most of the traditional physics, which relies precisely on linear equations and vector calculus, and therefore base themselves on the linear additive method, should not be worthy of credit either.
Under these conditions, and according to your assertion, that the linear method is out of date and therefore unsuitable, we should conclude that only fools can believe in the validity of quantum mechanics and classical physics!
Is this what you mean now?

Hilarius, somewhat embarrassed with Argus's sharp intervention, didn't know what to say and after a little while he got up and walked away. After a somewhat embarrassing silence, Argus spoke again:

To finalize this question, I'd like to point out, once again, that the linear method is a great method, and was in fact a great human achievement. It has many virtues, among them we must naturally highlight its great mathematical and conceptual simplicity. Its discovery was a major cognitive advance for humanity. However, deep down it's only a human construction. Under these conditions, this linear method naturally has its inherent limits of adequacy in the description of natural phenomena. Limits which, as we have seen, have already been reached.
The nonlinear method, which is intended to better describe real complex systems in reciprocal interaction, is much more general. More so, if I may say it, although from a linguistic point of view it may not be very correct: the nonlinear method includes the linear method as a particular case. Indeed whenever, at the scale of the description we are considering, it's acceptable to disregard the reciprocal interactions and the changes of the constituent parts of the whole, then we can and must use the linear method. It would be absurd to use the nonlinear method, which is much more difficult and complex, in solving the most elemental problems that can be solved by the linear process, which is much simpler from the operational point of view.
In conclusion, I would also like to add that in the human sciences, such as economics, sociology, psychology, or even certain sciences of nature (as if there was anything excluded from nature), such as biology, the problems we have to deal with are so complex that the

linear approximation hardly works, if at all. However, it's no less true that so far, all these complex sciences have tried at all costs to integrate themselves, with doubtful success, into the Cartesian linear model, considered as being the model that has reigned in traditional physics. Therefore, the new relational physics, eurhythmic physics, assuming from the outset the complexity of its most basic elements, establishes a kind of bridge, an approximation with those sciences that traditionally deal with the complex.

At this point, Iris intervened in the discussion. "I've seen, in the most recent scientific literature, many references to a subject that I find very interesting that is the symbiogenesis. I've even asked myself whether symbiogenesis is not in any way connected with the principle of eurhythmy! What do you think, Argus?"

"I think you are quite right!" he said.

Actually, this is precisely a subject I'd like to discuss with you. As you know, symbiogenesis is a biological process where different, more or less complex organisms come together to form a whole, the higher organism so to speak. What is extremely interesting in this gathering of different entities, from the simplest to the most complex, is that they all benefit in this reunion. This is, as can be seen, a typically nonlinear process. The parts that constitute the whole by interacting reciprocally with the others, modify and are modified, to a greater or lesser degree.

I believe you know that our own organism consists of a small number of elements with our specific genetic code and a multiplicity of other organisms forming a complex symbiome. In the case of the human organism this symbiome is so complex and diversified that it has led many biology researchers to claim that this complex interrelated system closely resembles an ecosystem.

In this case of the biological organisms, the whole is clearly much more than the sum of its parts. These parts, when interacting with each other, are modified and likewise contribute to the modification of the other parts to a greater or lesser degree. This interconnection between the constituent elements is such that in general, the properties of the emergent whole cannot be inferred from the knowledge of the properties of the individual parts.

One question that can be asked is, what's the reason why these parts, these complex entities, get associated, modify themselves thus

> losing some degree of freedom and eventually gaining new ones? The answer is, as you very well intuited, Iris, in the principle of eurhythmy. Deep down, complex beings, in their becoming, seek to follow those that lead them to increase their capacity for persistence among the multiple possible paths. For this they evolve, they adapt and so they will naturally change as they interact with the medium, i.e. the other entities that surround them.
> When complex beings, in their becoming, do not follow this eurhythmic process, then their capacity for survival will drastically diminish.

Amadeus, who had been very attentive following Argus's intervention, said:

> If I understood correctly what has been said and also certain things I have read, it seems to me that symbiogenesis, being a manifestation of the principle of eurhythmy, constitutes a very important driver in evolution, especially in human evolution.
> I must confess to you that this idea pleases me greatly because it's perfectly in harmony with my deepest beliefs. This is because in symbiogenesis there is a cooperation, a harmony between the various entities that constitute the whole. So much so, that from this union there is a benefit for all the parties. Basically, this is, if I may say so, the perfect deal. A deal in which all parties involved ultimately end up benefiting.
> This idea of symbiogenesis and cooperation is in every respect contrary to the widespread idea, especially from a very particular interpretation of Darwin's theory of evolution, that the strongest and the fittest survives to the detriment of the weaker that vanishes. This interpretation of the theory of evolution puts the emphasis, above all, on the aggression where the fittest, the strongest, eats or even destroys the weakest for free.
> In cooperation, unlike aggression, all elements proceed in a way that in the end everyone benefits, both at individual and collective levels.

"I completely agree with you, Amadeus", said Argus.

> In fact, no one with common sense can deny that aggression is a constant of human relations. Every day we observe phenomena of aggression and even gratuitous humiliation. Likewise, we just have to look at human history to see that it's full of wars and massacres,

where the strong, the winners, attack, enslave and crush the weakest mercilessly.
However, as you rightly said, it's no less true that another and perhaps most important driver of human evolution is cooperation. I think everyone agrees with me when I say that without cooperation there would be no human progress.
What is more, I am convinced that the path that uses only aggression as a driver of progress is much shorter than the eurhythmic path that is carried out through cooperation. If so, aggression would be, in the long term, far less advantageous in the difficult course of evolution than cooperation.
To further clarify this subject, which I find very interesting, I will relate a metaphorical example that I gave some time ago in a course on the foundations of science.

After a short break, Argus continued:

The action takes place on an isolated island in the Atlantic. This small island has two villages, one at each end. The villages live in peace and harmony, living off the resources from the sea and the countryside.
At some point a great storm comes to the island. This storm is of such intensity that it destroys the resources of the two villages. These resources that had been obtained at the expense of hard labour and that allowed the survival of the populations were almost entirely destroyed. So, from one day to the next the two villages were in the darkest misery. However, after all, one of the villages was still relatively not as bad as the other, as it was able to save some food with a lot of effort.
Assuming that the villages could not be rescued from the outside in due time, I ask, what do you think the attitude of the villages would be to try to solve the bad situation they were in?

After pausing, he continued:

To solve the difficult situation two lines of action are, in principle, possible: the way of aggression and the way of cooperation. Let us first look at the way of aggression:
The village that has no food resources decides to attack the other village that despite everything still has a little something to eat.

The people of the village gather and form a small army. They will attack the other village with the aim of stealing the little food they have left.
The two villages will fight fiercely against each other. This combat can have several outcomes:
a) The attacking army, at the expense of heavy losses, manages to defeat the other village. After the battle they plunder all the resources of the vanquished village and return home leaving a trail of death and destruction behind.
b) The attacking army is defeated. In this case the attacked village maintains its resources, but loses part of its elements, while others become crippled and many are invalids for the rest of their lives.
c) During the first skirmishes the attacking army realizes that it cannot win and withdraws. In this case the action was equal to the reaction and both villages, despite some losses, maintain their integrity.
In this case, where aggression was used as a survival factor, everything was ultimately lost. In reality there were no winners!
Even in the best situation for the attacking village, the victory was clearly Pyrrhonian. For although they were victorious in battle, they still had heavy casualties. On the other hand, once consumed the few provisions they stole, they would surely face serious difficulties to survive in the future.
The least bad situation, on average, is certainly the third. The one in which the action equals the reaction. In this case, although both villages were worse off, the final result was not so calamitous. In both previous situations at least one of the villages was practically destroyed. In the latter case both persist, although with difficulties due to the losses suffered.
Let us now see what comes from cooperation:
In this process the two villages, in order to deal with the calamity, meet in a single community and join the few existing resources, thus making the best of them. However, now that they constitute a larger community, they will be able to undertake larger scale works they would previously have no chance of carrying out. Thus, after a short time and despite the difficulties faced initially, they are able to develop means of production of goods and infrastructures. These means, developed in cooperation and harmony, are more than sufficient to ensure the subsistence of the two villages in the near and distant future.

Amadeus, who was enthusiastically following Argus's narrative, could not restrain himself and said, "Of course, in this case of harmonious cooperation, which after all is the only possible cooperation, since the other forms of cooperation only have the name, resulted not only a global benefit but individual as well. Of course, we cannot forget that there was a great deal of individual and collective effort to overcome the difficulties, but in the end, the two villages benefited greatly. In short, as I said before, it's a nice deal because all those involved came out to win."

"So there seems to be no doubt that in the long run, cooperation is much more effective, in the eurhythmic sense of the term, than aggression" said Argus.

> As you may have understood, this thesis of cooperation as an important driver of progress is not widespread. Unfortunately, what the media prefer is the thesis of aggression where the strong, the so-called conquerors, crush, exploit and humiliate the weak.
> I'd also like to clarify an important point. It's necessary to take into account that even in the case of aggression, complex systems, in this case the attacking village, always try to follow a process that has something eurhythmic about it.
> Of the many possible paths, they choose the one that seems to be the best for them.
> However, as it's very common, these complex systems make a very superficial analysis of the problem, not taking into account the possible results of their choice over a longer period of time. This short-term choice, while having the virtue of apparently resolving the situation in that moment, will eventually have serious repercussions in the future. This is because their 'sensorium', their wave of coherence, their theta wave, is very short and therefore of short range. In these conditions, by not considering a whole universe of much vaster possibilities, they are very limited by the smallness of their theta wave. Since their sensorium, through which they exchange information with the medium around them, has a short range they are limited to a very narrow range of options. These options, given their narrowness, will in general lead to very disastrous situations as it happened in the case we've just seen. Seeing further implies having a much broader wave of coherence, a wave of harmony, thus allowing a much more adequate eurhythmic process.

Turning to Iris, he asked, "Do you think I've clarified your question, or do you still have any doubts?"

"I think I'm clear Argus. However, I'd like to share with you something that I think, which results mainly from our conversations and from what I've read on the subject."

Since our human organism can, as we've seen, be considered as an ecosystem, then it's naturally composed of many relatively independent subsystems, although they are part of the whole that is our organism. Under these conditions, we may admit that in certain circumstances a given system begins to have hegemonic tendencies and forget its interrelationship of cooperation with the other subsystems. So, it triggers a real war of aggression against the other constituent subsystems of our organism. This particular subsystem, this real 'tumour', begins to expand and grow wildly eventually reaching a certain ephemeral hegemony at the expense, of course, of the destruction of other subsystems. If this unbridled growth is not stopped, the result on a longer time scale will be the destruction, the de-emergence of the human organism. In other words, what is commonly referred to as death will occur. It seems to me, therefore, to be quite reasonable to admit that the diseases which we suffer are in general a little eurhythmic movement of the subsystems that constitute our organism. It's then verified that in its blind urge to expand, the parasite subsystem also ends up perishing in conjunction with the whole organism.

Looking at us, she asked, "What do you think?" We considered it, and nodded. Shortly after, Argus said:

> I think that from what has been said it cannot be inferred in a naive and immediate way that competition goes against cooperation. Only in cases of unbridled competition, where it more closely resembles a deep desire for aggression and consequent humiliation of the partner, is competition against cooperation. In fact, healthy competition, where each one seeks to overcome itself in order to improve and contribute to the improvement of others, is the true eurhythmic drive of progress. So, competition is ultimately a real form of cooperation. It is, as we can see, a dynamic cooperation in permanent becoming – precisely the opposite of what happens in a closed, rigid, static system. These static and very balanced systems, due to their rigidity and consequent inability to deal with the novelty, with the becoming will sooner or later end up stagnating, thus

leading to their de-emergence, that is, to the death of the complex system.

Argus continued.

I think that after these brief incursions in the wider field of generalizations and extensions of the principle of eurhythmy to other sciences of the complex, it's time to return to the new physics.
Following the scientific tradition, the new relational physics, i.e. eurhythmic or hyperphysical physics, that has the goal of describing the behaviour of complex and therefore nonlinear physical systems, is built on five starting points or hypotheses.
Traditionally, the foundations or hypotheses on which theories were constructed, were designated as axioms or postulates. This nomenclature was mainly related to the unfounded belief that these axioms or postulates were absolute and definitive truths. Thus, in Euclid's geometry it was intended that these starting points, designated as axioms were truths of nature, self-evident, eventually revealed to man by transcendent and supernatural powers. Similarly, in Newtonian physics the postulates were understood as constituting the ultimate expression of the laws of nature, which would govern the phenomena, thus having a status of absolute and immutable truths.
As we know, the advancement of our knowledge has clearly highlighted how naive and unfounded these beliefs were. In fact, nature has always been much richer and more fruitful than any conceptual framework in which man arrogantly or naively tries to break it down. Since nature is one, there are no supernatural phenomena. All phenomena, observed or not observed, however complex they may seem at first sight, are natural because, ultimately, they are part of that one reality which is our Mother Nature.
Thus these hypotheses, or bases of support upon which the new physics is constructed, don't constitute ultimate and universal truths. They are nothing more than a set of foundations, which at the level of our present knowledge are more adequate to describe what we learn from reality.
Moreover, we are convinced that the advancement of our knowledge will lead, in a more or less distant future, to its replacement by more general ones.

Taking these considerations into account, let us begin by explaining the starting points, i.e. the bases of supports upon which the new physics is built:

1. First hypothesis
There is a unique and objective reality. This reality exists independently of the observer. However, we are aware that the observer interacts with this same reality by modifying it and being simultaneously modified by it, to a greater or lesser degree.

2. Second hypothesis
There is a primordial indefinite basic medium – the subquantum medium. This medium is characterized by a chaotic and indefinite nature. All the physical processes occur in this chaotic and indefinite medium.

3. Third hypothesis
Physical entities, waves, particles, fields, etc. are no more than a set of processes, relations, finite and relatively stable organizations of the fundamental basic medium – the subquantum medium.

4. Fourth hypothesis
What we call complex particles is, ultimately, a set of relations, relatively stable organizations of the subquantum medium. These complex entities are formed by an extensive but finite region, the theta wave, within which exists an extremely localized and highly energetic structure called acron.

5. Fifth hypothesis
The basic principle that allows for numerical predictions in new physics is the principle of eurhythmy. This organizational principle when applied to the 'acron–theta wave' reciprocal interaction, tells us that the acron moves in the theta wave field following a stochastic path such that takes it preferentially to the regions where this field is relatively more intense.

These are the hypotheses, the requests or bases of support on which eurhythmic physics is constructed. Let us see now, with a little more detail what these hypotheses consist of.
The first hypothesis, of an essentially philosophical nature, corresponds to the acceptance that there is something from which our ideas and

our science derive. To this something, relatively independent of the observer, we call reality. Our science is no more than an attempt to describe the interrelational processes of how we interact and understand that same reality at diverse scales of observation and description.

The need to make this realistic fundamental hypothesis explicit results from the fact that we want to present, right from the start and as clearly as possible, the basic assumptions on which eurhythmic physics is based. This attitude of clarification goes against a certain scientific practice that unfortunately is very much in vogue, because the main objective of these researchers, it is not to seek the truth and therefore to understand nature a little better, but to achieve at all costs an apparent success, although in the vast majority of cases, very ephemeral. Instead of having the purpose to clarify the problems, as it might be expected in a good scientific practice, they seek mystification and confusion, resorting, in general, to a highly esoteric formal or conceptual language. An example of this attitude of concealment of the basic starting assumptions can be found in orthodox quantum mechanics. This theory was built upon an essentially idealistic hypothesis.

This hypothesis, once accepted, leads in turn – explicitly or implicitly – into a radical indeterminism. This quantum indeterminism is deeply hidden in many, implicit and explicit, postulates that are never clearly elucidated. It was only thanks to the enormous effort from a certain group of bolder investigators that it was possible to clarify this problem. This long process led, as we well know, to the discovery of so-called quantum paradoxes. These so-called quantum paradoxes clearly highlight the hypotheses of departure, rooted in a highly idealistic attitude that lies at the deepest level of orthodox quantum mechanics.

Argus took a break to drink water, then continued:

In relation to the second hypothesis, of the existence of the subquantum medium, its origin is lost in time. Indeed, as far as we know, its first formulation is due to Anaximander, a naturalist philosopher of the Miletus school who lived between 610 and 547 BC. Anaximander proposed the existence of an undefined primordial medium which he called *apeiron*.

Its most recent formulation, to which this new physics owes its name, comes from the work of Louis de Broglie. As we have seen in previous Dialogues, in order to be able to explain in clear and intuitive terms the problem of wave–particle dualism, which was placed to microphysics in the first quarter of the twentieth century, de Broglie proposed the existence of a primordial chaotic medium, the subquantum medium.

Eurhythmic physics, following the Louis de Broglie research programme in the field of microphysics, also assumes the existence of a primordial, basic, chaotic and indefinite medium. In this context, by chaotic medium we mean a fundamental basic medium of indefinite nature whose properties are not generally known. In this context, it's not generally possible to establish cause–effect relationships in this basic medium.

The third hypothesis is intended to characterize the nature of physical entities. These entities, such as waves, particles or fields are understood as interrelational systems, extremely complex states of the subquantum medium. So, in this approximation to describing reality, it's assumed that natural phenomena at different scales of observation and description are ultimately nothing more than the reflection of a more basic process of evolution and interaction of the more or less complexes states of the subquantum medium. Under these conditions, physics has the goal to describe and predict the behaviour and formation or emergence of these organized structures and their reciprocal interactions.

The fourth hypothesis is intended to specify the nature of the complex particle. Also, in this case, the first proposal was advanced by de Broglie in the field of quantum physics, with aim to explain the so-called quantum mystery of the wave–particle dualism. In the new physics, this notion of a complex, extensive but finite particle, which was born in quantum physics, is extended to the different realms of physics. According to this perspective, the physical particles are then constituted by a finite but relatively extensive region, the theta wave, within which there is a relatively well-localized and highly complex entity called the acron. This term, proposed by the late Portuguese philosopher Eduardo Chitas, naming the extremely energetic and highly localized part of the particle, results from the Greek word άκρον (acron) representing the highest, the most prominent peak, as in the case of the Acropolis in ancient Greece. The acron, this relatively well-localized and highly energetic structure, is in turn also a very complex entity. I should similarly point out that the total energy of the complex particle is almost equal to that of the acron, since the energy of the theta wave is very, very weak when compared to that of the acron. On the other hand, in the most common interaction processes, the acron remains relatively stable and almost always indivisible in the vast majority of situations. On the contrary, the theta wave being relatively much more extensive, is almost always dividing itself.

A schematic representation of the complex physical particle can be seen in this figure, which you already know.

Argus pulled out a drawing (Figure 3-5).

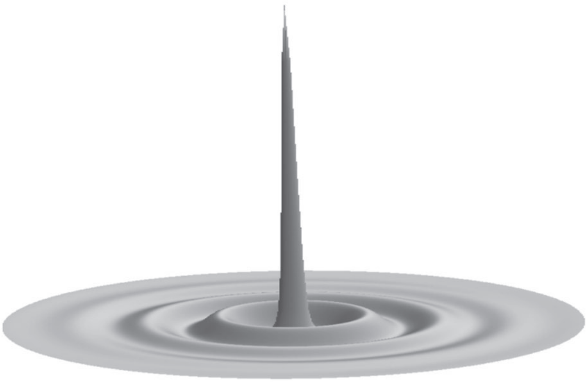

Figure 3-5: Representation of the complex particle.

As we mentioned before, and speaking in metaphorical terms, the theta wave forms some kind of *sensorium* through which the acron ‘feels’ the medium that surrounds it. So, the greater the degree of coherence of the wave, this global interaction field, the bigger the ability of the acron to feel the medium around it and vice versa.
The relatively well-localized and extremely complex structure, the acron, is in permanent chaotic movement within its theta wave.
By the way, I’d like to note that there is no acron without its associated theta wave because ultimately, the theta wave is generated by the acron. Whenever the acron moves to a chaotic region of the subquantum medium, its associated coherent theta wave tends to decrease, due to the interaction with the disordered medium. In this case the acron, at the expense of its own energy, regenerates a coherent and ordered field, its basic theta wave. This basic theta wave, associated with the acron, is sometimes called the ‘mother theta wave’. Since in the disorganized regions of the subquantum medium the acron loses energy due to the need to regenerate its mother theta wave, it will tend to avoid these chaotic regions of the

subquantum medium. If in its becoming the acron does not proceed in this way, its average life will of course be much shorter.

This natural behaviour of the acron, in order to persist as such, leads us to the fifth assumption of new physics, the principle of eurhythmy. This is in fact, the basic and organizational principle that will enable us to make statistical predictions about the becoming of complex physical systems. In its narrowest sense, when applied to the reciprocal acron–theta wave interaction, it simply tells us that the acron moves within the theta field following a path that, on average, takes it to the regions of greater density.

The application of the principle of eurhythmy in the description and prediction of natural processes, to be perfectly clarified, still needs some additional comments.

As it can be assumed, this basic principle of nature only has significance in the context of complex systems, for even the acra corresponding to the so-called fundamental particles are already themselves highly complex organized relational structures of the subquantum medium. The hypothesis of stochastic motion implies that the transition of an acron from one interacting state to another occurs in a non-deterministic way. In this sense, it becomes entirely impossible, based on the physical theory or in an attempt to analyse the highly complex interactions that occur in the subquantum medium, to predict the future of the state of the acron. This impossibility of unambiguously predicting the future state of the acron is mainly due to the chaotic nature of the interactions between the acron and the theta wave field, which imposes a practical limit on our predictive capacity.

At this point Lucius said:

Tell me one thing, Argus: this chaos, and the consequent stochastic processes you talk about, what is their nature? Is it a chaos of an ontological nature or, on the contrary, you are talking about an epistemological chaos? If the chaos you refer to is of an ontological nature, then we are in a very bad situation. If so, then we are inevitably doomed to fail to advance further in our knowledge of nature. We will be marked by this limit. This limit seems to me to have a great resemblance to the so-called Heisenberg's limit, which pretends to be an absolute barrier to our cognitive possibilities of apprehending nature. If it's an epistemological chaos then, on the contrary, these barriers will only be of a factual nature and may eventually be overcome in the more or less near future.

"Of course, you're right, Lucius", said Argus, smiling.

That's why I'd like to take this opportunity to add that this statement of unpredictability must be understood in a purely operational and pragmatic way, and therefore it does not refer to its ontological nature as such. I think it's also very important to emphasize this fact to perfectly clarify the basic foundations of the new physics, which, in essence, is an open science. Under these conditions, and as it could not be otherwise, the concept of chaos employed here has an essentially epistemological nature rather than ontological. It's mainly intended to describe a situation in which the complexity of the underlying interactions is so great that it's impossible – at least in our present stage of knowledge of the physical reality – to predict the outcome of the future state with more certainty.

However, and this is where the great virtue of the method is, despite the practical impossibility of unequivocally predicting the future state of the acron, it's nevertheless possible to establish a general average statistical trend for the propensity of the acron to move from a given initial state to the following state.

From these considerations we can then reach the concrete form the principle of eurhythmy assumes in each case. So, it can be seen that in certain approximation conditions, the principle of eurhythmy can be expressed in mathematical terms, in a relatively easy way.

However, we are also well aware that we are making a simplistic compromise when we assume that the propensity of an acron to move from one state to another is a simple linear function of the intensity of the theta field, i.e. proportional. However, as already mentioned, this hypothesis of linearity introduced here does not constitute an ontological statement; it only translates a very practical and relatively adequate operational process in the vast majority of situations. Likewise, in this first approximation, we assume that the probabilities inherent to each possible transition can be combined according to an additive linear process. Later, this linear approach may eventually be discarded in favour of a more complex and nonlinear rule of composition of functions.

We must remember, however, that we are at an early stage of a difficult transition process. This transition process corresponds to a profound change in our traditional way of looking at nature. In the same way we are also aware that until now we have been fully immersed in the traditional linear Cartesian paradigm. We are so conditioned in this simplistic way of thinking about science, that all our language and terminology are deeply rooted in the traditional Cartesian linear paradigm. Everything happens as if we were trapped in a conceptual prison from where it's very difficult to escape. So, in these conditions we have to do the best we can.

We must, however, be aware that some of the statements we make may not be entirely clear and entirely correct. The development of a better language, either conceptual or formal, more general and adequate for the new physics, intended to replace the traditional linear paradigm, will require time and very hard work. Of course, as you can imagine this process, this more general language to be developed to better describe complex and nonlinear systems, must contain the simpler linear processes as a particular case.

On the other hand, we must also keep in mind the highly complex and nonlinear nature of the transition from one scale of observation and description of physis to the next scale. Even in the simplest cases in which the entity, the newly emergent whole can be understood as being composed from its parts (or subentities), its properties cannot, in general, be derived from the knowledge of the properties of the constituting parts. This situation results, of course, from the fact that the parts which form the whole, by interacting with each other reciprocally, modify and modify themselves to a greater or lesser degree. From here, it follows that the whole – the resulting emergent entity – has unique properties. Properties that in general, cannot be inferred from the properties of the parts. In some cases, the best to be expected is to be able to predict the emergence of new physical entities under certain very specific conditions, and if we are lucky enough, to be able to predict at least some of their more general properties.

"Argus, since the new physics deals with the processes of interaction between already complex systems, should it not be expected that this notion of information that has recently become so fashionable, has a very important role to play in the new science?" Lucius asked.

Looking at Lucius with a smile, Argus responded. "I think this is a very intelligent question, Lucius. In fact, the word and the concept of information today pervades almost all the domains of our society. Therefore, it will necessarily have to play a significant role in our new way of looking at the world." He paused before continuing:

However, due to common misunderstandings about the notion of information, I think it's very important, right at the beginning, to seek to clarify its real meaning. The information is basically something subjective, since it ultimately depends on the agent receiving the information, i.e. the receiver. In fact, information is a particular case of a much broader concept that is the concept of interaction.

Interaction is an objective physical process, involving the reciprocal modification, greater or lesser, of the co-participating physical entities. This interaction, real and objective, is related with the emergence of new physical entities. The concept of information, on the other hand, requires the existence of a recipient that is subjected to a very particular type of interaction. In turn, this receptor constitutes a real physical entity possessing consciousness. This consciousness, ultimately, is not more than a highly developed and organized state of complexity. Additionally, this conscious entity must also be able to understand and organize these complex processes of interaction and likewise the processes of emergence and becoming related to them. For this to occur, it's necessary, among other conditions, that the scales of observation and description of these interactions are compatible. Change processes, which occurred very quickly or very slowly, so that the relevant functions of awareness of the observer can take place, cannot be considered as information. This is because change rates are always evaluated in relation to the observer-receiver. It's only the observer-receiver who sets the frame of reference when we are dealing with information. Even in the case where the scale of becoming is adequate in relation to the observer-receiver, it's still necessary that the alterations involved have some kind of regularities that can be evidenced, the so-called patterns. On the other hand, it's still fundamental that the observer will be able to identify such relatively regular patterns of becoming. But even in this case, these patterns may mean nothing to the observer-receiver, as is often the case.

The patterns observed in the becoming may result from 'natural' causes, i.e. not produced by conscious beings, or be the work of a conscious agent. In both cases, the patterns of becoming are real, in the sense that their existence is relatively independent of the observer-receiver, whether they understand them or not. In order to understand these patterns of becoming, it's necessary for the observer-receiver to have a conceptual framework of reference in which they can be integrated in a coherent and harmonious way. This conceptual framework of reference is what is commonly referred to as language.

Here, it's necessary to introduce an additional note of clarification. If the sequence of patterns is of 'natural' origin – that is, if it was produced by non-conscious agents, or better said, by relatively low-complex systems – then this sequence is not commonly regarded as information since it does not follow the typical scheme of sender–receiver. In this case, there is no sender intending to transmit some kind of information to one or a certain group of individual receivers. When it comes to communication between a conscious sender and a conscious receiver, the concept of information becomes doubly subjective. In either case, whether the patterns of becoming are of natural origin or not, the information itself is always objective but its interpretation, or its decoding, is always subjective. In this case, the notion of information gets very close to the concept of interaction. To be able to understand or 'read' information in the sense of patterns of change in becoming, the observer must have a certain prior type of knowledge.

When information is produced by a conscious agent, this knowledge corresponds to a sharing of what is called a common language between sender and receiver. In turn, in order to have a common language, the sender and the receiver had to somehow share a process, a common experience at some point in their becoming. Put in another way, they must have participated in and become part of the same complex global entity. This situation corresponds, in eurhythmic physics, to the interaction of particles that have already shared a common theta wave.

When information is produced by 'natural' means, without the intervention of conscious beings, then the receiving subject must develop an entire body of knowledge – in a word, a science – that allows them to evaluate and subsequently understand the sequence of patterns of becoming. In order to be able to develop the science, the observer must have, from the outset, a conceptual framework that allows them to progressively, and at ever deeper levels, unravel the meaning of the patterns of becoming that they observe. This conceptual framework produces some sort of replica or image of what we might call the global theta wave of our world.

We must, however, be aware that once the development and consolidation of this profound conceptual interrelationship is properly established, it can subsequently be developed or may eventually be lost.

> When this relationship is developed harmoniously through a mutual interaction with other physical agents, then we have what we call science. This science, our science, is nothing more than an organized set of conceptual structures that allows us to better understand the natural patterns of becoming.

At this point Argus paused and as it was quite late we decided, by mutual agreement, to end our meeting, taking care of course to schedule the next one.

FOURTH JOURNEY

Fabrus's house, located in a beautiful place in Lisbon, was where we assembled to decide on the place for today's meeting. So, at ten o'clock in the morning we all met there and soon we started to make plans how to get to our chosen venue, Cabeção, a small village located in the centre of the high Alentejo.

Cabeção is a very interesting village worthy of being visited for many reasons, one being the beauty of its varied landscapes with hills and flatlands, watered by a broad river. This river, due to the existence of a dam, always has plenty of water even in the driest of summers. Because of its particular characteristics this river has enjoyed, over time, the preference of both professional and sporting fishermen. We should also mention that along the river, in the vicinity of Cabeção, there is an interesting aquarium where you can observe a huge variety of freshwater fish in their natural habitat. Besides these attractions the village still has an interesting megalithic, Roman and Arabic archaeological heritage.

Added to this, the village of Cabeção is still famous for its excellent local wine and for the good restaurants where one can taste the magnificent Alentejo cuisine. The excellence of the wine of Cabeção results from the combined effect of the nature of the terrain, well exposed to the Sun, and a very special microclimate. These natural conditions allied to a know-how rooted in a long tradition dating back to the beginning of our era, naturally lead to the maturing of an admirable wine in all respects. The trip of our discussion group to Cabeção had been arranged for this date in January as it's when the new wine, from the recent harvest, is ready to drink.

As there were six of us, we decided to do the trip in Iris's all-terrain vehicle because it was able to take us all comfortably. There was also the added advantage of Iris being teetotal, so she was able to drive without any problem. So, by 10.30 a.m. we were on our way to Cabeção, the place for our lunch meeting.

We were all in high spirits but as soon as things calmed, we naturally started – as one would expect – talking about physics. It was Amadeus who started the session, saying:

> This crossing of the Vasco da Gama Bridge and the beautiful landscape of the Tagus river that can be enjoyed from it, leads me to

reflect, and I think I'm not the only one of course, on the subjects we discussed in our last meeting in Chiado. It seems to me that the new physics, the physics of the complex based above all on the principle of eurhythmy, leads us to look at nature in a much more comprehensive and unitary way. In this new perspective, the great dichotomy between the so-called non-exact and exact sciences no longer makes sense. In fact, it's noted that such exact sciences, for example mathematics and traditional physics, are not as exact after all as some authors naively or arrogantly wanted us to believe. By the way, as you must understand, this observation is not surprising in itself. It suffices to consider the basic fact that science is necessarily a human activity. So, being a human activity, science is naturally fallible, and so there goes the status of supposed accuracy and the alleged absolute rigour it would hypothetically enjoy.

At this point, Fabrus intervened. "I agree with you, Amadeus. In fact, to pretend that it's possible to advance a thought, a logical structure, absolutely coherent and without any gap is madness, arrogance and above all a complete lack of sense of proportion." Laughing, he added, "To have as an objective the elaboration of a reasoning that is absolutely infallible, absolutely correct, absolutely rigorous, will inevitably lead us to *rigor mortis*!"

We all laughed at this aside from Fabrus, who continued. "In fact, as history teaches us, all the societies who assumed they had reached the absolute knowledge became static and decadent, consequently ending up stagnating and then disappearing sooner or later."

Lucius, who was following the discussion, joined in. "Fabrus, are you saying that one should not seek rigour in scientific theories? If this is the case, what would allow us to distinguish science from other human activities?"

"Of course, you're quite right!" said Fabrus.

However, here is a very important point that needs clarification. Although science aims at the highest rigour and the greatest coherence possible, we are aware that it's an ideal. Ideal, which we naturally seek to achieve progressively but never achieve. In these conditions, what distinguishes science from other human activities is its great degree of relative rigour, its ability to predict and above all, the concrete fact of allowing to increase our ability to survive as a species.

Argus replied:

I totally agree with Fabrus when he says that the aim of science is to attain an ever-greater degree of rigour, but that it is in fact an ideal which is never, or hardly attainable. However, I wanted to add that if it was not so, that is, if it was possible to achieve such absolute rigour then science and all scientific activity would be definitely finished. This attitude of immobility leads, naturally, to complete stagnation. History teaches us that societies which naively thought they had attained absolute knowledge and are therefore supposed to know the truth, ended up in a process of decay that posteriorly led to their disappearance. Whenever you believe that you have the truth, what necessity, what motives will we then have to look for something? This 'new' knowledge in this perspective, will be, at most, equal to what we already know, or if different, will be necessarily false.

This idea that it's possible to tie nature, which is in permanent becoming, in a rigid frame goes against all that we have observed throughout human history, at least until now. To claim that in a hypothetical future, more or less distant, it will never be possible to overcome such a limitation, is nothing more than a mere conjecture, a faith, in all respects similar to the religious beliefs.

There is a situation here that I think is convenient to mention: For man to advance on the arduous path of the search of knowledge, he must be deeply motivated. However, it's verified that in his life, in his path, in his process of becoming, man can be in one of the following possible situations:

1. Perfectly balanced because he knows or rather, naively believes that he knows the truth. In this case he doesn't move – he remains static – he assumes that should seek nothing, since he knows everything and thus he inevitably ends up stagnating.
2. He's too confused, unbalanced and a complete misfit, putting everything in doubt. In this case, too, he has no possibility of moving, for he loses himself in a permanent web of hesitations and contradictions, thus inevitably ending up doing nothing.
3. The last attitude towards the permanent becoming corresponds, as you must have understood, to an intermediate situation, to the said middle way. In this case, man is neither too balanced nor too unbalanced.

In fact, for us to continue on the difficult path of the search for truth, that is to say of knowledge at a first stage, and of wisdom at a much

> more advanced stage, we need a certain degree of imbalance – a certain amount of dissatisfaction, otherwise what need would we have to look for something different. This healthy attitude of mental openness corresponds to assuming with full awareness that the observer, and the world of which they are a part, are deeply interconnected and in permanent becoming. In these circumstances, it must be assumed that what was appropriate in a given situation and in a certain specific context may eventually cease to be so when circumstances change. And these, as we well know, are in permanent change. Of course, we are also aware that in many situations, at our scale of observation and description, we can and must temporarily as a first approximation assume that the causes can stay relatively constant. Under these conditions, we can then – as we have already mentioned – assume as adequate the simplistic Cartesian description.

After a few seconds, Argus continued. "Despite these subjects we have been talking about being extremely interesting, it seems to me that it is about time to direct our discussion to the question that has been left open, that is, the bases of the new physics, the eurhythmic physics."

We all nodded in agreement with Argus's words and he spoke again.

> We saw on the previous journey that one of the fundamental hypotheses of this new physics consisted of the acceptance that the entity that is commonly called simplistically the particle is, in fact, a very complex interrelated physical entity. This complex entity – the particle – is, as we have seen, composed of two deeply interrelated parts: a relatively extensive but finite part called the theta wave, and another part, extremely localized and comparatively much more energetic, called the acron.

Showing us a drawing, he said:

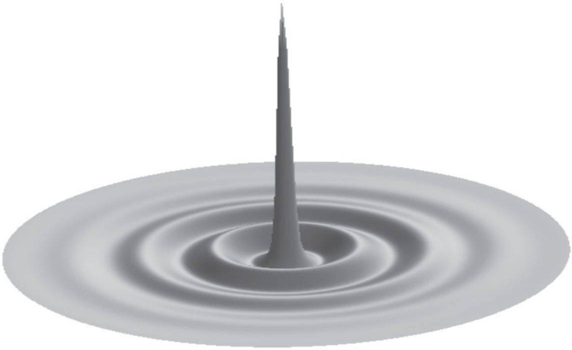

Figure 4.1: Graphic representation of a complex particle.

Here I am, showing you once again, an image – a simple graphical representation from which we can induce what a complex particle may possibly be.

In the figure you can see the acron and its associated theta wave. As we saw earlier, the acron moves within its theta wave according to a stochastic process and its average trajectory is described by the principle of eurhythmy.

In the previous Dialogues, we mentioned that this was the model associated with a quantum particle, and moreover, that this model had been proposed in the first quarter of the twentieth century by that great French physicist Louis de Broglie. Now in the new eurhythmic physics, this complex quantum particle model is generalized and extended from the restricted domain of quantum physics across all aspects of physics from relativity to electromagnetism to classical gravitation. Under these conditions, any relatively localized physical entity actually has a much more complex constitution than what might appear at first. A complex physical entity is thus composed of a relatively localized region – the acron – and a more or less extensive theta wave. That is to say, a physical entity cannot, in general, be characterized only by a simple point location. A physical system, being in permanent interaction with the medium, modifying and being modified to a greater or lesser degree, naturally has an extension, a region of influence, greater or lesser.

So, for us to better understand the situation, let's consider, for example, what happens with our Sun!

Turning to address Lucius he asked, “According to this new way of looking at nature, where do you think the Sun is now?”

We all looked at the Sun that shone brightly to our right. Lucius, after thinking for a few moments said:

> It seems to me, Argus, that your question is much more complex than it may appear at first!
> A first answer would be that the Sun is up there in the sky on the right, where we seem to observe it at first glance. However, I believe that in the interrelational new eurhythmic physics, this response is rather incomplete and only partially adequate. Since the Sun is a complex physical entity, it must also have an associated theta wave like any other relatively localized entity. This wave must therefore correspond to the extensive gravitational field where the action of the Sun manifests itself, which in this case extends to us. Therefore, and answering your question, I think we should say that the Sun is also here with us.’

Turning to Argus he asked, “Did I answer your question well?”

“Of course you did! Nothing else would be expected from you” said Argus, smiling. He elaborated:

> If here, in this vehicle where we are now on our way to Cabeção, we are under the influence of gravity from the Sun it’s because, in a sense, it’s also here. Otherwise, the real and objective physical action that the Sun exerts on us would have to have a supernatural, or rather unnatural origin. Now, we are aware that such a statement is not at all admissible. As we all know, everything we observe and realize is part of nature. Nothing that is not part of nature even exists! Thus, and ultimately, all observed and unobserved phenomena are natural. In this case, the explanation is quite simple: the gravitational field of the Sun, as we shall see later on, manifests itself through its extensive real physical field, its theta wave.
> Under these conditions, what we normally call the Sun corresponds, in this new way of looking at nature, to its acronic structure, whereas what we call gravitational field is ultimately the result of its extensive undulatory nature. Reducing the Sun only to its acronic structure, as it’s generally done, results from a very reductive and incomplete vision.
> However, as it happened in the vast majority of situations, this idea has already been somewhat anticipated by certain astronomers. I

don't know if you know that there is an empirical law, Bode's law, which roughly indicates the mean positions of most of the planets in the solar system. This empirical law, where the sequence of integers plays a relevant role, was first proposed in 1766 by Titius and later disseminated by Bode in 1772, hence the name of Bode's law. However, presently most of the authors, with the aim of restoring the historical truth, have duly designated it by the law of Titius–Bode. This empirical law, adequate for the planetary macroscopic scale for the great majority of the planets, bears a great analogy with certain empirical laws discovered in the field of microphysics.

In reality, it can be verified that the empirical laws of Balmer, Rydberg and others, proposed at the outset of quantum mechanics, are relatively adequate to describe the emission spectra of the hydrogen atom.

As we know, inspired by these empirical laws where, in perfect analogy with the law of Titius–Bode, sequences of integers are very important, Niels Bohr proposed his hybrid, semiclassical, semiquantum atomic model. In turn, this model, constructed on the basis of sequences of integers, suggested to de Broglie the extensive undulatory nature of quantum entities. This is because the observation of periodic phenomena, such as musical notes that can be described in terms of sequences of integers, is an indication that there is an underlying basic correlation of an extensive undulatory nature.

In fact, in the possible stationary waves, which naturally form in a given cavity, there is a pattern that repeats itself. This pattern is associated with a semi-integer sequence of wavelengths.

At this point Amadeus said, "Argus, I'm sorry, but I don't quite understand what you're saying. That's why I would like to ask you this: Why is it that the periodic phenomena we observe and that can eventually be described by sequences of integers imply that behind them ultimately lies an undulatory phenomenon?"

Argus, turning to Amadeus said:

I think you asked a very pertinent question. Naturally, the real situation is that we don't know what really exists. All we can aspire to is to develop theories that allow us to draw conclusions, provisional it's true, but that ultimately, may have an ever-greater

harmony with Mother Nature. So, in our case, let us see then what happens with the undulatory phenomena.
Most of the natural undulatory phenomena can be described as a more or less regular finite sequence of structures, of patterns, which are repeated either in space or in time, or in any other reference system. These undulatory phenomena can then be characterized by a certain frequency, which as we've seen above translates a repetition rate of a given structure, of a relatively regular pattern, in a given measuring system. In the case of standing waves, the ones that forever remain as such, this repetition of the pattern is permanent in both space and time. However, I must say that these entities constitute only a useful abstraction because, in reality, standing waves do not exist. What exists are phenomena, such as musical notes, which within certain approximations and at a given scale of observation, can be described as stationary waves. It's for this reason that strings of musical instruments, such as guitars, violins, pianos and others, have relatively well-determined lengths. Likewise, the lengths of the organ tubes and other wind instruments also have relatively accurately determined lengths. This need arises from the well-known fact that in order to generate standing waves, or better said nearly stationary, it's necessary that the regions, the cavities where they propagate have relatively well-defined lengths. In these zones where the harmonious musical sound is produced, the total wave path must be an integer multiple of half a wavelength. Under these conditions, the sound wave being reflected by the ends of the cavity will maintain approximately the same characteristics.

Grabbing the pen, he created a drawing on a piece of paper, and said: "Despite the difficulties of drawing in a moving vehicle, I think that for a better understanding of the subject it's necessary to make at least a draft of the situation."
After a few moments he presented a relatively understandable sketch which I improved with a CAD program, that can be observed in the following figure:

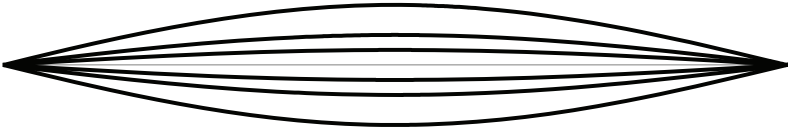

Figure 4.2: Stationary wave vibrating in a cavity corresponding to a 1 × ½ wavelength.

Continuing, he said:

This drawing seeks to represent a viola string fixed at the two ends of a cavity of well-defined length L. Pulling the rope results in a spacing, i.e. a maximum elongation. When we release the string, it begins to vibrate giving rise to a standing wave that we can easily observe. This stationary wave, generated by this simple process, corresponds to the so-called first mode. This means the distance between the two fixed points, the length of the cavity, corresponds to a half-wavelength (L = 1×1/2 length of the wave one, $= \lambda_1/2$). The region where the string vibrates in a relatively stable way, is also referred to as a resonance cavity. This is because, under these specific conditions, where the length of the cavity is equal to an integer multiple of half a wavelength, the incident and reflected waves at the ends, instead of destroying themselves as expected, will be reinforced. Under these conditions, the vibrations, the waves, will be able to be observed for a relatively long time, in such a way that at a common time scale of observation the vibration seems stable, i.e. stationary.

The following drawings, (Figure 4-3), try to represent other possible modes of vibration of the same string fixed in a cavity of the same length, L.

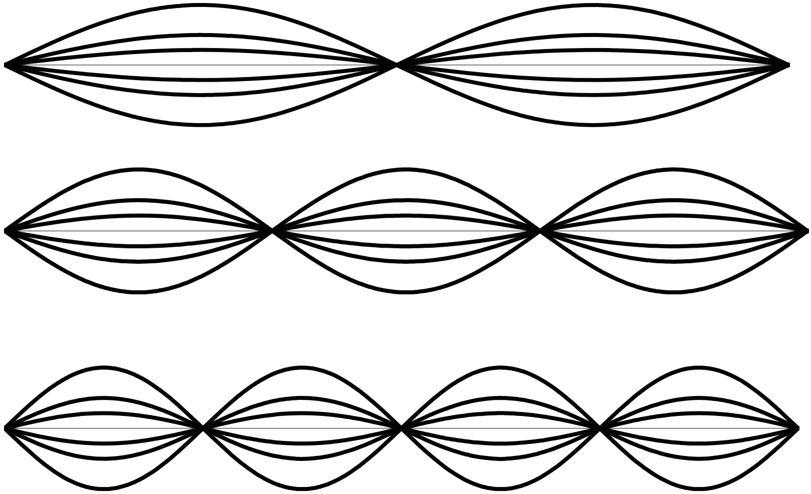

Figure 4-3: Stationary waves corresponding to: 2 × ½; 3 × ½; 4 × ½ wavelengths.

The first drawing corresponds to the second possibility of vibration of the string. In this case, the cavity length is equal to two half-lengths of harmonic wave number two, i.e. a full wavelength (L = 2×1/2 wavelength two, = $2 \times \lambda_2/2$). It's verified, under these conditions and for this oscillating system, that in the middle there arises a point where the amplitude of vibration is always zero. For this reason, this region is called a stationary point or more commonly a node. Of course, in this case, the length of wave two is half the length of the previous wave, wave one, $\lambda_2 = \lambda_1/2$.

The second drawing corresponds to another possibility of vibration of the string. In this case it gives rise to three lobes with two corresponding nodes. As each lobe corresponds, as we know, to half a wavelength we have three half-wavelengths which in turn are equal to the length of the cavity (L = 3×1/2 wavelength three, = $3 \times \lambda_3/2$).

Finally, in the last drawing one can observe four much smaller half-wavelengths that make up two complete waves. That is, four half-wavelengths number four are equal to the length of the cavity (L = 4×1/2 wavelength four, = $4 \times \lambda_4/2$). In this case, as you can see, three intermediate nodes are formed.

Of course, as you can imagine, other stationary modes of vibration are possible. However, as I told you, they must correspond to the condition that the length of the cavity is always an integer multiple

of half a wavelength. Under these conditions, the stationary waves that are formed will have an increasingly smaller wavelength.
In case the oscillating cavity is enclosed in a circle, as shown in the following drawing, Figure 4-4, the possible stationary waves are also, of course, those that meet the condition of the perimeter, i.e. the length of the cavity, to be equal to an integer multiple of half a wavelength.

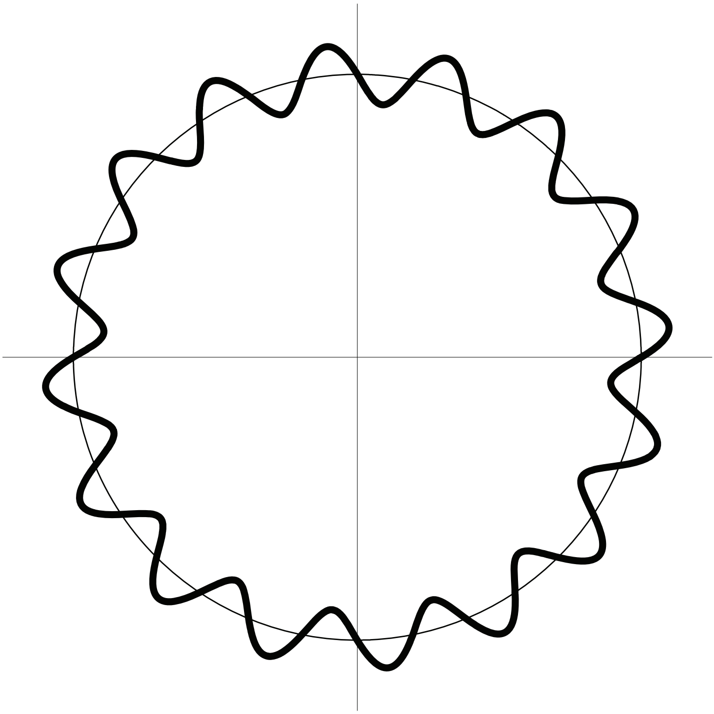

Figure 4-4: Stationary waves in a circle.

Amadeus, who followed Argus's exposition attentively, said, "It seems to me very clear now, why a phenomenon characterized by sequences of integers, that is, by a repetition of regular patterns, is a precious indication that behind it lies ultimately something closely related, in short, something extensive of undulatory nature."

"Of course!" said Argus.

> You went right at the heart of the matter. A wave, an undulatory phenomenon, translates as nothing more than a strong correlation between different elements or patterns, more or less regular, more or less distant, but all sharing a certain degree of interconnection, of close interdependence. Hence a wave phenomenon has an extensive nature characterized precisely by its frequency, i.e. the approximate rate of repetition of a given relatively well-defined element, in a given reference system.
> So, in this new way of looking at nature, the law of Titius–Bode tells us that the Sun and the planets of our solar system have a complex nature and are composed by an intimately interconnected acronic structure and theta wave.

At this point Lucius intervened: "Then if that is the case, Argus, how do you explain the movements of the planets, such as that of Jupiter, through its theta wave?"

"Before answering your question, Lucius, I'd like to ask you if you know the shape of the orbits of the planets revolving around the Sun."

Clearly enthusiastic, Lucius responded. "Of course! I think it's common knowledge that the planetary orbits, or the movements of the planets around the Sun are ellipses. This statement is Kepler's first law which tells us precisely that the orbits of the planets are ellipses, the Sun occupying one of the foci."

"You're absolutely right!" replied Argus. "However, this is only partially valid. I will say even more, it's only adequate at a certain scale of description of reality."

"What? Are you saying that Kepler's Law of Ellipses doesn't have a universal validity?" exclaimed Amadeus.

At this point, Fabrus replied:

> We all know that at the time of Kepler, in the seventeenth century, observational astronomy was not very developed. With regards to the methods and instruments at our disposal today, we can say in all fairness that the accuracy of his measures was not that great. So, although they did the best they could at the time, the accuracy with which they knew the positions of the planets was relatively low. Kepler got to the law of elliptical orbits based on the astronomical data available at the time, which had been obtained by Tycho Brahe

and based on the planet Mars. At this level of precision, the motion of Mars can and should be described as elliptical. However, it would be reasonable to think that if Kepler had at his disposal the observational data we currently have on the orbit of Mars, he probably would not have been able to reach his Law of Ellipses. This is because the position that Mars occupies in the course of time is very complex and somewhat irregular.
I must say, truth be told, that even from Newton's theory of gravitation, the orbit would only be an ellipse if our Sun and Mars were reduced to simple material points without any dimension, and moreover if space was totally empty. On the other hand, we also know that the Sun and Mars are not rigid punctual bodies and that there are other planets, comets, asteroids, etc. This means that space, instead of having only two material points, is full of astronomical objects. Being so, it follows that the actual movement of the planet Mars and similarly of the other planets is actually quite complex. Only within a certain level of approximation, relatively coarse, I must say it, one can affirm that the orbits of the planets are ellipses. Ultimately, and at best, the real orbit of an extremely complex planet can be said to be contained in a tube of elliptical toroidal shape, as can be seen in this figure.

Figure 4-5: Real orbit of Mars shown by an elliptical toroid.

"Now, I'd like to add", said Argus, "that the solar system, and even the universe at large, is a complex entity that is evolving, in permanent becoming. For example, let's see the case of the Moon: adding to the complexity of the orbit – because the precision we have about its position is very high – we still have the fact that the Earth's satellite is moving away. So, it's concluded once again that the orbits of the planets are not ellipses as it's said in Kepler's law."

Argus paused for a moment.

However, it would be utterly devoid of meaning to claim that Kepler's law is false. I must say, beyond any doubt, that Kepler's law of elliptical orbits was and is a great law! Of course, it doesn't have, as is generally claimed, an absolute and universal validity. It is, however, a very adequate law at its scale of description of nature. On the other hand, it should also be remembered that this law, although approximate, allowed very important cognitive advances in the development of classical physics.

Turning now to the question from Lucius, I'd like to say that I believe it will be possible to demonstrate that the orbits of the planets may be described approximately in much the same way as the orbits of the electrons around the atomic nucleus. This means that it will then be possible to express the orbits of the planets as a simple half-wavelength relationship. Naturally, the real orbit of the planet, extremely complex and in permanent evolution, will not be subject to a description expressed by such a simple relation. However, and within a very reasonable approximation, it will be possible to describe it in terms of a relatively stationary theta wave.

Now I imagine all of you must have the basic question: How is it possible for a theta wave almost powerless relative to its acron, to guide the movement of the planet, or should we say, the planetary acron?

"I think that within the conceptual framework of the new physics of the complex and nonlinear, this question has a simple and immediate answer", replied Iris, who although she was driving was paying full attention to the conversation. "As in eurhythmic physics there is not necessarily an equality between action and reaction, it may, under special conditions, happen that an action, although very tiny, gives rise to a great reaction. Thus, the theta wave, despite having a relative energy level that is thousands of millions of times lower than that of the planet, it still has, through nonlinear processes, the ability to guide the planetary acron in a eurhythmic way such that, on average, its movement can be described as approximately elliptical."

"Thanks Iris, I couldn't say it better!" said Argus, and continued:

I'd now like to address a different and relatively more complex subject, especially from the formal point of view. It's the visitation hypothesis that is related to the relative stability of the complex particle.

This hypothesis assumes that the acron is – so to speak – the motor, the generator of the complex particle. So, the acron in its interaction with the subquantum medium, of generally chaotic nature, will generate its basic theta wave. In turn, the acron, while moving to other regions will generate successive 'instantaneous' waves. These individual theta waves are ultimately structures, ordered disturbances from the underlying chaotic medium, the subquantum medium. In these conditions, we can then say that a wave is a region of the basic medium, usually chaotic and undefined, the subquantum medium, relatively ordered where it's possible to make predictions. These waves, these regions of order, will naturally and progressively undergo a degradation until eventually they will be mixed with the chaotic medium. In these conditions, if a theta wave is not visited by the acron, the generator of order, it eventually degrades itself completely and therefore disappears as an ordered structure of the subquantum medium. In turn, the acron, to persist as a highly organized structure, has, as we know, a propensity to move to the regions where the total wave, the wave resulting from the composition of the previously generated waves, has greater density. This eurhythmic movement of the acron, as we know, results from a simple fact: for an ordered complex system to increase its capacity for persistence, it should move, on average, preferably to the regions where the degree of organization of the medium it's interacting with is greater. It's possible to show, analytically and numerically, that this set – acron and its associated theta waves – which make up the complex particle, has a relatively stable structure.

At this point Fabrus decided to intervene in the discussion. "As you might suspect, the mathematical calculations that support Argus's last statement are relatively complex. So, I think he'd better be excused from doing them. All the more so, we find ourselves in a moving vehicle which would make such a mathematical demonstration very difficult", said Fabrus, smiling. "Anyway", he continued, "anyone who's interested can consult the work *Eurhythmic Physics* where these calculations are available."

"Certainly. You're quite right Fabrus! I also think that it's best to dispense with these parts, which are more complex from the formal point of view and in the end, add nothing new to the understanding of the process we are talking about", said Argus.

So, once again, we conclude that a particle constitutes a relatively stable and highly complex structure, in permanent interaction with the medium and with itself. Under these conditions, this complex structure while moving in the subquantum medium, naturally has a certain zone of interaction, greater or lesser. The volume of this zone of interaction of the particle – the region where its action is felt – is related, under typical conditions, to its wavelength. The size of this interaction zone is described, in a first approximation, by the following formula:

$$\sigma = M\lambda$$

The first Greek letter, σ (sigma), defines the extension of the 'particle' which is a function of the wavelength λ. The wavelength and the size of the theta wave are related by the fundamental constant M.

On the other hand, we also know that the inverse of the wavelength corresponds to the spatial frequency. Under these conditions, we can say that the region of interaction of the particle is inversely proportional to its frequency. This means that the larger the spatial frequency of the acron, the smaller its associated theta wave. The same can be said for the time frequency. Thus, we conclude that the region of interaction of the complex particle varies inversely with its frequency, be it temporal or spatial.

"Of course", said Fabrus, "That result is very well understood!"

For a higher frequency, that is, at a higher rate of variation of the system, it corresponds to a greater need from the medium to change. Since the speed of propagation of the interaction in the medium is finite, it follows that if the rate of change is very large, the action has few possibilities of propagation. This happens because everything occurs as if we were pushing up and then down, so continuously doing and undoing the action. Under these conditions, this interactive process of doing and then undoing will severely limit its zone of influence of the action. Thus, it's found that the slower the vibration or the frequency of the particle, the more time the action has to propagate in the medium, contributing to an increase of its interaction zone.

After a pause, Argus continued:

However, at this point, I'd like to draw your attention to an issue which seems basic to me. Although this constant *M* is very important, even fundamental, it cannot be said that it is in fact a universal constant. This is because it can change from medium to medium. Thus, if the region where the particle is found is very chaotic, its value will naturally be very small due to the fact that the dimension of the theta wave, that is, the zone of influence of the particle, is smaller in case the medium is very chaotic. If, on the contrary, the particle is in a region where the medium is relatively more organized, then the dimension of the region of interaction or coherence of the particle will be larger, which will, of course, translate into a higher value of *M*.

Then Lucius said, "Argus, I'm a little confused! It looks to me like you're saying that this constant *M*, after all, is not a constant! If it's not a constant, then why do you call it a constant?"

"Your observation makes perfect sense, Lucius!" Argus replied.

In absolute terms, it should not be called constant because, as a matter of fact, it's not. In the same way as all the other constants of physics, and moreover the so-called universal constants, are not in fact constant. However, from the heuristic point of view the concept of constant has a great practical utility. In the vast majority of experimental situations, which we encounter in our day-to-day lives, these entities – these relations between variables – behave as approximately constant. Hence, they're called constants. Several physical entities are in the same situation, namely the said stationary waves that we've just seen.

These stationary waves, as you know, are abstract entities that only exist in our minds, for every real physical wave has a beginning and an end. For this simple reason it cannot be said, in fact and at all, that standing waves exist. However, and in spite of everything, this concept has in itself a great heuristic and operational value especially when used at an adequate scale of observation and level of description of reality.

To better illustrate this situation of the relational adequacy of our concepts to a certain scale of observation and description of nature, I will refer to a very interesting device, especially from a conceptual point of view.

This mechanism can be found in the main hall of the Science Museum of the Massachusetts Institute of Technology (MIT), in the United States. This system consists of an electric motor connected to a system of multiple gears. The motor shaft, connected to a small gear, turns 212 times each minute. So, its initial speed is:

$V_0 = 212$ revolutions per minute (rpm)

In turn this small wheel is attached to another larger gear. The relationship between the two wheels is such that there is a reduction in the rotational speed of 1/50. Thus, this first large gear, due to the reduction, rotates at the speed of

$$V_1 = V_0 \times (1/50)$$

that is,

$V_1 = 212 \times (1/50)$ revolutions per minute (rpm).

In turn, the large gear is connected to a second small gear, equal to the first of the electric motor, forming a solid pair. Of course, in each solid pair, both the big and the small wheel turn at the same speed. This second small wheel of the first pair will likewise engage a second large wheel by experiencing a similar speed reduction of 1/50. That is, this second wheel rotates at a speed of

$V_2 = V_1 \times (1/50) = V_0 \times (1/50) \times (1/50)$,

this means

$V_2 = 212 \times (1/50)^2$ revolutions per minute.

Similarly, this large wheel is connected directly to a small one forming a solid pair, similar to the previous one, which in turn connects with a third one and so on until a number of twelve reducing assemblies is reached.
Under these conditions, since we have in total twelve sets of reduction gears, the rotation speed of the last axis will be given by:

$V_{12} = V_0 \times \left(\frac{1}{50}\right)^{12} = 212 \times \left(\frac{1}{50}\right)^{12} = 8.68 \times 10^{-19}$ revolutions per minute.

Now, knowing that a year has 365 × 24 × 60 = 525 600 minutes, it follows that in one year the output axis of the device gives $525\,600 \times 8.68 \times 10^{-19} = 4.56 \times 10^{-13}$ turns.
That is to say, the final axis of the device gives one complete rotation in about 2.19×10^{12} years, or 2.19 trillion years.
In short, the electric motor gives 212 revolutions per minute. In turn it's connected to a mechanical speed reduction system such that at the end, the output shaft gives a complete turn in 2.19 trillion years.
To make the device even more interesting the constructors connected the output shaft solidly, through the use of cement, to a concrete pillar of the building.
Let us now suppose that the device, motor and gear system is enclosed in an opaque box, so that it's not possible to see the internal mechanism. From this box only comes the final shaft, a metallic cylinder we can see, firmly attached to the concrete of which the building pillar is made.
The question I'd like to ask you now is: Looking at the metallic cylinder that comes out of the box and that is solidly attached to the concrete, what can we conclude? Is this cylinder, this shaft, standing still in relation to the building? Is the shaft in motion?

Iris, who was following Argus's words closely, said, "I think we all agree with the answer to be given. All the more so that is in perfect harmony with everything we've been saying."

So, the answer to your question, Argus, can be divided into two:
The first is the response given by an observer who is unaware of the internal process of the mechanism.
Since he doesn't have access to the mechanism because it's enclosed in an opaque box, this observer, based on the concrete facts resulting from his direct observation, will say that the cylinder, the shaft coming out of the box, is still. All the more so that it's perfectly welded to the concrete pillar of the building. I will say that the observer will be somewhat perplexed by your question because what they 'see' is a cylinder, a completely immobile metallic axis.
In the second case, we assume that the observer, to whom the question is addressed, knows the internal mechanism of the system:
This observer knows that if he opened the casing covering the device, he would see the mechanical system spinning with a great initial speed. This initial speed is progressively decreasing due to the system of reducing gears. Thus, given his prior knowledge of the

system, the observer would say that the output shaft of the device would in fact be rotating.
However, this speed of rotation is so, so, slow, that for all practical purposes everything happens as if the metallic cylinder would be motionless.

"Of course, Iris! You gave, as expected, the proper answer" said Argus, smiling.

This concrete example, put to the consideration of the visitors of the museum, clearly shows us that the notions of stationary or non-stationary, moving or non-moving, constant or not constant, large or small, etc. are, interrelational concepts. Concepts which only make sense within a certain scale of description of reality. In other words, these notions are traditionally assumed as constant, as immutable; after all, they only have a meaning in the context of a relatively well-defined conceptual relational framework.

Fabrus took advantage of Argus's pause to speak.

I can't stress this aspect enough. An affirmation only has a meaning in a certain context. So, in a certain interrelational context a certain statement may be valid, or rather adequate, whereas in another context and in another scale, the same statement may be false, that is, inadequate.
Consider for example our planet, the Earth!
On the galactic scale our Earth is nothing more than a simple dot.
However, at another scale, for example for an ant, the Earth constitutes an entire universe, which for all practical purposes behaves as if it was infinite.

"Well!" said Argus. "After this illustrative tour, let us then return to our particle."

We've found that this rather complex system is relatively stable, that is to say, possesses a significant degree of persistence. The next step will be to see how its energetic core, the acron, behaves in different types of fields resulting from the composition of a multiplicity of theta waves.
First, we shall consider the simplest case, in which the medium where the acron moves, characterized by the intensity of the global

theta wave, can, at the scale of description in which we are interested, be considered as constant.
In this case, since the intensity of the global theta wave may be considered, on average, as constant in all directions, I = constant, then there is no privileged direction for the acron to move. So, although the acron is in permanent random motion, forward and backward, rightward and leftward, upward and downward, its average speed is, however, close to zero.

$$\bar{v} \cong 0.$$

Naturally, this conclusion does not surprise anyone since it can be interpreted as a direct consequence of the principle of eurhythmy.
Let us now consider the situation in which the intensity of the theta field varies. Let us also suppose that the field strength in the zone we're studying increases steadily, for example, linearly, $I = kx$. In this case, as we already know, according to the principle of eurhythmy, there will be a propensity for the acron to move to the regions where the theta field is more intense.
However, there is something particularly interesting about this movement to which I'd like to draw your attention:
Since the theta field strength is not constant then, there is a privileged direction for the movement of the acron. The question at this point is to know how this movement takes place. What is the average speed at which the acron moves in this medium of increasing intensity?
To simplify the problem, we can admit in this approximation that the random motion of the acron is made only in one direction.
In these conditions, the acron, which at a given moment is in a given position, has only three possibilities to move:

1. Moves forward, advances
2. Moves backward, reverses
3. Remains in the same position

Of course, each of these possibilities corresponds to a probability:

p = probability of moving forward,
q = probability of reversing,
δ = probability of remaining in the same position.

The sum of these probabilities must be equal to one

$$p + q + \delta = 1$$

The tendency of the acron to move, the average speed, must then be expressed by the difference between the probability of advancing and of reversing, i.e.

$$\bar{v} = \alpha(p - q).$$

This means that the propensity of the acron to move, its average speed, is proportional to the difference of these probabilities as seen in the formula, where α is the proportionality constant.
From this formula it can be inferred immediately that if the theta field density is constant, then the probability of advancing is equal to the probability of reversing, $p = q$, and therefore the average speed of the acron comes null.
It's possible to show that the mathematical expression of the probabilities can be expressed as a function of the theta field intensity and from there derive the approximate expression for the average speed of the acron to move.
Of course, I am not going to bother you with relatively complex mathematical calculations. So, for obvious reasons, I will not make any derivative of this expression here. We may, on another occasion, make this mathematical derivative. Or those of you who are interested, may consult the book *Eurhythmic Physics* where this and other mathematical calculations can be found.
On the other hand, this variation may be expressed, in the continuous approximation, by the so-called intensity gradient divided by the intensity.

Under these conditions, the propensity for the acron to move can be briefly translated by this beautiful expression

$$\Gamma = \frac{\nabla I}{I}$$

where ∇I is known in mathematical slang by the name of gradient of the intensity. This gradient shows the way in which the theta field intensity I varies with distance. This mathematical expression is also commonly known as the genesis formula given its adequacy in describing certain aspects of the becoming of complex systems.

Let us now see what happens when, as in the case under consideration, the theta field intensity grows linearly

$$I = kx.$$

By simple substitution in the genesis formula we get

$$\Gamma = 1/x$$

whose graph can be seen in this figure, (Figure 4-6)

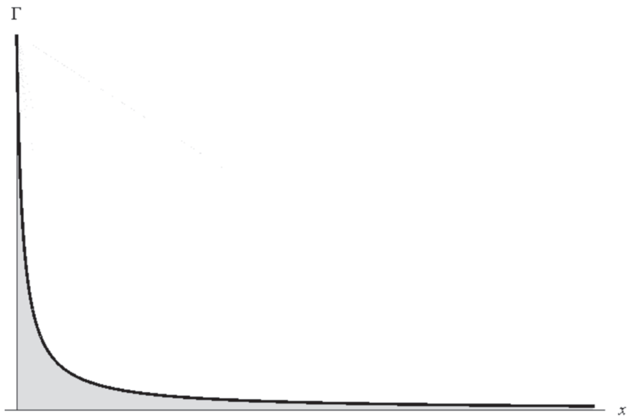

Figure 4-6: Average speed of the acron in a theta field with a linearly growing strength.

This somewhat unexpected result may seem surprising at first glance. As you can see, although the field intensity increases continuously, the propensity for the complex system to move decreases, until eventually becomes null.

Pausing, he asked, "How can this seemingly strange result be understood?"

Argus gave the answer himself:

> To better understand this situation, I think the best thing to do is to consider that this rather complex system in reciprocal interaction with the medium is, for example, a human being.
> Let's look at the following case, of a purely conceptual nature, in order to illustrate this situation in an easy-to-understand way.
> Consider the case of a person who's in this particular situation of having no money at all.
> In order to win ten euros this person will work very hard. Now that they have ten euros, they will continue to work, perhaps not as hard, to earn another ten euros. Possibly, at this time when they have twenty euro, their fitness to work will be lower than before.
> Suppose now that this person, continuing this process of earning ten euros at a time, without spending anything, will be in possession of a large sum of, say, ten million euros. In this case, now that they have a very large amount of ten million euros, the motivation, the propensity to earn another ten euros will surely be very small. This is because, compared to the fortune that they own, ten euros will make absolutely no difference.
> In short, for a constant gain of ten euros, the average tendency of a person to work hard decreases as the overall value of their fortune increases.

Iris, who like all of us, was following Argus very carefully said, "Argus, I found the example you gave very interesting to help us understand the deeper meaning of the genesis formula."

> However, it seems to me that many other examples can be found where the genesis formula proves to be quite adequate to describe the average behaviour of complex systems such as the human being.
> Since I have a sweet tooth and I quite like chocolate, I am thinking about the following situation:
> Let us consider a man who loves chocolates but who, in the place where he lives, lost in the confines of the African wilderness, does not have access to them. One day, he is fortunate to receive a huge box full of small chocolates as a gift. As he is keen on chocolates, he immediately begins to eat them, one at a time. At first, his enthusiasm for eating chocolates is too great. However, as he gets satiated, his enthusiasm gradually diminishes until, when he is full, he stops eating chocolates completely, otherwise he'd become ill.

> So, at first, his appetite for eating chocolates is enormous. However, as he's eating chocolates, one by one, this propensity to eat more will decrease until it's null.

Argus, in chorus with us, congratulated Iris on her simple but significant example to illustrate the appropriateness of the Genesis formula in describing certain behaviours of complex systems in reciprocal interaction with each other.

Suddenly, we realized we were about to arrive at our destination. The bridge over the river that passes through Cabeção, the river Raia, a tributary of the Tagus, was just in front of us. After crossing the bridge, we found the beautiful pine tree forest surrounding the village and we went straight to the *Solar da Vila* restaurant. As we had already booked a table, we sat down immediately. After reading the menu, and in order to taste the various recipes of the delicious Alentejo cuisine, we decided to order one of each and share them. Of course, to accompany the food we ordered the excellent wine from the village.

Lunch was both enjoyable and exciting, with everybody talking enthusiastically. When things began to settle down and appetites were satiated, we resumed, even if briefly, our discussion about the new science. It was Amadeus who triggered the process, by saying:

> We were talking about the way an acron moves on average in a theta field of increasing strength. We also had the opportunity to see that when the theta field has a constant strength, the acron on average doesn't move.
> Now, it seems to me that there's something here that I don't understand. If for the acron to move it has to be immersed in a field of variable strength, that is an asymmetric field, how do you explain the movement of bodies in approximately constant fields?

"You've asked a very interesting question, Amadeus!" said Argus, smiling. "The answer to your question results from the fact that the speed of the acron in a given theta field depends not only on the eurhythmic propensity but also the so-called initial speed. This initial speed is nothing more than the speed at which an acron, coming from another medium, is launched into a certain extensive theta field. Naturally this initial speed is due to an asymmetry of the incoming theta wave field."

> Let us consider the case where an acron is injected into a given theta field with a certain initial speed. This speed, traduced by the

asymmetry of the incoming theta wave field, will be expressed as the probability of moving in that direction by a constant term. So, the shape of the probability of movement in that direction will depend on two terms: the eurhythmic probability $\tilde{p}$, plus a term corresponding to its initial speed γ

$$p = \tilde{p} + \gamma.$$

Of course, we know that this term relative to the initial speed can only be taken as constant in a first approximation. Due to the reciprocal interaction with the medium, this initial asymmetry expressed by the speed of the acron will be progressively reduced until it stabilizes or eventually stops completely. However, it may be the case that in certain particular circumstances of interaction such a decay is not relevant and can then be taken as constant.

This situation may occur when the acron moves in such a medium that its reciprocal interaction is practically null. Under these conditions, whatever the speed at which the acron is injected in the medium, this speed will remain approximately constant. This speed is then called natural speed for it corresponds to the speed of the acron, free of any interactions that hinder its movement. In this case, the eurhythmic contribution of the extended medium becomes practically zero. It should be noted here that this natural speed may be very, very large. In any case, in a given medium we may have similar particles moving at different speeds. These different speeds, of course, depend on the asymmetry of the incoming theta wave field, that is, the initial speed with which they were injected into the larger medium.

At this point, in connection with this situation, I'd like to introduce a very important concept: the so-called saturation speed.

To better comprehend the meaning of this concept, let us admit that the acron is injected into a given medium at its natural speed. However, unlike the previous case, the interaction of the particle with the medium cannot, in general, be neglected. Due to this reciprocal interaction with the medium, the movement of the acron will be more or less hindered, until eventually a balance is reached. The speed reached in this situation of dynamic equilibrium with the medium is called saturation speed. No matter how great the speed with which the acron is injected in this medium, and for these specific conditions of reciprocal interaction, its final speed – the saturation speed – remains approximately constant.

In conclusion: If the medium in question is not very perturbative, meaning that the degree of reciprocal interaction is relatively low, the average speed of the acron corresponds approximately to its natural speed. It's understood here that by natural speed, we mean the speed that a particle would have when, for practical purposes, its reciprocal interaction with the medium could be neglected.
If, on the other hand, the interaction with the medium cannot, for practical purposes, be neglected, then the average speed of the acron will tend towards saturation. This means it tends to reach a maximum possible value relative to the specific conditions of interaction with the medium. So, however great the velocity with which the particle is injected in a given medium, its maximum average speed always ends up reaching a limit, i.e. it becomes saturated.

At this point Amadeus said, "Argus, I don't quite understand the question of saturation speed you've been referring to. Is it possible to clarify this question, which seems to be important, a bit better?"

"Of course!" replied Argus. "To better clarify the situation I will, as usual, resort to metaphor."

Suppose, Amadeus, that you are in Lisbon at the beginning of the Restauradores square, next to Avenida da Liberdade, and that you intend to go to *A Tendinha do Rossio* to eat one of those beautiful ham sandwiches they sell over there. Let's also admit that for very particular reasons, at this moment, the square is completely empty of people or cars.
In these rare and very particular conditions, as you have no obstacles in your way, you will move at an average speed that, in practice, will be the same as your natural speed, for example 6 km/h.
Now, as you arrive at Rossio, to your surprise, you come across a large crowd. People and more people, all moving in a perfectly chaotic way. To cross Rossio square, something you'd do in a few minutes if there were no obstacles, you'll have to walk in zigzag from one side to the other, back and forth. So, although your natural speed is 6 kph, your average speed crossing Rossio square will surely be much lower. No matter how hard you try, on average you cannot walk any faster, reaching a maximum level.
This means that in this situation, your average speed reaches a limit, in sum, it saturates, say, for example at 0.5 km/h. This value then represents the maximum possible average speed at which you can

move, compatible with the conditions of your concrete interaction with the chaotic medium in which you move.

If you do it the other way around, the opposite is true. You are moving in Rossio at an average speed of 0.5 km/h. When you reach the Restauradores square your speed suddenly starts to increase until it saturates in this medium, eventually reaching your natural speed, of, say, 6 km/h. This enormous increase in your average speed results from the fact that in this case the degree of interaction with the medium has drastically diminished until it's practically null.

He took a break, then said, "I think this example taken from our common practice, and if we do not demand too much from it, allows us to understand the meaning of the concept of saturation speed." We all nodded in agreement. Then he said, "To clarify this question a little more I'd like to discuss with you, in slightly more detail, what happens to the average speed of the acron resulting from the interaction with the medium when it's injected into different theta fields, which we will assume – at the scale we are considering – as constant."

Argus drew the following figure:

Figure 4-7: A little theta wave with its acron is injected in an extensive theta wave.

Argus continued.

In this case, two extreme situations can then occur:

1. The relative intensity of the incident theta wave is much smaller than that of the field where it's injected, as can be seen in the drawing:

Figure 4-8: The extensive theta wave has a very big relative intensity.

In such a situation the acron, for all practical purposes, will remain sensitive to the extensive theta field. Thus, its average speed will then be relative to that extensive medium where it was injected. If the injection speed is less than the saturation speed, then the acron will maintain this speed. It's only when the speed begins to approach the saturation speed that a significant reduction begins, as can be seen in this drawing (Figure 4-9)

Figure 4-9: The saturation speed is reached from a certain value of the initial speed.

As you can observe, this was essentially the case we've been considering.
2. The relative intensity of the theta wave of the acron is much greater than that of the extensive theta wave, as can be seen in this drawing:

Figure 4-10: The extensive theta wave has a low relative intensity.

In this case, the complex particle, the theta wave and respective acron, completely ignore the extensive field where they are immersed.

> Thus, the average speed of the acron is equal to that of its own theta wave.
> Of course, as you must understand, between these two extreme cases there is a huge range of variations. For these intermediate cases, the behaviour, the average movement of the acron results from the combined action of the two theta fields, its own field and the one from the extended medium where the acron is immersed.
> Later on, we'll see the extremely important consequences that can be drawn from this concept of limit speed.

After this intervention from Argus, we decided to return to Lisbon. As many of us were a little tired because of the succulent meal we had the privilege of savouring, we stopped the scientific discussions and started talking about current affairs.

FIFTH JOURNEY

It was already half past eight in the evening when I arrived at the Fábrica de Braço de Prata. As we mentioned previously it is a very nice place, well known to the people from Lisbon, but also from outside Lisbon mainly because of its initiatives in favour of vanguard culture. The main activities developed in this beautiful place range from art exhibitions, painting, sculpture, to concerts, cultural lectures that are usually followed by interesting discussions, and cinema. It is in all respects a very interesting place by the Tagus river, equipped with a restaurant, a bar, a bookstore and also areas for the sale of antiques and other, handicraft products. After parking the car, I went straight to the bar where we had decided to have today's discussion.

All the elements of our group were already seated at a table. This time, due to the bad weather which made traffic very difficult, I was the last one to arrive. However, truth be told, I arrived just in time.

After the usual greetings and a few moments of "coffee talk" we decided to start our discussion about the new physics. Argus started off.

> On our last journey, on the way to Cabeção for lunch, we discussed the behaviour of a single acron or many acra, assumed as statistically independent, in interaction with the medium. This medium, ultimately, is nothing more than just the global theta wave where the acron is immersed. Now, we will see in a little more detail, how the collective reciprocal interaction of many acra with the respective theta fields can be described.
>
> On the other hand, we also know that classical physics mainly studies gravitational and electromagnetic interactions. Gravitational interaction is described in terms of the so-called law of universal attraction, which says that the gravitational force is proportional to the inverse of the square of the distance separating two material bodies. The magnetic interaction is a bit more complex, since it depends not only on the static law of Coulomb, similar to Newton's universal law of attraction, but also on the movement of electrons. In any case, these so-called laws of nature, which hypothetically govern the phenomena, are essentially linear in nature. We must add that these expressions which describe natural phenomena relatively

well, and to a certain scale of approximation, have already shown their limits of adequacy in the description of natural phenomena. This happened precisely when we changed the scale. Indeed, at the level of microphysics – that is to say at the quantum scale, or even in the domain of high speeds, speeds of the order of the speed of light that correspond to acceding to a very small temporal scale at very short time intervals, these linear laws are no longer appropriate in describing the phenomena.

Our aim now is to show how it's possible to derive these classical interactions within the conceptual framework of the new physics, the eurhythmic physics, the global physics, interrelational, of the complex and nonlinear. This way, we'll see how the new physics promotes, in a natural and comprehensive way, the unification of physics.

For that, we'll analyse the general processes of interaction between particles and theta wave fields, from which the classical laws of interaction will be derived as simple specific cases.

Consider the simplest case of two theta waves interacting, having just one acron present. This physical situation corresponds to the quantum interference of a single particle.

The initial particle, the theta wave with the acron, interacts with a medium (for example a screen with two slits) such that the initial theta wave gives rise to two waves while the single acron follows one or another wave, as can be seen here.

Argus created the drawing I reproduce here:

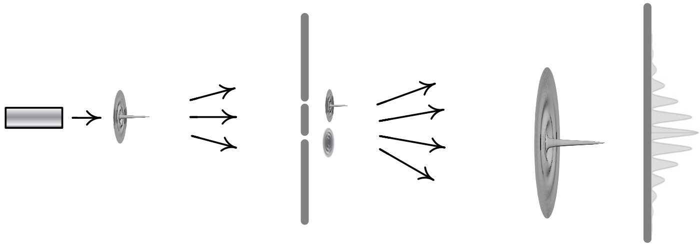

Figure 5-1: One acron shares two theta waves.

The two waves, coming from the slits, will expand in their path to give rise to a single global wave where the acron is. As this total wave results from the composition of two waves it will then display

> maximum and minimum intensity, i.e. an interferential pattern. In this case, and according to the principle of eurhythmy, the acron will have a propensity to move given precisely by this field intensity. As this field has an interferential distribution, successive acra would, of course, be spread according to an interferential figure.
> Now let's look at what happens when we have two particles. I mean, two theta waves with the respective acra.
> In this case, as you can imagine, the interaction is more complicated and cannot be roughly described as a simple linear composition. It's a complex, nonlinear process of reciprocal interaction, resulting in something similar to a self-organizing system.

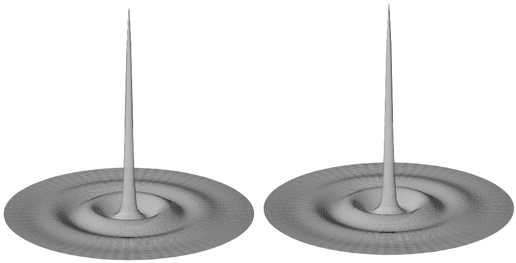

Figure 5-2: Two particles interacting.

At this point, noticing the perplexed looks from some of the group's members, Fabrus decided to intervene:

> For those who are less familiar with these self-organizing phenomena, I'd like to mention a well-known experience that has been widely disseminated on the Internet.
> The experiment consists of placing several equal pendulums on a table. These pendulums are put to oscillate in such a way that at the beginning each of the pendulums oscillates at its own pace in a perfectly chaotic global movement. As time passes, the pendulums will begin to oscillate in the same way until the pendulums swing at an equal rate at the end. This process of self-organization of the various pendulum movements is due to the fact that all the pendulums are supported on the table top which they interact with. The pendulums will then supply energy to the table. The table, in turn, will give back, on average, part of this energy to each of the pendulums at the appropriate times so that in the end they all end up vibrating coherently in phase, that is, in harmony.

After a pause, Argus continued:

After this excellent example presented by Fabrus, I think that this phenomenon of self-organization, a lot more common than is generally thought, has been well clarified.
In our case of the two interacting particles, they may eventually be subject to a process of self-organization that will lead, as in the case of the pendulums, to a process in which the waves are going to stay in or out of phase.
When this process of self-organization leads to the two theta waves of the particles to become in phase, then in the superposition zone the amplitude of the global wave will be reinforced. In this case, an asymmetry in the distribution of the wave intensity occurs so that each acra tends, on average, to approach the centre where the intensity of the global wave is relatively larger. This drawing, (Figure 5-3), seeks to illustrate this situation in three successive instants.

Figure 5-3: Attraction of two particles in three successive moments.

Due to the principle of eurhythmy, the two waves will tend to coalesce into a single global wave, making the acra come closer to the more intense centre of the global theta wave. In the end, this process may be described as if there was some kind of attractive force that would bring the acra closer to each other.

At this point, Hilarius, who had arrived some time ago and had been, as usual, listening to our conversation, approached us and with his usual arrogance said in loud voice, “What is this all about? You want, as usual, to explain trivial things, well known to everybody!”

We all know that the law of the free fall was discovered by Galileo from simple observable facts. Moreover, it was Newton, that great man of science, who discovered the law of gravitation, also from simple observable facts, as he himself emphasized in his great work. After the work of Galileo and Newton, nothing more was left to be said about the force of attraction! The situation is so evident that today any high school student between the age of 14 and 16 can deduce Galileo's law of the free fall in the laboratory, i.e. the movement to which a body is subjected due to the attractive force of the Earth's gravitational field, purely experimentally and from the simple facts he observed.

I think it's a waste of time to be discussing such matters, and even more with assumed innovative claims. What really matters are the facts. All speculation, or should I say, philosophical-intellectual ramblings, trying to explain what we all know very well are perfectly gratuitous.

As usual, after this blunt speech from Hilarius, there was an absolute silence on the table. After a few moments Argus calmly responded.

It is indeed true that any student of physics in high school is able to arrive to the law of falling bodies, in about two hours of work in the laboratory.

However, I'd like to remind you that this problem of the fall of the bodies took about two thousand years to solve. Great thinkers of the past have tried unsuccessfully to solve this great problem that you, Hilarius, find very simple. Among these men we may mention, Aristotle, Archimedes and many other researchers of high intellectual calibre.

If, according to what you said, the problem is extremely simple, for as any moderately prepared young man solves it in the blink of an eye, a possible conclusion to draw would be that today's young people have evolved to such a degree that they are endowed with a great intellectual capacity. So great, that it's superior to that of the greatest thinkers of antiquity. They have attained, in your view, a degree of immense intellectual development, so that from just simple experimental facts they are able to solve a problem which has afflicted the greatest human thinkers until Galileo.

By the way, as a caricature, we could then say that the great Archimedes is nothing more than an intellectual dwarf when compared to any youth of today, for this young man, in about two hours, can solve a problem that Archimedes could not solve, and more, that took about two millennia to solve.

However, I'd like to say that these young 'wise men' can only discover, from the facts, what is already discovered. In fact, they can't find anything new by this process.

It's a vain illusion! A process similar to that used by illusionists who are continually pulling rabbits out of their hats. Basically, as I said, it's an illusion, because the rabbits don't come out of nowhere, they are already there. Only very well hidden. They are so well disguised, that a superficial observation doesn't allow the said animals to be seen. However, only a fool believes that rabbits come out of nowhere.

In the case of students, before entering the laboratory, they are conditioned to a whole set of explicit and implicit attitudes leading to the result. In fact, what happens in the laboratory is that students are conducted, according to a previously elaborated experimental protocol, to the intended solution. It should also be noted that the solution of the problem is already implicitly included in this experimental protocol.

I must add that this attitude, unfortunately very common, in relation to the teaching of science is extremely pernicious. It can lead students to great insecurity and make them lose confidence in themselves. In fact, by this process they can only discover what is already discovered!

When they want to tackle a really new problem, they feel completely lost and unable to move forward. Hence, they give up or, at best, become simple repeaters or commentators of authors and previous works.

The process of innovation – and I mean true innovation – implies looking at the world with other 'eyes', in short, 'seeing' things differently. Well, it was precisely this new way of looking at the world that took about two thousand years to develop. This change of mentality was due to the hard collective and continuous effort of many human beings. It was not a solitary effort, as it's often claimed, but an enormous joint task that blossomed mainly in the seventeenth century.

Without that change of mentality, that modify drastically the way of 'looking' at the world, the discovery of the law of free-falling bodies would have been impossible. No matter how great the human genius can be, in a certain historical time, it's always limited by the conceptual framework in which it's inserted. In these conditions, it can only discover what is possible in that same conceptual universe. To make progress in the path of knowledge it will be necessary to break the bars of the conceptual jail in which we are enclosed.

On the other hand, I must also add that the laws of nature, contrary to what many have pompously asserted, are not solely derived from the facts. The reason for this is very simple: the facts, as we understand them, are, as we know or ought to know, somehow created by theory. There are no facts by themselves. A fact only makes sense, only exists as a fact, when integrated in a given conceptual framework.

It's also worth mentioning something often concealed: it's known that Newton, in his great work, the *Principia*, affirms, as you well said Hilarius, that all the conclusions contained in his book had been deduced from the simple facts of experience.

However, we must consider that such a statement does not correspond to reality. In fact, two fundamental ingredients of his theory, without which Newtonian mechanics would make no sense, are the concepts of space and time. It's the concepts of absolute space and absolute time that exist, or better said, they are assumed as existing since the beginning of time and forever. We know that one of the greatest thinkers of the time of Newton, the so badly treated Leibniz, sharply criticized these basic hypotheses of classical mechanics.

These concepts of absolute space and time were, as is well known to any half-informed person, superseded by relativity with the introduction of the concept of space-time. So as I've said, and contrary to Newton's assertions, these fallible and later superseded concepts were not deduced from simple experimental facts, but on the contrary they were constructs, highly elaborated hypotheses, inspired mainly by a set of more or less implicit and explicit beliefs. Tell me Hilarius, how could it be otherwise? How could one deduce these concepts, of absolute space and absolute time, highly abstract work bases, only based on simple experimental evidence, from the facts?

By the way, still on this subject, I recall a very concrete situation that clearly illustrates what I'm saying: In an interesting, remote village lost in a valley of the Serra da Estrela mountain range, called Avelãs da Ribeira, there is a drinking fountain for the animals. A closer look reveals, however, that it's a pre-Romanic tomb used as a drinking fountain.

For the honourable inhabitants of the village, it's only a simple drinking fountain where animals can quench their thirst.

For an archaeologist, the same very object is a vestige, an important historical document that may eventually contribute to the clarification of the region's ancient past.

So, can we then ask ourselves what thing, what entity is that artefact of chiselled stone in the village? A simple drinking fountain for animals, or, conversely, a prehistoric tomb?

The answer to this question obviously depends on the point of view, i.e. the conceptual framework in which the artefact is integrated.
For someone unfamiliar with historical artefacts, the stone object, the fact, is a mere drinking fountain for animals and nothing else.
For an historian, the same artefact of stone may eventually constitute a precious vestige that allows the reconstitution of the past, and therefore assumes the status of an historical document.
So, I once again ask the question: What is a fact?

After this incisive intervention from Argus, Hilarius, withdraws, saying nothing. For quite some time, there is a certain embarrassment among those present until Argus returned to the subject he had been presenting.

Before this interruption, I was trying to present a process of reciprocal interaction that can be described as if there was a propensity, a kind of attractive force that brought the two particles closer to each other.
Let us now look at the opposite process, which leads two particles, instead of approaching, to move away from each other.
Let's consider this process somewhat opposite to the previous one. In this case, the self-organizing process will, after a certain time, lead the two overlapping theta waves to be out of phase. Thus, in the overlapping zone, the waves will tend to destroy each other, because they are out of phase. As a result of this reciprocally opposite action, in the overlapping region, the global wave will be destroyed instead of being reinforced, thus digging a gap between the two waves.
Faced with this interactive situation the acra will have a propensity, described by the principle of eurhythmy, to move away from that central region where the intensity of the global theta field is smaller.
This figure (Figure 5-4) seeks to translate this spacing into three growing moments in time. At first the waves are relatively close, although there is a gap between them. This gap gradually widens leading to a distance between the particles.

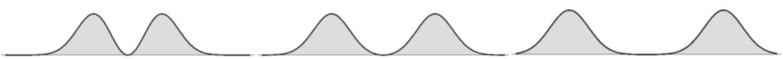

Figure 5-4: Repulsion of two particles in three successive instants.

This process can be broadly described as if there was something, a tendency, a repulsive force that causes the particles to move away from each other.

Apart from these processes, where the self-organizing aspect plays an important role, there is a third case to consider. It's the overlapping of two or more waves where globally the self-organizing process is not significant at the scale we are considering.

In this case, the waves will overlap in a perfectly chaotic way, that is, without any significant phase coherence. In some cases, some waves are in phase, while others are out of phase, thus occurring all the possibilities of overlapping without any correlation between them. Precisely for this reason, this type of wave composition is called an incoherent superposition.

Even in this case of incoherent composition, it's verified, however, that there will be a relative increase in the overlapping zone of the waves that will lead the acra to approach the central region. Of course, this increase of the wave intensity in the central region is less than in the case where there is phase coherence between the overlapping waves. For this reason, this process is called weak interaction, while the former is called strong interaction.

The following figure attempts to illustrate, in three dimensions, this situation for three growing moments of time.

Figure 5-5: Weak attraction in three successive instants.

As in the case of strong attraction, as the theta waves get closer due to the eurhythmic propensity, the acra move to the regions of greater intensity of the global wave. This process continues until, ultimately, the two waves coalesce into a single wave.

At this point Iris asked, "From what you have said, Argus, it looks like one can infer that the traditional concept of force, so dear to traditional physics, is not a basic notion in the new physics. So, in this context we can say that force is not a fundamental notion but in reality it's a simple concept derived from more general principles. Of course, we must be aware that this concept of force can be quite useful at a certain scale. However, the fact remains that the concept of force is devoid of intrinsic ontological value."

"You're quite right Iris! I could not say it any better." Argus continued:

> In fact, in certain cases, it can be verified that the concepts of force, whether attractive or repulsive, are well suited to a certain scale of description of reality. However, I must emphasize, and this is where the issue resides, if we want to go forward in the understanding of natural processes we must try to go further and know what lies behind such concepts.
> To embrace this problem, I'd like to present to you a situation of an entirely fictional nature, which I think will enable us to better understand what we're talking about.
> Consider then the fictional situation that occurred in Lisbon in our beautiful Terreiro do Paço square along the Tagus river. It turns out that the square is full of people for some unknown reason – a concert, a demonstration or something else. These people must remain in the square for a certain time. On the other hand, we can see that each person has a backpack filled with their personal clothes. Let's also assume the temperature of the square is relatively mild, about 25 degrees Celsius. We should also add that a drone, hovering over the square, films the whole scene continuously.
> By a process that's not relevant here to describe, an observer, who is placed on the Augusta Street arch, has the capacity to vary, at will, the temperature in the square.
> Suppose now that our observer decides to start lowering the temperature of the square so slowly that people don't realize it.
> So, the temperature that was initially fixed at 25 degrees Celsius will start to drop until after some time, it reaches the value of 15 degrees, then 10 degrees until it eventually reaches zero degrees.

Turning to Lucius, Argus asked, "What do you think, Lucius, happens to the clothes each person has in their backpack?"

After hesitating for a few moments, he responded:

"Well, I think that people, as it gets colder, begin to take their clothes from their backpacks and put them on to protect themselves, because if they didn't, surely they would get ill."

"And now", said Argus, "what would happen if our observer decided to start raising the temperature from zero degrees until it eventually reached 35 or even 40 degrees?"

"In this situation, inversely", Lucius replied, "people are beginning to take off their clothes until they eventually have as little as possible on them, for a temperature of 35 or 40 degrees is quite something!"

"Of course!" said Argus.

However, if the film, recorded by the drone, is shown to many people, what you'll see is that at first the clothing starts to come out of the backpacks going to people's bodies. In the second phase, the clothes leave the people's bodies, eventually going to the backpacks. This extremely complex behavioural phenomenon, of the people's decision to dress or undress, which we can all see on the screen, can be described in a very simple global and even quantitative way:
Suffice it to admit that there is something we can designate as a kind of force, attractive or repulsive. Thus, in this context we can say:
a) In the initial phase, there is an attractive force. Force that attracts the clothes to the body of the people.
b) In the second phase, the force instead of being attractive is repulsive and the clothing is removed from the people's bodies.
In the end, this concept of force which can be introduced here, translates no more than the eurhythmic propensity of complex beings, in this case people, to try to persist when interacting with the medium in which they are immersed. In this case, if it is cold people protect themselves by putting their clothes on. On the other hand, if it's hot, it's advisable to have as little clothing as possible.
The model may even be more refined leading to the establishment of a law that allows us to numerically translate this observed phenomenon as a function of temperature. So, if the temperature drops the force is attractive, when the temperature rises this force is repulsive.
Moreover, if the number of people is very large and the kind of clothing that people have is not very different, this law, this mathematical expression, which allows us to estimate the amount or the weight of the clothes that each person has put on, can acquire a great degree of precision.
Naturally, as you can understand, this is not an absolute and deterministic law, but rather an average statistical law. This is for the simple reason that each person, considered individually, behaves differently when facing cold or heat.

“Of course! It’s evident that this nonlinear, complex and interrelated way of looking at nature has a great advantage over the traditional linear process. In these conditions, we can understand, in a very simple and intuitive way, what lies behind the concept of force”, said Amadeus. “Basically, in my opinion, this concept of force has a great practical utility because it allows us – in a very simple way – to translate numerically, and more with excellent accuracy, the average behaviour of complex systems in reciprocal interaction with the medium.”

After a short pause, Argus spoke again:

> We have just ascertained that what we call forces are nothing but mere abstract concepts, useful to a certain scale of description of reality, it’s true, but devoid of any real physical existence. Similarly, I think it’s also convenient to mention the concepts traditionally associated with forces, such as gravitational and electromagnetic fields.
>
> Let us see: The notion of gravitational field is closely associated with force and consequently, through Newton’s law, with acceleration. Deep down, what the gravitational field tells us is how a gravitational particle reacts when placed in a certain point in that field. In this case it gives us the force the particle experiences when placed at each point of space. If it’s gravitational, of gravitational forces, if it’s electric, of the electric forces.
>
> So, the concept of field, whether gravitational or electromagnetic, has no real physical existence since it merely provides us with the distribution of attractive or repulsive forces. Forces which in turn don’t have any real ontological status, since they seek only to translate the eurhythmic propensity of complex systems to move when in reciprocal interaction with a given real theta field. Consequently, just like forces, gravitational or electromagnetic fields are nothing more than abstract entities, useful in certain contexts in the description of reality, but yet devoid of any objective physical reality.
>
> To summarize: What we usually term gravitational field, corresponds only to a description of the propensity that the actual complex particle experiences to move in the gravitational field. It’s this theta field, this global theta wave resulting from the composition of the theta fields of many gravitational complex particles, which possesses physical reality.
>
> It’s possible to derive the so-called law of universal gravitation

$$F \propto \frac{1}{r^2}$$

where F is the force and r is the distance, from eurhythmic physics. However, we must emphasize that this so-called universal law is only appropriate at a certain scale of description of reality.

"You are saying, Argus, that this law, considered universal, is not so universal after all, since it has limits of application!" said Iris.

"That's precisely what I'm saying!" exclaimed Argus, "just look at the graph of the function that describes the force of gravitation" (Figure 5-6).

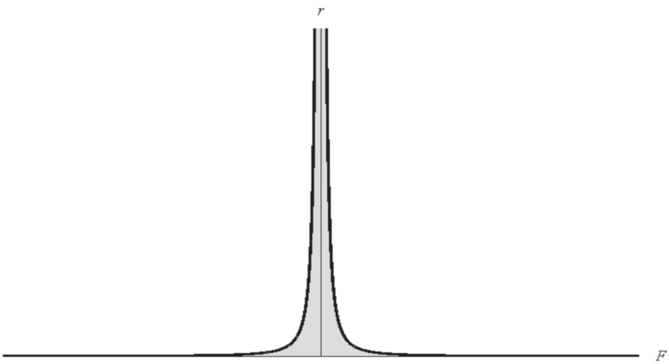

Figure 5-6: Law of universal gravitation.

As you can see, when the distance is very, very small, the force becomes practically infinite. At the limit, when the distance is zero, the force will be infinite

$$r \to 0 \implies F = infinite$$

It's exactly for this reason, by the appearance of this infinite force, that we speak about black holes. In other words, it's assumed that matter will be compressing until for very small distances the attractive force becomes infinite, resulting in a discontinuity in space, i.e. a *black hole*.

After taking a break, he said:

Look at what really lies behind this simplistic reasoning followed by many astronomers and astrophysicists who proclaim to exhaustion the physical existence of these *black holes*.
This conclusion results from the supposition, not experimentally substantiated, that the law of universal gravitation, which has proved relatively adequate at the classical scale, is valid, whatever the spatial scale considered. By classical scale, we mean phenomena related to distances ranging from the macroscopic band, which we deal with on a day-to-day basis, to distances that encompass our solar system. I must say that, here in this range of distances, this law has proved to be very acceptable in the description of the observed physical phenomena.
However, I think we must ask ourselves, at quantum distances is this so-called universal law still suitable to describe nature at such a diminutive scale?
In other words, if we are considering phenomena at a quantum scale, with very small distances will the law of universal gravitation, derived in a classical context, remain adequate to describe reality?
It seems to me that the wiser, more reasonable answer will be to admit that for very small distance scales, at the quantum scale, the said law of universal gravitation will not be adequate to describe reality. The intensity of the theta field instead of tending to infinite at very small distances close to zero, which in the new, global and complex eurhythmic physics has no meaning, actually has a finite value as can be seen in this figure (Figure 5-7).

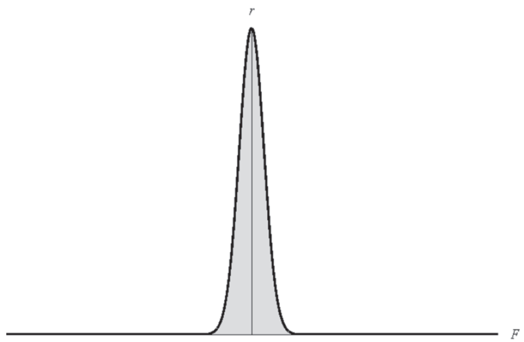

Figure 5-7: In the neighbourhood of zero, the intensity of the theta field has a finite value.

> In these conditions, even when the distance approaches zero, the intensity of the theta field is finite thus leading, naturally, to a finite propensity or force.
> So, in view of this sensible line of reasoning, we are led to the natural conclusion that these *black holes* are mere ideal constructs, devoid of any physical reality.

"Are you, Argus, then saying that the so-called black holes do not exist?" asked Amadeus.

"Of course, the black holes exist!" said Argus, smiling, "all we have to do is talk about them for them to exist! However, what we are discussing is their existential status. Are they merely abstract constructs, devoid of physical reality or, on the contrary, endowed with objective physical reality? This is where the crux of the matter lies."

> From our point of view, there are no infinities in nature. The notion of mathematical infinity is very useful, but it must be used with great care when it comes to describing physical reality. From the physical point of view, there are no infinites: all natural phenomena are finite. However, as we've already mentioned several times, the question of whether large or small is relative. In relation to a human being our solar system is enormous. In turn, our solar system in relation to our galaxy almost has no dimension. So, if we take the dimension of the human being as a benchmark, then our galaxy can, for practical purposes, be considered as infinite in size. However, and in spite of everything, its dimension is, in fact, finite.
> Under these conditions, any conclusion drawn by assuming the existence of an entity which possesses physical reality and at the same time is infinite, in the absolute and non-relative relational sense of the term, cannot have great consistency. Thus, the said black holes cannot possess any objective physical reality.
> I must add, however, that I believe in the possibility that there are regions in nature where the gravitational attraction may be very large. Huge indeed! However, this attraction, this gravitational propensity, no matter how great, will always necessarily be finite. So once again I say that black holes are mere theoretical constructs and nothing more!
> Another reasonable conclusion to be drawn from what we've been saying is that the so-called universal law of gravitation may also not be suitable for very large scales, for example at galactic distances. If

so, then the said dark matter and the dark energy would only be mere artefacts, devoid of any objective physical reality. In fact, dark matter and dark energy, which according to some speculations (and worthier of bad sci-fi rather than science) constitute the great majority – about 90% of the known universe, will also have no scientific validity. These conjectures, even if their authors don't say it explicitly, were, as is well known, advanced with the objective to keep the law of universal gravitation adequate for any scale at all costs.

After these words from Argus there was a pause, interrupted by Lucius:

"By the way, I'd like to know what's going on with the concept of mass or charge. Are they fundamental categories of our understanding in the new physics, or are they merely derived concepts?"

"Good question!" said Argus, "you're absolutely right! In fact, these concepts considered fundamental in traditional physics, have only a relational status in the new physics. We know that in the definition of force also enters the concept of mass. Therefore, if the notion of force is not fundamental then that of mass will not be basic either. However, the concept of mass must be understood in the new physics as corresponding to a function of the number of gravitational acra."

"Argus, there is something here I don't quite understand!" exclaimed Lucius.

On the one hand you said that mass is not a fundamental concept because force also is not. On the other hand, you are saying that mass is a function of the gravitational acra. Now, I think that gravitational acra have a basic and fundamental status in the new physics. So, if the gravitational acra have a basic status it follows that the concept of mass, elaborated from them, must also have a basic status. So how can the same entity have both a basic and ancillary status simultaneously?

"Good question, Lucius. Spot on!" said Argus, smiling.

Deep down, as we've seen on the previous journey, if a complex particle – theta wave and acron – is injected into a theta field, its overall behaviour will depend on how it interacts with the field.

Suppose that a gravitational complex particle is injected into a gravitational field, for example here. Precisely where we are now.
We saw that two extreme cases may occur:
1) The relative intensity of the mother theta wave directly associated with the acron I_0 is much smaller than that of the I_M medium,

$$I_0 \ll I_M \, .$$

In this case the acron, for all practical purposes and at this scale of description, is subject to the intensity of the theta field, which in turn will correspond to the gravitational field of the Earth. So, according to the principle of eurhythmy, the gravitational acron will be subject to the intensity of the theta field and will therefore experience a natural propensity to approach the centre of the Earth where the field is most intense. That is, it's subject to the Earth's field of attraction. This attraction is all the greater the greater the number of acra the complex particle possesses. This increase in gravitational interaction may also be expressed by saying that this complex particle is endowed with mass.
2) The relative intensity of the mother theta wave directly associated with the acron is much larger than that of the medium

$$I_0 \gg I_M .$$

Since the relative intensity of the mother theta wave is much greater than that of the medium in which it moves everything happens, at this scale of description, as if the gravitational theta field didn't exist. Under these conditions, the particle completely ignores the medium where it moves.
Summing up: When the relative intensity of the mother theta wave of the complex particle is much smaller than that of the medium, it will react to it. In this case, since it's sensitive to the gravitational field, it's then said that the complex particle is endowed with mass.
In the opposite case, when the relative intensity is much greater than that of the gravitational field where it moves, the particle will ignore it. Everything happens as if the same particle was devoid of mass.
So, the same very entity, the complex particle composed of more or less acra, when moving in a given gravitational field, can be attributed with the characteristic, the property of possessing or not possessing mass. Depending on the relation of the intensity of the

> global theta wave of the particle with the intensity of the field, so this attribute of mass can be associated to it or not.
> Now I'd like to add that a similar situation occurs with the concept of electric charge. The concept of electric charge, like mass, is also not fundamental but only relational.

"So then, if I understood correctly what you've just said Argus", interrupted Amadeus, "the traditional concepts of mass, charge and forces are completely out of date. In these conditions I think we should go without them ..."

"I think I might have not expressed myself properly", replied Argus. "The traditional concepts of mass, charge and force have been and continue to be very useful at their scale of description of reality. What is wrong is to suppose they are absolute and therefore have a universal application." He paused, then said:

> Now, and to clarify the case a bit better, let's look at the following situation:
> Let us remember our previously example, of a shepherd in the Alentejo. He gets up at dawn before the Sun rises and leads his sheep to the areas with the best pasture. After a day of toil, he returns home at night and puts the sheep in the fold. This manoeuvre is repeated, with greater or lesser variations throughout his entire life. His existence runs smoothly in this conceptual universe that he fully understands.

Turning to Amadeus, he said, "If you asked this shepherd if the Sun is still or moving, what do you think he'd say?"

"Well", said Amadeus, "since we are implicitly assuming that this shepherd has no scientific culture, his answer would be, of course, that the Sun is in motion. This is for reasons that seem perfectly obvious to him! In the morning, he sees the Sun at a certain position in the sky. As the day progresses, he observes the Sun in different successive positions of the sky, following a regular trajectory, until it goes down in the horizon at sunset."

"You are quite right", continued Argus.

> The 'fact' observed, confirmed and reconfirmed by our shepherd in his day-to-day life, is that the Sun is in motion. Any other conclusion

will seem absurd to him. In his daily life, and for his work, it would be utterly meaningless to think otherwise.

If they told him that the Sun is still and that it was the Earth that was in motion, he would probably think that this person would not be that bright. For everyone sees the Sun moving in the sky!

What this situation illustrates particularly well is the fact that the geocentric model was, is, and continues to be a good model for describing reality. Of course, this statement only makes sense if we limit ourselves to a certain scale of observation and description of reality.

In the conceptual universe of the shepherd, the geocentric model is a very simple instrument, and by all means adequate, for him to be able to interact with reality in order to survive.

Of course, we will be wrong if we pretend this simplistic and geocentric model is the only, the ultimate way of understanding reality. Unfortunately, as we know, many brave people have been persecuted, tortured or even burned alive for questioning the universal validity of such dogma. As I said, it's a good model for its scale of observation and description of reality, however, if we want to enlarge our conceptual universe, and for example, if we want to build a whole more general physics, then we will have to abandon the geocentric model, quite simple and very limiting, in favour of the heliocentric model, much more general, as done by Copernicus, Giordano Bruno, Galileo and their followers.

Therefore, and to conclude, we can say that the traditional concepts of force, mass and charge are on an equal level. In the conceptual universe of traditional physics these concepts naturally hold all their validity and usefulness. However, if we want to progress in the knowledge of nature we will have to go much further and therefore these concepts, adequate in traditional physics, will have to be overtaken by more basic ones.

After this intervention from Argus we all went silent, perhaps because we wanted to better understand what we had been talking about. After a few moments, and as it was already late, we decided to end our discussion having taken care to schedule the next one.

SIXTH JOURNEY

The day was magnificent! A radiant Sun shone in the blue sky as I parked the car next to Argus' house, located in the village of Alfarim near the well-known Meco beach, some twenty miles south of Lisbon.

Most of the members of our group were already there and were collaborating enthusiastically in the preparations for lunch. I immediately joined them in order to give my personal contribution.

However, as there were too many people for the work to be done, and consequently a danger of confusion, but also to satisfy my curiosity, I decided to make a brief visit to the house. It's a modern newly-built house, if modern is the right word to describe this rather original construction. Simply put, it can be said that this dwelling is nothing more than a sculpture in large scale. A kind of ship. Hence, it's also called Argus, the ship that symbolically demands knowledge at an early stage, and has wisdom as the ultimate goal. According to Argus, who was the author of the project in collaboration with an architect friend, the guidelines that oriented its elaboration consist mainly of making the most of the natural features of the place, with the aim to ensure form and function integrate as much as possible into a global and harmonious whole. In other words, a eurhythmic construction. Of course, to carry out this complex programme and given the various constraints, it was necessary to go beyond the limiting notion of square walls, so dear to routine architecture. In this case, traditional linearity was replaced by a more interrelational and organic attitude. This option for the complex and nonlinear made it possible to obtain a greater degree of eurhythmic interrelationship between the various architectural elements, integrating them into an organic and harmonious whole.

Always within this objective of harmonizing the human contribution with nature, the building was designed in such a way that it forms a natural calendar.

In the cylinder that gives access to the terrace, immediately below the observatory, there are three round windows separated by 30.7º from each other. These light entries are oriented and as perfectly aligned as possible with sunrise on only four days of the year. A window, the lowest one, is aligned with the rising Sun on the day corresponding to the winter solstice; the other, the central one, aligned with sunrise at the spring and autumn equinox, thus facing east; the third, in a higher position, is pointing at the birth of the Sun on the day when summer begins, that is, the summer solstice. So, this set forms something like a natural calendar where, as the seasons of the year go by the lighting will consequently vary. The round window on the first floor is facing south so at noon the Sun enters the stairwell, illuminating the marble pavement where there's a compass rose. When the Sun's rays are aligned with the north–south direction, the image of the Sun then incident in this direction is indicated by the marble compass rose. Under these conditions, we know that it's solar noon.

The Foucault's pendulum, which, as we know, constituted the first experimental evidence that the Earth actually revolves around itself, responds perfectly to the concerns that guided the design of the building. It constitutes living proof that the Earth actually moves, as once affirmed by Copernicus, Giordano Bruno, Galileo and so many others, with the danger of their own lives. In addition, the pendulum also contributes with its simple beauty to give a harmonious rhythm, providing a constant pulsation to the whole architectural set, integrating movement with static in a natural way. Its slow oscillations introduce a harmonic rhythm, a eurhythmic movement, which naturally induces a sense of calm and tranquillity.

The stairway giving access to the observatory on the terrace, inspired by the Mesoamerican, Mayan and other observatory temples, constitutes an architectural element that through its design, is clearly evident throughout the whole building. Under these conditions, the problem of its orientation came to the surface. If the building followed the traditional, Cartesian linear standard of the right angle, the problem could be considered, perhaps, of having a relatively easy solution. However, since this simplistic criterion was rejected for reasons of principle and there is no privileged direction in the building, what would be the criterion that should preside to the orientation of the stairs? The answer was, once again, to resort to the basic principles that guided the project. So, in this way, the answer is immediate: In this conceptual framework, the orientation that emerges as being more natural for the stairway, is the direction of north; the circle of the tower cylinder depicting the Sun and the stair with its shadow at noon. This principle is reinforced with the location of the chimney which is in the prolongation of the direction of the stairway, thus constituting a basic point of orientation, the north.

Finally, the cylinder, one of the dominant elements of the assembly, was designed to meet two requirements: On the one hand, to provide the necessary rigidity and stability to the base of the observatory; on the other hand, the cylindrical structure naturally houses the Foucault pendulum, providing at the same time an aesthetically beautiful access, a helicoidal suspended stairway to the different levels of the building. The cylinder height from the ground is precisely 10 m, which corresponds to the perfect proportion as it was understood by the Pythagorean School.

In summary, and to restrict myself here only to the basics, it can be said that this is a eurhythmic, organic, complex, interrelational and nonlinear construction where the traditional dichotomy, exterior vs. interior is very blurred, with the house and landscape integrated into a single harmonic entity.

I was still exploring the house when someone called me. Lunch was ready!

I sat at the table and we began to eat the delicious traditional Cação soup from Alentejo. During lunch we barely had time to talk because we were all hungry and the food was very appetizing.

After the meal we went to the front of the house – some sitting, others lying down, each at their own will, on the sloping lawn overlooking the pool.

Argus started the conversation.

Quantum physics is based on two basic formulas, of a mainly phenomenological nature: Planck's formula and de Broglie's formula

$$E = \hbar\omega \text{ and } p = \hbar k,$$

where, as usual, E represents the energy, $\hbar = h/2\pi$ a constant, ω the temporal frequency, p the moment and k the spatial frequency.

It's possible to show that these relations, which arose in the domain of quantum physics in the early twentieth century, can now be derived as particular single cases of eurhythmic physics. So, this constant $\hbar$ that appears in the equations, in fact doesn't have an absolutely constant value. As a matter of fact, it's a relational constant whose value ultimately depends on the scale we are considering in describing certain aspects of reality.

In its initial context, the first time it appeared in physics – better said in microphysics – it was designated as Planck's constant in homage to this great physicist. It relates and connects the photon energy, the minimum quantum of light, acron and theta wave, with the frequency of the associated theta wave. Since the energy of the photon is for all practical purposes the energy of its acron, it follows that this Planck's constant can also be named the quantum constant $\hbar_Q$.

It's found, however, that these relations also prove quite adequate to relate, in a particularly simple way, the very small energy of the theta wave with its frequency. On the other hand, we also know that the energy of the theta wave, or the subquantum wave, $E_\theta \equiv E_{SQ}$, is billions of times lower than the energy of the acron $E_\xi \equiv E_Q$. In fact, a very reasonable estimate for the case of the photon gives values in the order of $E_\theta/E_\xi \equiv E_{SQ}/E_Q \sim 10^{-54}$ for this relation. Hence, it follows that at this scale of description of reality, this constant relating the energy of the theta wave E_θ with its frequency, should be called the subquantum constant $\hbar_{SQ}$. The choice of this nomenclature is due to the fact that this constant relates to energies many orders of magnitude lower/smaller than the energy of the minimum quantum of light, E_Q.

Likewise, on a planetary scale, those relations are also quite adequate. In these conditions, they then relate the frequency of gravitational theta waves with their energy. The actual existence of these gravitational theta waves can, as we have seen, be inferred from the existence of a quantification of the planetary orbits expressed by Titius–Bode's empirical law. In this case, the constant is then called the gravitational constant $\hbar_G$.

On the other hand, I'd like to draw your attention to the status of the concept of energy. As we know, this concept arose in physics in the mid-nineteenth century. Since then, it has had such an enormous success that it has been extended from the realm of physics to the most diverse areas of human knowledge. However, I want to tell you that in the new physics of the complex and nonlinear, this concept doesn't constitute a fundamental physical entity. In fact, this physical entity can be derived from much more basic conceptual structures, namely the concept of frequency.

"Come on!" said Lucius.

It seems now evident that if we give primacy to frequency as a fundamental physical entity, then it's quite natural that this Planck's constant has different values, and therefore different names depending on the context, that is, the scale being considered. Thus, at the level of the minimum quantum of light, it assumes, as expected, the name of quantum constant. For energy levels much lower than the minimum quantum, as for example the energy of the theta wave, or subquantum wave, is now designated as a subquantum constant. On the other hand, if we consider much higher energy levels, and therefore, if we place ourselves at the planetary scale, then this constant adopts the name of gravitational constant.

Therefore, and to conclude, for a certain frequency value, this constant that relates energy with frequency only remains constant at a given scale of description of reality. Changing the context, changing the scale, the value of the energy changes. However, and here is the interesting point, the concept of frequency remains invariant in the various scales of description of reality. Then, we can write:

$$\frac{E_Q}{\hbar_Q} = \frac{E_{SQ}}{\hbar_{SQ}} = \frac{E_G}{\hbar_G} = \omega$$

Of course, as one must understand, each one of the relations is adequate only at one scale of description of reality. The concept of frequency, however, is more basic than the concept of energy, since it remains constant at any of the scales considered. Thus, for the frequency to remain constant at any scale, it then becomes necessary, as we've seen, that the value of the relational constant h varies concomitantly.

We all smiled, looking at Lucius, who was very happy with his intervention. Argus responded:

I totally agree! So, in the new physics, the eurhythmic physics of the complex and nonlinear, the concept – a most basic physical entity – is not energy as Lucius very well pointed out, or even moment, but rather frequency – temporal or spatial.
From the previous Dialogues we also know that in eurhythmic physics it's possible to derive the nonlinear master equation that describes the evolution of physical systems.

"I've noted, Argus", said Fabrus, "that you said **derive** the fundamental nonlinear equation and not **deduce** as it's mentioned in the vast majority of scientific textbooks."

I think you've stressed a very important point. The majority of authors refer, in my view unjustifiably, to the concept of deduction in the sense that it's an absolutely rigorous logical process, and therefore implicitly considered to be error-free. As if a fundamental equation, an equation that by nature can even be assumed as some kind of postulate, as for example happens with the Schrödinger equation of quantum mechanics, could be deduced from the basic

> principles on which a theory is based. In the end, and at best, what is actually done is to follow a heuristic process, relatively coherent, as rigorous as possible and constructive, that ultimately leads to the emergence of a fundamental equation. Contrary to what is said, it's not a completely rigorous process, but an irregular course, full of zigzags, even eurhythmic I should say, with a certain degree of coherence, admittedly, but in any case, never entirely rigorous.

"I think you've highlighted an extremely important point Fabrus", exclaimed Argus. "I think that attitude is a lot more common than is generally thought. Not only in the field of physics, but also in other fields of knowledge as for example in the field of logic, where some have the naive pretension of an absolute, totally infallible rigour."

> We have already mentioned in previous journeys, and we once again reaffirm, that the value of this naive and credulous attitude is, in my view, very arguable; it's a very unproductive attitude.
> In this regard, I remember the well-known example of the so-called Buridan's ass. This pseudo-logical paradox, that as far as we know goes back to Aristotle, illustrates in a particularly interesting way the problem of the unfortunate consequences that result from wanting an infallible rigour, an absolute accuracy, in decision-making.
> This interesting story may briefly be summarized as follows: A hungry donkey is between two succulent bales of hay. However, this is not an ordinary donkey, but a donkey with logical pretensions of absolute rigour. He wants, at all costs, to know which is the best bale of hay to eat. This is because he believes, as unfortunately many humans do, that for him only the 'best' will do, the absolute best. As if the best or possibly the worst were not relative concepts, dependent on the context and therefore devoid of ontological content.
> But let's go back to our donkey. As he plans to eat the best, absolutely the best of the bales, he looks closely to the bale on the right, then to the bale on the left.
> At first it seems to him that the best bale of hay is surely the one on the right. He then begins to move towards it. However, after a few steps, he hesitates, assailed by a cruel doubt: Will the bale on the left not be the best? In fact, it now seems to him that the one on the left is the best bale of hay. He reverses and begins to head to the left.
> Again, he hesitates. Will not, in fact, the right bale be the best one? Then he stops once more, and again he moves to the right. This

process of going to the right and to the left continues until, at last, full of hunger and exhausted, the donkey falls to the ground and dies.

Fig. 6:1: Buridan's ass.

However, if this donkey has no pretensions of absolute rigour in the decision-making process, and therefore if he proceeds intelligently, iteratively – that is to say, if he's a eurhythmic donkey – the final result will surely be very different. In these conditions, our honourable donkey, after observing the two bales, concludes that perhaps the best is the one on the right. In this case, he approaches the bale and, following the experimental scientific method, he gives one, two or three bites in the hay. Then, suspecting that perhaps the left bale is better, he goes there. At the bale, he will again experimentally evaluate its goodness. And so, he gives one or more bites at the hay. After properly savouring the hay, he suspects that after all, maybe the right hay is better. Again, he goes to this bale and he gives it one, two or more bites to be able to make up his mind. This iterative process, of savouring first one bale of hay and then the

> other, may eventually repeat itself until it ends with the donkey completely satiated. In this case, the problem is solved. There is nothing left for the moment to decide on the goodness of each bale of hay. Once our donkey is properly bloated, he is no longer interested in hay. In this case, calm and at peace with himself, he takes a good nap.

We all smile with this happy ending to the story. After a pause, Argus continues:

> What happens when you want an absolute logical rigour, is that we forget a fundamental aspect! As I have already said, and I repeat, logic is no more than a simple human construction, a human tool. Therefore, like any other human product, it's fallible and has far more inaccuracies and contradictions than we'd like.

"Are you saying Argus, that there is no rigour in logic and mathematics?" exclaimed Amadeus.

"Of course, there is a certain degree of rigour! In general, much greater in logic and mathematics than in any other human construction. But we can never say that with logic and mathematics one obtains absolute rigour" said Argus, continuing:

> As I've often said, the path of knowledge is an arduous process that aims to achieve ever-greater rigour and precision. It's not an absolute and immutable rigour, but a degree of rigour that is always increasing and in permanent becoming. Only people who believe that there is a truth, possibly revealed by a superior entity, may think that there is infallibility and immutability in what they say. These people, implicitly and often even explicitly, pretentiously or at best ingenuously, consider themselves to be heralds of that absolute and immutable truth which, as they believe, has been revealed to them by a supernatural superior entity.

Fabrus, who followed Argus' speech very closely, said "I agree! As I have said, and I maintain it, trying to follow a process of reasoning so rigorous, absolutely rigorous, ends up in rigor mortis. That is to say, the same happens to them as to Buridan's ass. So much rigor is sought in the decision-making process that after all nothing really ends up being done!"

"But let's go back to our fundamental equation of eurhythmic physics!" said Argus.

From the equations of conservation or balance of classical physics, we know that it's possible, as I said, to derive and not deduce the master equation. Just for the sake of curiosity I mention here that this equation roughly describes the behaviour of the theta wave, and therefore the average trajectory of the acron without having any pretension to govern natural phenomena, but only to describe them as approximately as possible.
The explicit form of this equation

$$-\frac{\hbar^2}{2\mu}\nabla^2\theta + \frac{\hbar^2}{2\mu}\frac{\nabla^2(\theta\theta^*)^{1/2}}{(\theta\theta^*)^{1/2}}\theta + U\theta = i\hbar\theta_t$$

looks quite hermetic (to say the least), for the vast majority of people, especially those less familiar with mathematical physics.
However, this equation can be perfectly rewritten in a much more understandable form. Deep inside, what this differential equation intends to convey is the behaviour, i.e. how we can describe the change, the becoming, of this theta wave θ in space S and time t when inserted in a given physical medium U.
The equation then tells us that the sum of the following four terms equals zero:

1. The second variation in space, i.e. the variation of the variation in space, $\theta_{SS} = \nabla^2\theta$,
2. The first variation in time, θ_t,
3. The interaction of the wave with the medium, $U\theta$,
4. The nonlinear term, $NL(\theta)$.

This term translates the reciprocal interaction with the medium in which the theta wave modifies and is modified. This means, it's the term responsible for the existence of a reciprocal interaction medium wave, behaving, in reality, as a single entity.
In these conditions, the master equation can then be written in the symbolic formula

$$a\theta_{ss} + b\theta_t + cU\theta + dNL(\theta) = 0$$

where a, b, c, d are proportionality constants.

This equation, when the nonlinear contribution is negligible – that is, constant or null – becomes, as expected, the well-known Schrödinger equation of quantum mechanics which, as we know, is a linear equation.
In this case

$$cU\theta + dNL(\theta)\theta \rightarrow U\theta$$

that is, at this scale of description, the reciprocal interaction theta wave-medium can be neglected and then the medium can be considered as perfectly independent from the theta wave.
Equally, this equation contains, as a natural solution, a mathematical expression that describes the complex particle relatively well.
In this figure, there's a graphical representation of that solution of the master equation representing the complex particle:

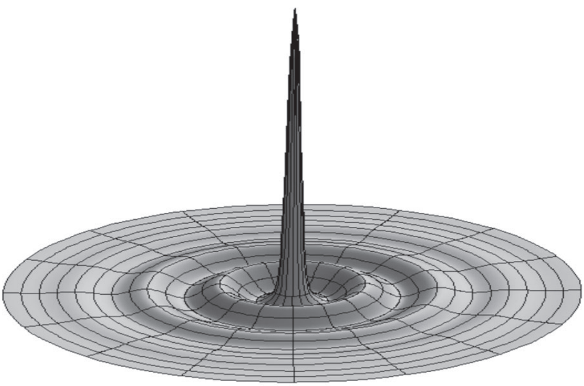

Figure 6-2: Solution of the master equation representing the complex particle.

Since we've already discussed this equation at length in previous Dialogues, we shall limit ourselves here to only a very particular and interesting type of solutions for it. We will thus analyse solutions for the so-called potential barrier, under tunnelling conditions. However, as this subject is extensively treated from a formal point of view in the work *Eurhythmic Physics or Hyperphysics: The*

Unification of Physics,[6] we'll only examine its physical meaning and some of its possible implications.

To better assess the magnitude of the problem that we intend to address and given its great conceptual importance, we will consider the following situation, although in some ways it has already been addressed in previous Dialogues.

Suppose we have a person throwing ping-pong balls against a wall, which constitutes our barrier. Let's also assume that this pitcher is throwing balls against the wall at a steady pace.

Turning to Lucius, he asked, "What do you suppose, Lucius, will happen to the balls?"

Lucius responded, "Well, the balls will be reflected as they hit the wall."

"Do you think some of the balls will appear on the other side of the wall?" asked Argus.

"Of course not! The wall is strong enough to prevent the balls from going through it."

"You are saying then", said Argus, "that the balls do not appear on the other side of the barrier – the wall in this case – because their incident energy is lower than the binding energy, that is, the energy of cohesion of the barrier. This figure (Figure 6-3) seeks to illustrate this situation.

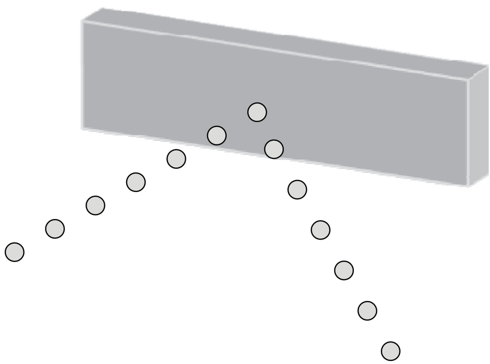

Figure 6-3: The energy of the incident particle is lower than that of the barrier.

[6] Croca, J. R. (2015) *Eurhythmic Physics or Hyperphysics: The Unification of Physics.* Berlin, Germany: Lambert Academic Publishing.

And now, if we put on a heavy machine gun mounted on a tripod firing bullets from a heavy metal, such as titanium, what would happen?"

"In this case", replied Lucius, "since the incident energy of the projectiles is much greater than the cohesive energy of the wall, it would be perforated as if it were made of paper. Therefore, in this new situation, bullets would be observed on the other side of the wall."

"From the classical point of view", confirmed Argus, "that is precisely what happens."

For an incident particle to appear on the other side of the barrier it becomes necessary that its energy is higher than that of the barrier, as this figure (Figure 6-4) seeks to evidence.

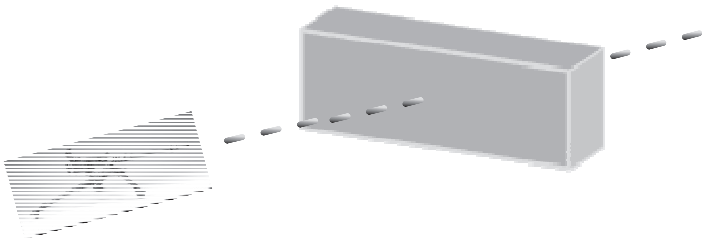

Figure 6-4: The energy of the incident particle is higher than that of the barrier.

However, and here is the crux of the matter, at the quantum scale things don't happen in the same way! It's precisely for this reason that this strange phenomenon, observed and continuously confirmed by experience, is called the tunnelling effect.

A quantum particle, an electron for example, although it hits a barrier with an energy lower than that of the barrier, it can actually be observed on the other side.

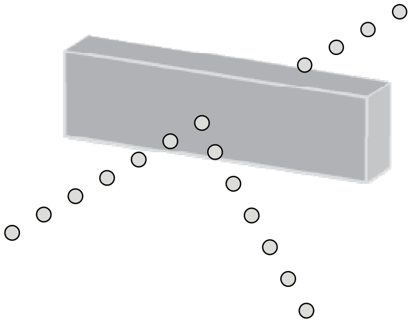

Figure 6-5: Quantum particle: tunnelling effect.

“Are you saying, Argus”, asked Iris, “that the electron has crossed the barrier and can then be seen on the other side?”

“Things are not that simple! In fact, they are much more complex than they seem to be”, exclaimed Argus. “At the quantum level, at the quantum scale and possibly also at other scales, all this problematic has to be seen with other ‘eyes’, as we will see next.”

However, before answering your question, Iris, first I wanted to say that this strange effect was observed and recorded for the first time by Newton, when he studied the phenomenon of total reflection of light, without him realizing what he had in his hands. Deep inside, he found that even under the conditions of total reflection, a tiny part of the light appeared in the forbidden region.

It was only much later, at the end of the nineteenth century, that this phenomenon, referred to as frustrated total reflection, could have a mathematical description with the aid of Maxwell’s electromagnetic theory.

This strange and elusive wave, characteristic of the forbidden region, was given the name of evanescent wave. Initially, this strange evanescent wave was no more than a mere mathematical curiosity. Only in 1910 were Schaefer and Gross able to experimentally study the properties of these waves with a radiation wavelength of the order of one centimetre focusing on paraffin prisms. More recently, in 1960, Coon was able to experiment with these waves using radiation on the visible band. At present, this strange evanescent wave, coming from the frustrated total reflection, has wide

applications in modern technology, namely in mobile phones and other devices with sensitive touch screens.
In quantum physics it was Gamow, in 1928, who showed that the alpha emission by radioactive nuclei could be explained in terms of an effect similar to that of the frustrated total reflection. Since then, this strange phenomenon has been called the tunnelling effect. However, although this tunnelling effect was theoretically very interesting, for about half a century it was nothing more than just a simple and exciting laboratory curiosity. This state of affairs changed drastically when, in the eighties of the last century, due primarily to the work of two IBM researchers Binning and Rohrer, the first prototype of a whole new generation of microscopes was developed.
These new instruments are called super-resolution microscopes. The principle of their operation is based precisely on this strange phenomenon called the tunnelling effect with electrons.
This new type of technology to obtain images, based on the tunnelling effect, was immediately extended to the optical domain by Pohl and his experimental research group. Naturally, as expected, due to its enormous potential, this innovative technological process of obtaining images has undergone a rapid development. So much so, that presently we have at our disposal super-resolution optical microscopes with a resolving power hundreds of times bigger to the traditional microscopes also called Fourier microscopes. Currently, the most advanced imaging devices are based precisely on this strange tunnelling effect. These super-resolution microscopes are now common instruments in any relatively well-equipped laboratory.
I think it's now perfectly clear that the tunnelling effect and the frustrated total reflection are nothing more than a direct and simple consequence of the extensive undulatory nature of the complex particles.

At this point Amadeus, addressing all of us, asked, "I've heard before, and now here several times, of total reflection and of frustrated total reflection. Could any of you be so kind to clarify this question a little more?"

Fabrus, who was with Amadeus, replied "Gladly. The phenomenon of total reflection basically consists of the following: When a ray of light coming from a higher refractive index medium is directed to another optical medium of lower refractive index, such as, for example, from glass to air, what can we expect to happen?"

Now let me remind you that the refractive index of a given optical medium is defined by the ratio of the speed of light in vacuum c to the speed of light in that medium v,

$$n = \frac{c}{v}$$

In these conditions, the higher the refractive index of an optical medium, the lower the speed of light in that same medium.
But returning to our question: In this case, the light ray will be incident on the separation surface of the two optical mediums, with an angle of incidence θ_i and will then be transmitted in the second medium with a transmission angle θ_t. Now it happens that when the light goes from a medium of higher refraction index to a medium of lower index, the angle of transmission is higher than the angle of incidence, $\theta_t > \theta_i$. Of course, there is always a relatively small part of the light that is not transmitted, the so-called reflected component. However, for the purposes of conceptual simplification, in this scheme, (Figure 6-6), only the incident and transmitted light rays are indicated.

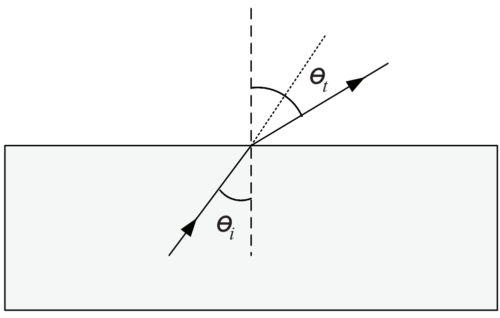

Figure 6-6: Transmission of light from glass to air.

Picking up his smartphone, which he's very proud of, he made a calculation and said:

Assuming that the light goes from the glass, with a refractive index of 1.5, to the air, which has a refractive index close to one, we will have, for an angle of incidence of 10 degrees the transmission angle is 15.1 degrees.
To better understand the situation, I'll draw up a small table here, with only a few values:
Angle of incidence θ_i= 10º
corresponds a transmission angle θ_t= 15.1º
Angle of incidence θ_i= 20º
corresponds a transmission angle θ_t= 30.9º
Angle of incidence θ_i= 30º
corresponds a transmission angle θ_t= 48.6º
Angle of incidence θ_i= 40º
corresponds a transmission angle θ_t= 74.6º
Finally, for an angle of incidence of 41.48°, the transmission angle is 90°.
In this particular case, and at this angle of incidence, no light is transmitted to the second medium. Precisely for this reason, this angle is called the critical angle θ_c, meaning that for incident angle values greater than this critical angle, $\theta_i > \theta_c$, all the light is reflected, and therefore none is transmitted to the second optical medium.
This scheme tries to translate this situation (Figure 6-7).

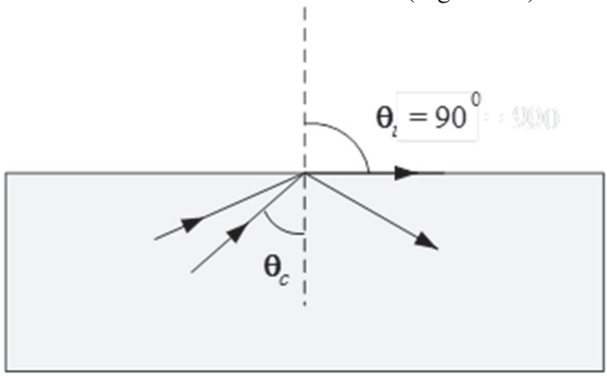

Figure 6-7: Total reflection of light.

I would like to take this opportunity to mention that initially this phenomenon of total reflection had relatively little application in technology. However, today things have changed dramatically. In fact, the vast majority of communications, by land and even by sea, are currently made by the well-known optical fibres. Now, the fundamental effect used in these fibres for the transport of information is precisely the total reflection.

As Fabrus pointed out, a big part of modern information and imaging technology is based precisely on the total reflection and tunnelling effect. However, we will now see the reason why we come back to the discussion around the tunnelling effect, something that has already been done in the previous Dialogues.

The answer to this question is mainly related to the question posed by Iris.

Is it that, as would be expected, in a first simplistic analysis, the quantum particles, the electrons, for example, which are observed on the other side should, at least in principle, have crossed the barrier?

Against all that was expected, and as strange as it may seem, the answer is negative!

Lucius cut in, to say:

What? Are you saying Argus, that the quantum particle, an electron for example or any other, hits the barrier and appears on the other side without having crossed it? How is this possible? You mean to say, using a classic metaphor that you gave yourself, that if I'm throwing ping-pong balls against this wall, the balls will appear on the other side without having crossed the wall?

It's already difficult to accept that a particle when incident on a barrier can cross it, and I emphasize the word cross, having an energy of incidence lower than the energy of cohesion of the barrier. Now, it's even harder to accept that the particle appears on the other side of the wall without passing through it. I mean, to believe that a material incident particle may appear on the other side of the wall without having crossed is really hard to swallow. So that we can accept your statement as creditworthy, you have to better explain to us how things work!

We all looked at Argus, perplexed, who smiled and replied:

I must say Lucius, truth be told, that I too had the same doubts. However, when we begin to 'look' at nature with other 'eyes', things that until then seemed to us as impossible and without any meaning

then become clear. Let's see if I can explain this complex situation to you:
My answer will be divided into two parts: the first of an essentially theoretical-formal nature; the second, of experimental nature, confirming the adequacy of the theoretical description.
From the formal point of view, to solve this problem we just have to look for the solutions of the nonlinear master equation of eurhythmic physics. By the way, as a simple note, I want to tell you that finding an evolutionary solution to this type of problem was no easy task. In any case, once we have found the mathematical solution, we face the great problem of analyzing it with the aim to understand its physical meaning. We all know that one thing is mathematics and something quite different is physical reality. Now, in this case, a great problem arises right from the outset. Inside the potential barrier, the wall, using the language of Lucius, the solution has an imaginary speed in its structure. That is, a speed which, from the mathematical point of view, is expressed by an imaginary quantity.
In fact, the condition of tunnelling may eventually be described by a mathematical operator, the tunnelling operator. The function of this operator consists of transforming the actual speed of the wave incident on the barrier into an imaginary speed.

$$v_{incident} = v_{real} \xrightarrow{\text{Tunnelling Operator}} v_{barrier} = v_{imaginary}$$

This means that the finite theta wave, which describes the quantum particle, will hit the barrier at a certain speed, called real speed, which can be measured experimentally. If there is not a tunnelling condition, this speed will of course be changed inside the barrier, but it remains a real magnitude. However, when there is an interaction that leads to the tunnelling condition, in this case when the energy of the incident particle is lower than that of the barrier, then the real speed becomes an imaginary quantity and therefore not susceptible to being experimentally determined.
Since this question of imaginary entities is critical, I will briefly give a simple explanation, for the benefit of those less familiar with mathematics, of what imaginary quantities are.
This story of imaginary numbers is quite long and can be said to have begun in antiquity. However, it was Descartes, in the seventeenth century, who designated these entities by the name of imaginary. These quantities are related to the square root of negative numbers.

Basically, we try to answer the question of what the number x is, that multiplied by itself, $x \times x = x^2$ gives (-1). That is

$$x^2 = -1$$

or,

$$x = \sqrt{-1}.$$

This very special number was designated as imaginary, being represented by the symbol $i = \sqrt{-1}$. Its square, $i^2 = 1$, may eventually have physical meaning and therefore corresponds to something real. However, for the imaginary number i itself, we cannot see any relation with something real, with something concrete that can be determined experimentally.

Now, as I have already told you, the solutions within the barrier under tunnelling conditions carry an imaginary speed, in the mathematical sense of the term. It's precisely for this reason that it's not possible to assign a real, i.e. measurable, speed to the particle. As an immediate consequence of this impossibility, it's equally not possible to assign a position to the particle within the barrier. Thus, an explanation which appears to be relatively adequate is as follows: The particle, described by its theta wave, approaches the barrier with a certain real speed, therefore, is subject to being determined experimentally as shown in the following figure (Figure 6-8):

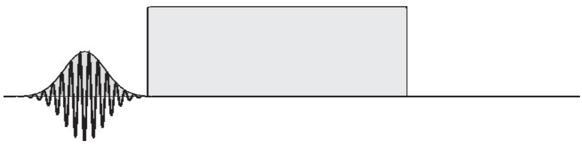

Figure 6-8: Particle hits a potential barrier.

This particle moves with a certain speed until it reaches the barrier. Once arriving in the vicinity of the barrier it begins to interact with it as shown in the drawing (Figure 6-9).

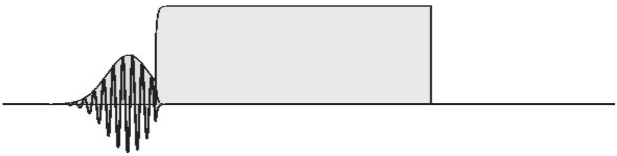

Fig. 6.9: The particle begins to interact with the barrier.

The particle begins to interact with the barrier, being modified and modifying the barrier similarly. Thus, as time passes the incident wave disappears, and within the barrier a very minute disturbance begins to emerge at the other end, as can be seen in this drawing (Figure 6-10).

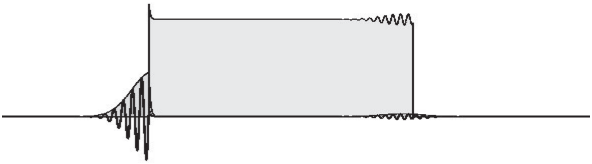

Figure 6-10: The particle begins to de-emerge and a small disturbance arises at the end of the barrier.

This de-emergence process of the particle before the barrier continues while at the other end, the slight initial disturbance begins to increase, as indicated in the drawing (Figure 6-11).

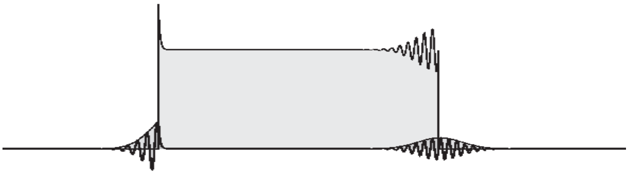

Figure 6-11: The particle continues to de-emerge before the barrier and to emerge from the other side.

Note that there is a reciprocal particle-barrier interaction where both are modified to a greater or lesser degree. That is, everything happens as if particle and barrier constituted the same global, inseparable and complex entity. As time passes, this process continues until one particle emerges completely from the other side of the barrier. In the region of incidence, it starts to concomitantly appear as a reflected theta wave (Figure 6-12).
As can be seen, the particle approaching the barrier begins to interact with it giving rise to its de-emergence and simultaneously on the other side of the barrier, a particle begins to emerge.

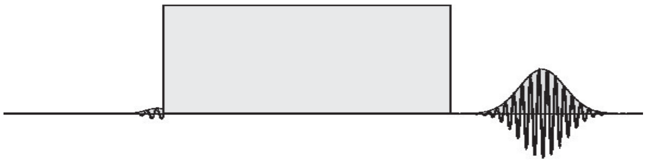

Figure 6-12: The particle emerges completely from the other side of the barrier.

Look! All this happens without the particle actually crossing the barrier. What happens is that the particle approaching the barrier begins to interact with it. From this reciprocal interaction, in these very particular conditions, the particle begins to de-emerge at the beginning of the barrier and to emerge on the other side.
Of course, a tiny portion of the theta wave runs through the barrier. This residual part of the theta wave carries the information that allows the regeneration of the particle on the other side.
I also want to tell you that these drawings correspond to a part of a graphic simulation of the mathematical solution made some time ago by one of our collaborators.

At this point, Iris, full of enthusiasm, said:

I find this explanation very interesting, Argus. All the more so that it clarifies, in a particularly clear way, this apparently – at first sight – strange question. I mean, the quantum particle appearing on the other side of the barrier without going through it.
So, if I understood correctly what you said, the barrier behaves as if it was an information transmitter. Thus, this information will allow,

under tunnelling conditions, the emergence of a structure in all similarity to the one that hit it. Of course, for the emergence of this organized structure to take place, it's necessary to have adequate interaction conditions with the medium. Basically, for the tunnelling effect to occur it's necessary first to create very specific interaction conditions that make it possible. I see here a certain analogy with the behaviour of much more complex beings, for example the trees that reproduce to disseminate information, in the form of seeds. When this information, condensed in the seeds, finds a suitable medium, it will give rise to replicas of the same tree. Basically, everything happens, considering the natural limitations of metaphors, as if the tunnelling effect was the motor of a process of continuous creation, seemingly out of nowhere.

She paused.

Now, in the wake of this reasoning, an interesting possibility just occurred to me. Can an incident particle, under tunnelling conditions, give rise to the appearance of one or more similar particles on the other side of the barrier? If so, we would have a device that in practice behaved like a replicator. Does this conjecture make any sense, Argus?

Argus, a little hesitant, replied:

It's worth remembering that one thing is mathematics and its formulas, another thing is nature, physis!
In spite of everything, in line with what you have just said, I'd like to point out that everything leads to believe that there are situations, that is, solutions that have a transmission coefficient greater than one.
This said transmission coefficient translates into no more than the relation between the particles that appear on the other side of the barrier and those that hit it.
From the traditional point of view, this transmission coefficient will necessarily have to be always smaller or at most equal to one. This imposition is made so that within the conceptual universe of traditional physics, the principle of conservation of energy remains adequate.
However, in the new physics, nonlinear and complex, in eurhythmic physics, we know that a tiny action, under appropriate conditions of

interaction with the medium, may give rise to a great reaction. To prove it, just remember that example I gave earlier of the shepherd leading the sheep to the fold. In these circumstances, it may be that the interactive conditions of the medium are such that allow this possibility – all this, of course, without any violation of the principle of energy conservation.

However, and once again, I want to emphasize this is only a mere mathematical possibility.

Therefore, the answer to your question, Iris, can only be given by nature, that is by experience, by concrete practice.

After a pause, Argus continued:

Apart from this situation, which may seem strange in a classical perspective, of the quantum particle appearing at the other side of the barrier without having crossed it, this tunnelling interaction has other, no less strange aspects.

The mathematical solution for the time that mediates between the moment when the particle hits the barrier and the time when it emerges on the other side, against everything that would be expected, does not depend on the extent of the barrier. This time, which is called the emergency time, depends only on the nature of the incident particle and the energy of the barrier. It's a kind of 'warming' or ignition time of the system.

Curious, Lucius asked:

If it's as you say, Argus, then this would have very curious consequences. To see that it's so, let's consider a barrier characterized by a certain energy and a certain extent, for example, of a millimetre. From what you said, after the particle hits the barrier it will take some time for the system to *warm up* and a particle to appear on the other side.

Let us assume, for example, that the time of emergency is one second.

Now if we increase this extension by ten times, leaving us with a one-centimetre barrier, the emergency time remains a second.

If the extension is increased to one metre, the time for the appearance of the particle on the other side of the barrier will remain one second.

Similarly, if we increase this distance to, say, one kilometre this time will continue to be one second.

This reasoning can continue, in a way that, if what you said is true, we may eventually obtain transmission speeds much greater than the speed of light.
Now, this is precisely where I want to get to: Are there concrete experiments in which you get transmission speeds higher than the speed of light in a vacuum? We must be aware that such a conclusion would be an impossibility, because according to the theory of relativity, the maximum possible speed is precisely that of light in vacuum, i.e., 300,000 km/s.

"You're quite right Lucius!" said Argus, "in fact, many experiments have been carried out in tunnelling conditions, where speeds far exceeding that of light, the so-called superluminal speeds, have been observed."

Many of these experiments were done in Germany by a physicist named Nimtz and his collaborators. In fact, he, with barriers of about one metre in length, managed to transmit a piece of Mozart's symphony No. 32 at more than four times the speed of light, $v = 4.7\,c$. In conclusion, I'd like to say that the results of these experiments have been confirmed in several laboratories around the world.

Amadeus, who followed the explanation like the rest of us, asked "We've been talking about the tunnelling effect, but being open and honest with you, I still haven't understood what a barrier of potential in tunnelling conditions is. I would like you, if possible, to clarify this to me."

"I think you've asked a very good question, Amadeus!" said Argus.

I too think that this issue of potential barriers needs to be better clarified. For this, it's convenient to remember the basic essence of the complex particle. We know it's made of the theta wave and the acron. The acron is guided, according to the principle of eurhythmy, to the regions where the theta wave is relatively more intense. This theta wave, in turn, is in general the composition of many waves that when interacting reached, on average, a high degree of spatial coherence. From the composition of this multiplicity of waves then emerges a global theta wave with its own identity.
Now, what we designate by the name of potential barrier is nothing more than a region of space where there is a complex fabric of many theta waves interacting reciprocally, giving rise to a global theta

wave which constitutes our barrier. When an incident particle interacts with the potential barrier, with this complex global wave, two things can happen:

1. The degree of coherence of the theta wave of the incident particle increases due to the reciprocal interaction with the wave of the barrier.

In this case we are faced with what is called an attractive barrier. Since in the region of interaction the intensity of the theta wave seen by the incident particle increases, it follows, according to the principle of eurhythmy, that the acron acquires a tendency to move preferentially towards the barrier. Everything happens as if there was a kind of attractive force that pulls the particle to the barrier. The greater the tendency to increase the degree of coherence of the waves, the greater the attractive force.

This drawing seeks to illustrate this situation (Figure 6-13).

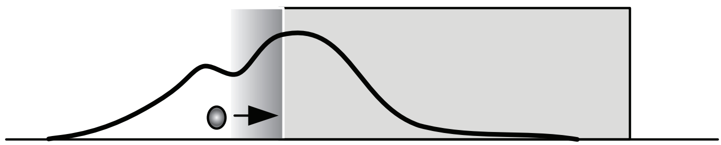

Figure 6-13: Attractive barrier: There is an increase in the degree of coherence of the incident wave.

2. The degree of coherence decreases due to the reciprocal interaction between the incident theta wave and the global theta wave that constitutes the barrier. In this case, we are dealing with what is usually called a repulsive potential barrier. In practice, the action of this barrier consists of causing a decrease in the degree of coherence in the incident theta wave. The greater the decrease in the degree of coherence, the greater will be the repulsive action of the barrier. Since the average intensity of the incident wave decreases in the overlapping zone with the barrier, the acron will naturally, according to the principle of eurhythmy, avoid that region. Therefore, everything happens as if there was a repulsive force acting on the particle, on the acron, causing it to avoid the repulsive barrier, as can be seen in this drawing (Figure 6-14).

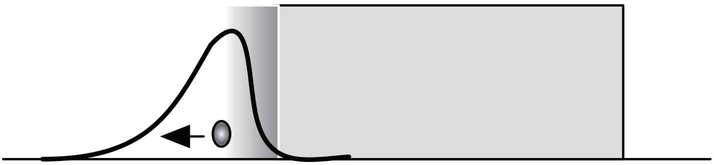

Figure 6-14: Repulsive barrier: There is a decrease in the degree of coherence of the incident wave.

As we would expect, in the absence of any increase or decrease in the degree of coherence of the theta wave of the incident particle, everything happens as if there was no potential barrier. In these specific conditions of interaction, we can say, improperly, that we find ourselves in full empty space. In fact, what it means is that we are in a region of space where there is no observable action on the incident particle. However, for another, or even for the same particle and for other types of interaction, the same region may not be considered to be empty.

In any case, as we have just seen, what is usually called a potential barrier is nothing more than a region of space where there is a particular and very complex fabric of theta waves. This multiplicity of theta waves, due to their reciprocal interaction, will give rise to a global complex theta wave whose properties characterize what is generally designated as a potential barrier.

When the behaviour of this complex fabric of theta waves increases the degree of coherence of the incident wave, we have an attractive barrier. When it causes the decrease, we have a repulsive barrier.

So far, we have been analyzing the notion of the potential barrier as either 'normal' or 'tunnelling', in the classical sense of the terms. In fact, the notions of normal or tunnelling are somewhat misleading. In some cases, the same physical medium can be normal or tunnelling.

To confirm this, just remember the case of the total reflection of light. Here, the same medium, air, can be considered as normal for angles of incidence lower than the critical angle. For higher angles of incidence, the same medium, air, can then be considered as a tunnelling medium, as illustrated in this scheme, Figure 6.15.

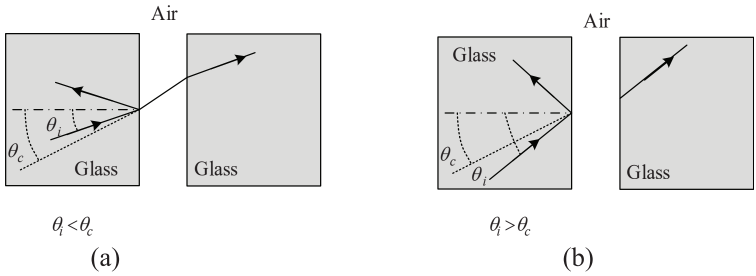

Figure 6-15: The same medium, air, can behave as “normal” (a) or as a “tunnelling” (b).

As it turns out, what really matters is not the incident particle and the physical medium considered as independent, but rather the complex and nonlinear nature of the reciprocal particle–medium interaction.

We paused to better think about what had been said.

After a few moments Argus continued. “I don’t know if you’ve realized the possible implications that this phenomenon of tunnelling, an attribute of the complex systems, can have! It’s related to space and chronological time.”

“Chronological time! What is chronological time?” asked Amadeus.

“Chronological time, as the name implies, is the time of the clocks” replied Argus, and went on, “By the way I want to ask you a question, Amadeus. Tell me, how do you or anyone else, measure time?”

After thinking for a second, Amadeus replied. “Well, I think the easiest method, the one that was followed until very recently, was to put a stick on the ground. From the position of the shadow projected by the stick on the ground we infer the time. One thing is certain, when the shadow of the stick is the smallest, we know that we are precisely at the middle of the day. Of course, many other devices exist to measure time.”

“I recognize that your example is very interesting and significant”, said Argus. “The basic process of measuring chronological time always consists of associating a position to a time. From a position we infer the time. In the case of the sundial, from a given position of the shadow we make it correspond to a time. In other devices, as for example in ordinary clocks, from the position of the hands we make it correspond to a time. As you can imagine, chronological time is intimately associated with space forming like an inseparable whole."

"Precisely", said Fabrus.

It was exactly because Albert Einstein realized this profound interconnection that he replaced absolute space and absolute time, assumed to be perfectly independent of each other, by the concept of space-time. These concepts, as we know, were introduced in classical mechanics by Isaac Newton, so that his laws of motion could have a meaning. However, in relativity, space and time are no longer understood as separate entities, but as constituting an inseparable whole, the space-time.

"Of course, you're quite right Fabrus!" said Argus.

However, I think this association is somewhat restrictive because the relation of interdependence which in relativity is established between space and chronological time is a purely linear relationship. One question that can be asked is whether this relationship of interdependence between space and chronological time will always have the same linear form, whatever the interactive context. It seems to me that the more reasonable assumption will be to admit that in a first approach, this relationship will be linear. However, when we wish to treat more complex phenomena this deep interdependence between space and chronological time, probably, it will not be adequately described by a linear relation.
It's precisely because of this profound interdependence between space and this time that it's rightly designated as chronological time. Thus, this chronological time has no meaning without space. In turn, in a perfectly analogous way, space has no meaning without chronological time. They constitute a single entity, the space-time. From this fact, results something surprising at first sight.

He paused and after a moment of silence, continued:

Let us suppose now that we intend to establish the position of, for example, four points which may eventually constitute an object, a tetrahedron.

To begin with, we'll have to define a frame in relation to which we can make our measurements. Let us assume that the observer is the point of reference, as shown in this drawing (Figure 6-16).

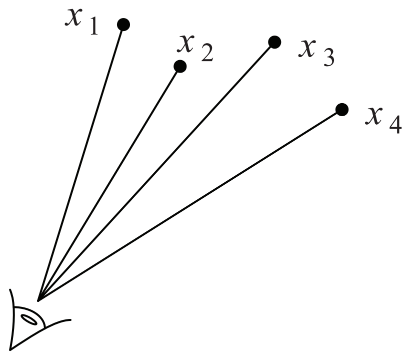

Figure 6-16: Determination of position.

For the observer to determine the distance at which the four points, x_1, x_2, x_3, x_4, are, he can eventually use several processes. Anyhow, ultimately all these traditional processes are reduced to sending a light signal that starts from point 0 at time $t = 0$, reaches the material point x_1 where it's reflected to the origin at the end of time Δt_1, having made twice the length, i.e., a round trip at the same velocity c. Under these conditions the distance Δx_1 between the origin and the point x_1 is given by

$$\Delta x_1 = \frac{1}{2} c \, \Delta t_1,$$

where c is the speed of light. The other distances can also be determined as follows:

$$\Delta x_2 = \frac{1}{2} c \, \Delta t_2,$$
$$\Delta x_3 = \frac{1}{2} c \, \Delta t_3,$$
$$\Delta x_4 = \frac{1}{2} c \, \Delta t_4.$$

In the end, this process of measurement basically consists of relating, through the speed of light, a distance Δx to a time interval, Δt,

$$\Delta t \leftrightarrow \Delta x.$$

That is, space is proportional to the measured time, chronological time

$$\Delta x \propto \Delta t,$$

with the speed of light in a vacuum being this proportionality constant

$$\Delta x = c\, \Delta t.$$

So far, it looks like everything is fine and there is no problem whatsoever. Let us see what happens if we change this traditional process of evaluating distances.
Suppose we now determine the position of the four points using the tunnelling effect. The process will be in all similar to the previous one, except that now a barrier will be placed under tunnelling conditions between the observer and each point, as indicated in this scheme (Figure 6-17).

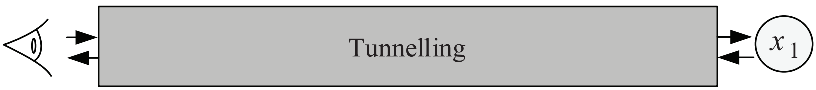

Figure 6-17: Calculation of the distance to a point using the tunnelling effect.

In this case as before, we send a light signal that starts from the origin, finds the tunnelling barrier and will emerge from the other side, near point x_1. The time of this process, Δt_1, is called the ignition time, Δt_i, being, of course, $\Delta t_1 = \Delta t_i$. This material point, in turn, reflects the ray that rejoins the tunnelling barrier re-emerging at the origin precisely at the end of the same time, $\Delta t_1 = \Delta t_i$. So, the total time interval measured by the observer will be $2\Delta t_1 = 2\Delta t_i$.
Repeating the process with point x_2, we get the total time $2\Delta t_2 = 2\Delta t_i$. Similarly, for the third x_3 and fourth x_4 points, we can determine that $2\Delta t_3 = 2\Delta t_i$ e $2\Delta t_4 = 2\Delta t_i$.
As can be seen, when using the tunnelling effect, the communication time with each point is precisely the same

$$\Delta t_1 = \Delta t_2 = \Delta t_3 = \Delta t_4 = \Delta t_i.$$

In these conditions, whether using a linear or other correspondence between time and space, the conclusion to be drawn is that all the points are at the same distance

$$\Delta x_1 = \Delta x_2 = \Delta x_3 = \Delta x_4.$$

Now, this is really the crux of the matter! Using this measurement process, the tunnelling effect, we come to the conclusion that after all, all points are at the same distance, and therefore are inseparable,

$$x_1 = x_2 = x_3 = x_4,$$

thus constituting, in fact, a 'single point' assuming, of course, one-dimensional space. In these conditions, the separation between the points, i.e. near and far, inside and outside, is just a matter of process or point of view. On one hand, using the traditional measurement process, all points are considered as different. On the contrary, if the method of interaction, or if the measurement process used is based on the tunnelling effect, all points are at the same distance and therefore can be taken as equal.

So, if this is the case, the conclusion to take is that the concept of space does not have a basic, but relational, statute. As in turn, chronological time – as we have seen – is intimately connected with space, it follows that this too is not a fundamental concept.

"If I understand correctly, you are saying, Argus, that space and time – I mean, chronological time – don't exist as fundamental categories of our understanding. At most they are only useful concepts, adequate, as you might say, to a certain scale of description of reality. However, if we want to improve our knowledge of nature, we need to live without them!" said Lucius.

"Spot on! I could not have said it better", replied Argus.

These experimental results confirm, to a certain extent, the ideas advanced by the great thinkers of the past.

However, time, the change, the becoming, is what constitutes the very basic concept of our understanding.

"So, if that's the case, what we have to do is to build a more advanced, more general science where space and chronological time don't play a fundamental role, as it has been the case so far. What do you say about this, Argus?" Asked Lucius.

After thinking for a moment, he responded:

> I think your proposal is rather appealing. However, I must say I don't believe that the development of a more general physics, which goes beyond space and chronological time, the physics of becoming, is an easy task. On the contrary! Of course, this new, more advanced physics to be developed must contain as a particular case, and at its scale of application, the eurhythmic physics, where space and chronological time play, as we know, a fundamental role.

As it was late and we still had to return to Lisbon, we decided to close this session, which we would resume as soon as possible.

Some Applications of the New Physics

SEVENTH JOURNEY

It was a beautiful summer afternoon when I arrived at Fabrus's house, where today's discussion about the foundations of physics was going to take place. Fabrus's house is located near the university, so he is very fortunate; just a short walk along the Campo Grande gardens is enough for him to get to his work place.

It was with joy that I found my friends who were sitting drinking beer or other refreshments and having snacks on the pleasant terrace of Fabrus's house.

They were discussing holidays and the best places to go. As soon as all the members of our group arrived and after the usual welcoming words, in my capacity as narrator I insisted to Argus that he resume the conversation from the previous day. He didn't need to be begged, and began:

> In the previous journeys we spoke about the bases and foundations, either conceptual or formal, of the eurhythmic physics. I can't stress enough that this global, nonlinear, relational and complex new physics proposes a new way of looking at nature. In this approach, for a better understanding of nature, interdependence and cooperation play a key role.
>
> We also know that this new way of looking at nature is contrary to the traditional, simplistic linear and Cartesian method, where it's assumed, as a starting point, that the whole is no more than the simple sum of its constituent parts. These parts, which constitute the whole, combine themselves in such a way that when interacting, they don't undergo any modification, thus maintaining their so-called unchanging identity. This process conveys, implicitly and explicitly, the principle of perfect independence of the entities, of the 'every man for himself', where the strong dominates or even crushes the weakest, utterly disregarding possible future repercussions.
>
> Now, to better appreciate the importance of this new method, it seems to me that the time has come to mention some of its applications not only at a conceptual level but also at experimental and technological levels.
>
> We'll start with nonlinear quantum physics. This, as we had the chance to see, is only a particular case of eurhythmic physics when

applied to the study of physical systems at the quantum and subquantum scale.

As in the previous Dialogues, we promoted a long and detailed discussion of either the nonlinear quantum physics or the traditional or orthodox quantum mechanics; we'll now briefly summarize their most fundamental points.

One of the fundamental notions of the new physics is surely the concept of frequency. This concept of frequency has, as we had the chance to verify, an extremely relevant role in nonlinear quantum physics. An in-depth analysis of this concept led to a break with the Fourier ontology, proposed in a surreptitious way by Niels Bohr in the famous Solvay congress of 1927. What this ontology, the Fourier ontology, categorically states is that only a harmonic waves, infinite in space and time therefore devoid of any physical reality, have a well-defined frequency. These frequencies, temporal or spatial, are later interconnected with the fundamental phenomenological formulas of quantum physics: the Plank formula, $E = \hbar\omega$, and the de Broglie formula, $p = \hbar k$. This conceptual hard core constitutes the so-called Fourier ontology. It's on this pillar that all orthodox quantum mechanics is supported. Although it has never been made explicit, it can and should be said that it constitutes, in fact, a sixth additional implicit postulate of the traditional quantum theory, and therefore, given its conceptual importance, it must be properly explained.

Similarly, we also know that the acceptance – implicit or explicit – of this postulate entails the absolute rejection of locality and identity leading naturally to indeterminism.

So, by rejecting the Fourier ontology and assuming that a finite wave may have a well-defined frequency, we recover a relative locality and relative individuality characteristic of the physical systems at a certain scale and level of description of reality.

After taking a break to drink a sip of beer, Argus continued:

There is another point to which I'd like to draw your attention. In the new physics, the eurhythmic physics, the primacy goes to the real finite waves. For that reason, whatever the physical entity, it can never be characterized by a perfectly defined position. This is for the obvious reason that any physical particle is always ultimately a rather complex entity, and therefore cannot simply be characterized by a very precise position. A real physical entity is necessarily extensive, but finite. It's nothing more than a predictable disturbance relatively stable on the considered scale of the basic indefinite medium, the subquantum medium. That is, it's nothing more than a wave. In these circumstances, it can never be given a perfectly well-defined position. At most, we can determine an average region of space where, at a certain temporal and spatial scale, it can eventually be located. Therefore, we aren't dealing with an accidental uncertainty that can eventually be removed, but rather with a truly and essentially irremovable uncertainty in position.

Following this conceptual statement, and as its direct consequence, resulted in the possibility of going beyond the limits imposed on our capability to predict or to know, mathematically translated by Heisenberg relations. Within this much broader conceptual framework, it was possible to derive more general relations of uncertainty which contain the Heisenberg relations, from the formal point of view, as a mere particular case. On the other hand, I am pleased to stress this point: modern solid-state technology related to the production of computer elements, memories, processors and others, is presently made beyond the Heisenberg boundaries. It was then shown not only theoretically but also by the experimental evidence of our day-to-day lives that the supposed limits imposed on human knowledge by Heisenberg relations were not fundamental but factual.

"You mean, Argus, that Heisenberg relations are wrong and therefore are no longer of any use?" asked Lucius.

"Not at all", replied Argus, "Heisenberg relations were, are and will be adequate to describe what happens to a given scale of description of reality."

Indeed, within a certain experimental context, Heisenberg relations are well suited to describe certain experimental results. This happens when, in the linear approach, the Fourier relations are adequate – that is, they are more than enough to describe the concrete physical situation. What is wrong is to claim these relations have a superior statute of absolute truth and therefore are 'valid' in all present and future physical situations.

Another important issue that I'd like to refer to has to do with the meaning of a concept we have already mentioned several times. It's the concept of coherence.

In the conceptual framework of the Fourier ontology, where the primacy goes to infinite harmonic waves in space and time, and

> consequently devoid of any objective physical reality, there is only one kind of coherence. This coherence is then interconnected with the phase relation of the several waves combining themselves.

"Throughout our discussions we've spoken several times about the coherence of waves. If you want me to tell you the truth, I didn't quite understand what this is about. Would it be possible for someone to clarify this question a little more, which after all is so important?" asked Iris, addressing all of us. I also nodded in perfect agreement with Iris. The issue of coherence seemed very important. So, I also thought it needed clarification. Fabrus, addressing all of us, responded:

> In fact, Iris, you're absolutely right! This issue of coherence is very delicate. So much so, that there are some works about optics dedicated only to this interesting subject.
> In the conceptual framework of the Fourier ontology, the fundamental elements – our conceptual bricks, our atoms – are ultimately harmonic waves, infinite in space and time.
> So, in this context of infinite harmonic waves, let us then see how these waves can be combined. To simplify the question, let's look at what happens when we have only two harmonic waves.

He pulled out his smartphone and showed us the graph below:

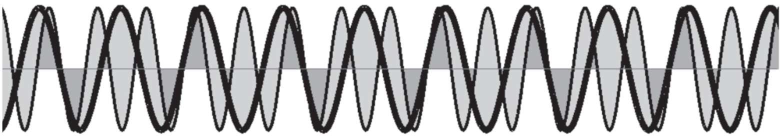

Figure 7-1: Two harmonic waves with different frequencies.

"Here in this graph, we have the representation of two harmonic waves with different frequencies. If we make the linear composition, in other words, the sum of these two waves, we will obtain a pattern, i.e. a final wave resulting from them, as can be seen in this other graph." Again, he turned to his smartphone.

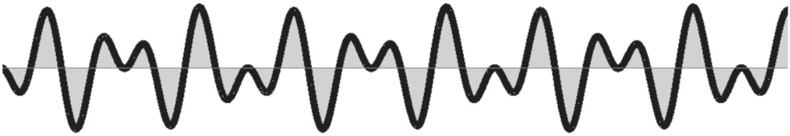

Figure 7-2: Sum of the two waves.

If this pattern, if this final wave maintains the same form over time we say the two waves, which give rise to it, are coherent. In turn, for this pattern to be maintained it's necessary that its phase relation, the difference of phase of the waves, remains constant over time.
When the pattern, the wave form resulting from its sum – the global wave does not remain constant over time, as can be seen here, for three different moments (Figure 7-3), the waves are said to be incoherent.

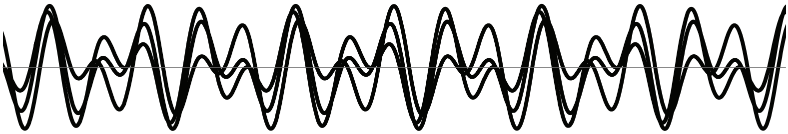

Figure 7-3: Composition of incoherent waves in three different moments.

Since the waves are incoherent, their phase difference varies from moment to moment. In this case, its linear composition gives rise to a final wave whose shape is permanently varying. On the contrary, when the waves are coherent the final wave always maintains the same shape.
To summarize: Because these waves are infinite, the relevant variable to describe the behaviour of the final wave resulting from the linear composition of all the waves is its relative phase.
If this phase difference remains constant, the waves are coherent. In this case, the final wave resulting from their composition always maintains the same shape.
When the phase difference does not remain constant, we have incoherent waves. In this case the final wave varies from moment to moment.
It's a different story when it comes to finite waves. In these conditions, besides the relative phase we must add another important variable: the position correlation.

In this situation, even keeping the relative phase difference constant, the shape of the final wave will change as the relative position of the waves change. Let us see here two finite waves (Figure 7-4)

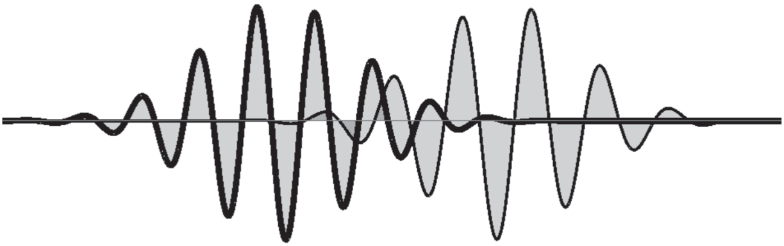

Figure 7-4: Two finite waves.

The linear composition of these two finite waves gives, in a certain instant of time, the following graph (Figure 7-5).

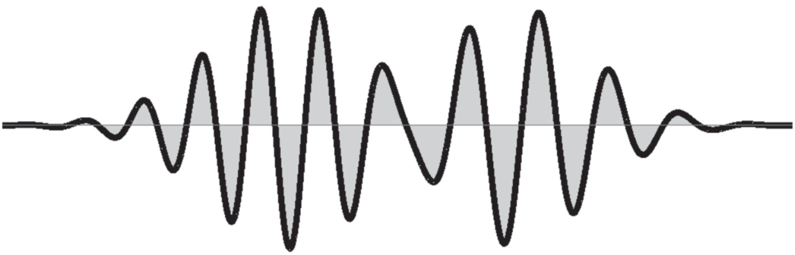

Figure 7-5: Composition of two finite waves in a certain moment of time.

Let's see what happens when the same phase difference is maintained but the relative position of the waves between the two waves varies. This graph (Figure 7-6), represents the final wave at three different moments.

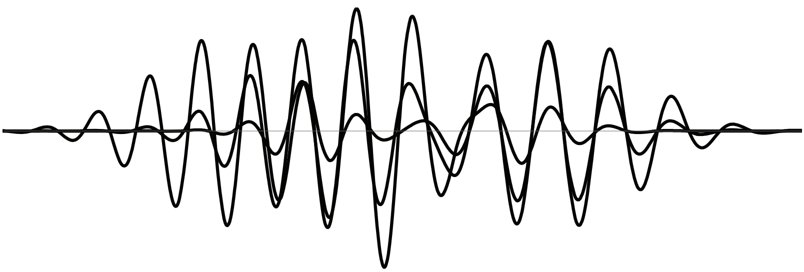

Figure 7-6: Composition of two finite waves in three moments.

As the relative position of the waves varies, from time to time the shape of the final wave will also vary.
Under these conditions, we can conclude that for the shape of the final wave resulting from the composition of several waves to remain constant, it's necessary that both the phase relation and the relation between the position of the waves remain constant over time.

Fabrus paused and Argus took up the speech:

I think that after this beautiful and interesting explanation from Fabrus, everyone has learned that when going beyond the Fourier ontology we should consider not one, as it was done before, but two types of coherence:
1) Phase or angular coherence. The concept of phase coherence is suitable for both finite and infinite waves. This phase coherence corresponds to the traditional notion of coherence and translates the relative stability between the phases of the waves that give rise to the final wave by linear composition.
2) Position or spatial coherence. This attribute of coherence, exclusive to finite waves, corresponds to the relative stability in time between their relative positions.
In any case, the greater the degree of coherence, phase or spatial, of the multiple constituent waves, the greater the stability of the final wave resulting from its linear composition.
To conclude this subject, I'd like to mention that the problem of knowing the ontological statute of quantum waves, whether they are real waves or, on the contrary as traditional quantum mechanics asserts, are mere probability waves devoid of any real physical content, can be finally solved experimentally.
The answer given by the most recent experiments done in Germany by Menzel and his group is that quantum waves are actually real physical waves. These interesting experiments are based on a newly developed quantum imaging technique. This is the so-called ghost imaging technology.
This recent imaging technology is based on the high degree of correlation, temporal and angular, between two twin photons produced by a nonlinear crystal in the parametric decay.
When a photon of a certain frequency ω_0 hits one of these crystals, due to the nonlinear interaction, two twin photons ω_1 and ω_2 are

produced whose sum of frequencies gives the frequency of incidence, $\omega_0 = \omega_1 + \omega_2$, as seen in Figure 7-7.

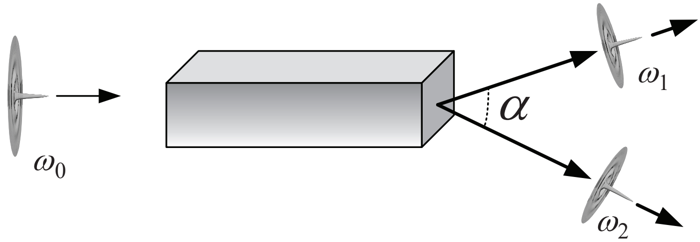

Figure 7-7: Production of two photons correlated in space and time.

The two resulting photons, besides having a good temporal correlation since they are produced almost at the same time, also have a strong angular correlation. So, these photons follow a very well-defined angular cone. In these conditions, if a photon is located at a certain point in space, P, it's certain that the other will be detected at the corresponding homologous point, P'. Figure J7.8.

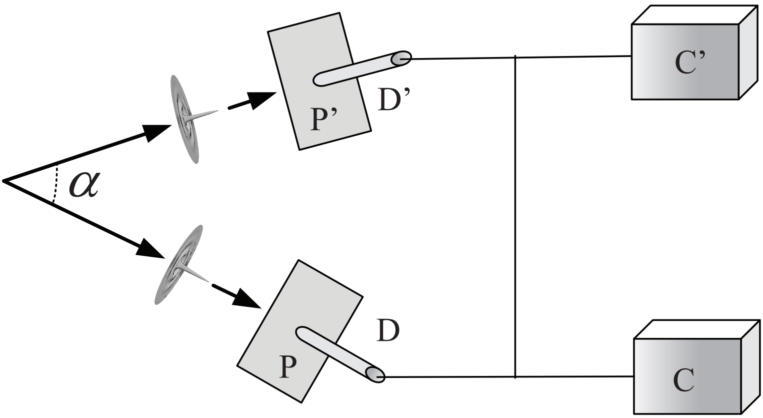

Figure 7-8: When one photon is detected at point P the other is detected at P'.

So, when the bottom photon is detected at point P by detector D and recorded by counter C, the twin photon is detected at point P'. This

means each of counters C and C' will simultaneously register the arrival of a photon detected respectively by detectors D and D'.
Having in mind this correlation in time and position of the twin photons, and in perfect analogy with the pantograph, where to each object point corresponds an image point, it was possible to develop an entire imaging process called ghost imaging.

Iris, who followed the explanations from Argus very closely, said, “It seems to me, in fact, that this is a very innovative process of imaging. However, I don’t quite understand its principle. Would it be possible, Argus, to explain a little better what this process of producing images consists of?” We all joined Iris in perfect agreement with her, as we thought the subject of ghost imaging should be better explained.

“Yes, I think you’re all quite right! This subject of ghost imaging, for its great originality and importance, deserves to be somewhat further discussed”. Argus continued:

For this, let’s consider the previous device; but now, in the region of observation or arrival of the lower photon, we’ll put an opaque screen, E, where there is a transparent figure, for example an arrow, that will constitute our object, O. In the region of observation of the upper photon we place only one totally transparent screen, E', of glass. These two screens, these two surfaces, will be swept, each by its corresponding detector, D and D'. The counts, corresponding to the detections, are to be recorded in panels R and R', as indicated in Figure 7-9.

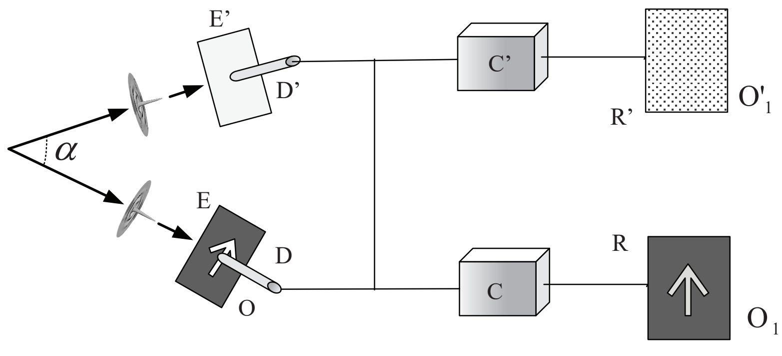

Figure 7-9: Detectors D and D’ sweep surfaces E and E’, and their readings are registered by panels R and R’.

As detector D sweeps the whole screen E, an image of the object O naturally begins to appear in the registration panel R. Since screen E is only transparent in the region that characterizes the object, O, in all the other areas, detector D registers nothing. Under these conditions, an image O_1 of the initial object O will appear in the registration panel after a certain period of time.

The case is totally different in the upper zone, where the entire detection surface E', is transparent. In this case, the registration panel R' will be completely filled with detection points. There, no image can be observed since the registration panel is filled almost uniformly.

Nothing new until now! However, I draw your attention to something very interesting. If we begin to progressively remove the points that were recorded in R' which do not correspond to any point detected simultaneously by D, a replica of the original image O begins to appear in this panel. Simply, what we do is to remove from this registration zone all spurious points to which no homologous point corresponds in D.

It's precisely for this reason that this recent and interesting process of imaging is called ghost imaging.

Everything happens as if a replica of the initial object began to appear progressively in the image plane R' out of nothing. Moreover, this process can occur even when the region where this ghost image is observed is eventually very far from where the original image is located.

In the end, as you can see, there is no mystery in this process of imaging. What happens, as I said, is that the twin photons produced in the nonlinear crystal are correlated in space and time. So, if we know where a photon is at a certain point in time, we can also know where its homologue photon is at the same instant.

"Thank you, Argus!" said Iris, I think I now understand this innovative imaging process much better."

Argus, turning to us, said:

After this little digression let's return now to our subject that consists of proving experimentally the actual physical existence of theta waves, or de Broglie waves or even of subquantum waves.

Keeping in mind what has been said, let us now consider the simple case in which object O is reduced to two points, or two slits S_1 and S_2, as indicated in Figure 7-10.

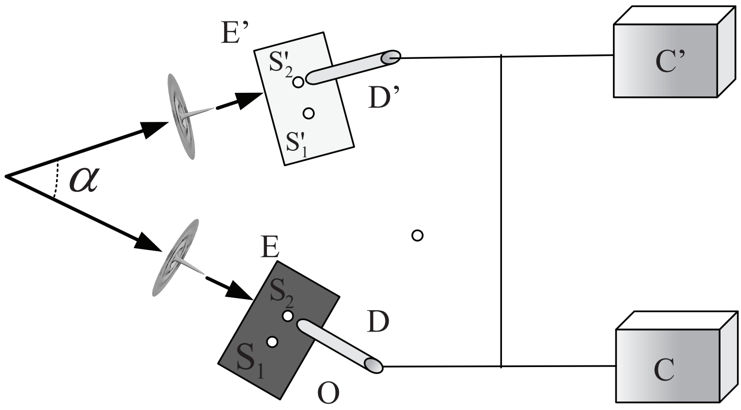

Figure 7-10: Object reduced to two slits.

In this situation, when detector D is placed in front of slit S_1, detector D' can only make a simultaneous detection when positioned in front of its homologous virtual slit S'_1. Likewise, if detector D is positioned in front of slit S_2, there will only be coincidences, simultaneous detections, when detector D' is in front of the homologous virtual slit S_2.

To summarize: In these experimental conditions, given the great degree of temporal and spatial correlation of the two twin photons from each pair, the two photonic detectors only detect simultaneously, that is, in coincidence when:

1) detector D is placed in front of slit S_1 and detector D' is in front of the homologous virtual slit $S'_{1;}$

2) detector D is placed in front of slit S_2 and detector D' is in front of the homologous virtual slit S'_2.

This means that if we fix detector D' in front of the virtual slit S'_1 its twin photon, or homologue, will necessarily have to pass through slit S_1 and can then be detected simultaneously by detector D.

When we place detector D' in front of the virtual slit S' then its twin photon will have to pass through the homologous slit S.

So, when we know where a photon is at a given moment, we know the position of the twin photon at the same instant. Under these conditions, if the top photon passes through slit S'_1 we know with certainty that its homologue will pass through slit S_1. This detection occurs regardless of the position where the observation is made, either in the near field, immediately ahead of the slit, or in the far field, much further away.

More concretely, let us see what happens in the following experimental situation, Figure 7-11, which is more than a slight modification of the previous device.

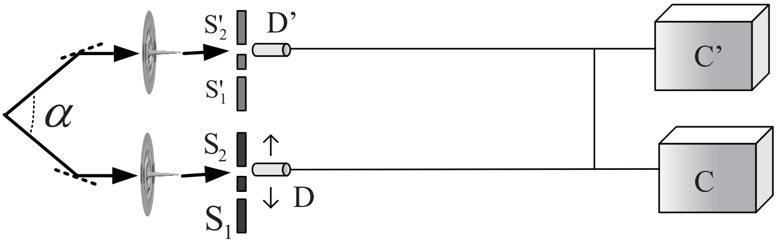

Figure 7-11: Detector D' is fixed in front of slit S'_2 and moving detector D is in front of slit S_2.

When detector D' is placed permanently in front of slit S'_2, and detector D is free to move, it turns out that it will only be able to detect the homologous photon in coincidence if it's positioned in front of slit S_2. In any other position, particularly in front of slit S_1, nothing can ever be detected since the homologous photon can only pass through slit S_2.

Let us now look at what happens when detector D is removed from the immediate vicinity of slit S_2 in the near field, and is dislocated to the far field, as seen in Figure 7-12.

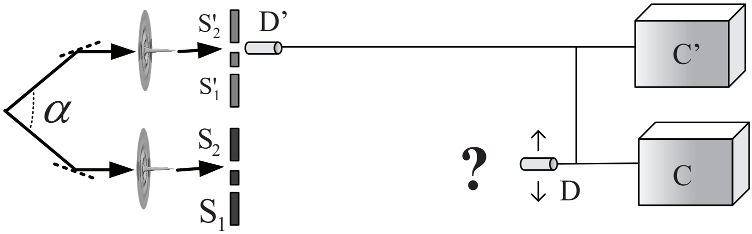

Figure 7.12: Moving detector D is dislocated to the far field.

Turning to all of us, he asked, “In these conditions, what distribution of arriving photons will we observe in the region of distant observation?”

There was a great silence! A few moments later, Fabrus replied:

“I would like to be the one responding to this question, which seems to be very pertinent: Of course, we have to take into account that detectors D and D' are always in coincidence, which means that only the simultaneous detections are to be considered. All detections performed on detector D that do not have a corresponding counter in D' are ignored.”

Once again, he stopped to reflect. “Well Argus”, he said, “it seems to me that your question has two possible answers.”

1. Answer given by traditional or orthodox quantum mechanics.
As can be deducted, this is a typical experience of the two slits. Now, in this fundamental experiment of quantum mechanics, when we know which of the slits the photon passes through, there is the collapse of the wave function. This happens because it’s assumed that the wave function is a mere wave of probability and therefore devoid of any real physical content. So, the initial wave of probability would be decomposed into two waves, one corresponding to the probability of passing below, ψ_1, and another, ψ_2, to the probability of going above.

$$\psi = \psi_1 + \psi_2.$$

However, as we know with certainty that the photon will pass through the upper slit, the initial wave function will collapse into a single function.

$$\psi = \psi_1 + \psi_2 \rightarrow \psi_2$$

That is, the initial function becomes just one,

$$\psi = \psi_2$$

which corresponds to the upper passageway, through slit S_2. In these conditions, and according to this way of thinking, since we only have one wave in the area of detection, we will never be able to observe interferences, as can be seen here in Figure 7-13.

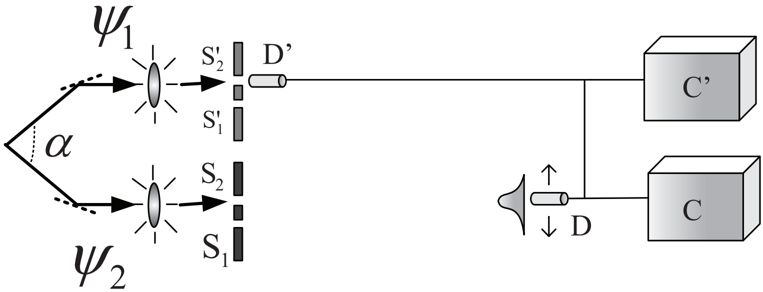

Figure 7-13: Predictions of orthodox quantum mechanics.

So, in the far field we observe a Gaussian distribution of readings, whether the lower slit S1 was uncovered, (Figure 7-13), or covered, (Figure 7-14).

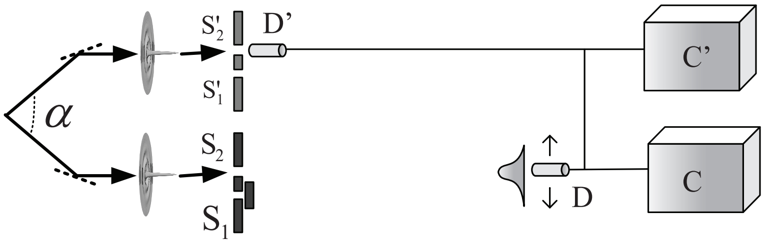

Figure 7-14: Predictions with the lower slit closed.

2. Predictions of nonlinear quantum physics.
In the latter case with the bottom slit closed, the predictions of either orthodox quantum mechanics or nonlinear quantum physics are precisely the same. This conclusion follows naturally from the simple fact that in the overlapping region we have only one wave, because we know that to be able to observe any interferences, we must have at least two waves overlapping simultaneously in the same region of space.
The case changes completely when the bottom slit is uncovered.
In this situation, given the great spatial correlation between the photons, we know that the acron of the bottom photon passes through slit S_2. However, we also know that in addition to the acron, the

photon also follows, accompanied by its extensive theta wave. So, although the acron passes through the upper slit its associated theta wave will pass simultaneously through the two slits.
In summary, and to finish with this, in the region of detection we'll have two theta waves, sharing an acron. These two waves will naturally interfere, giving rise to an interferential figure (Figure 7-15).

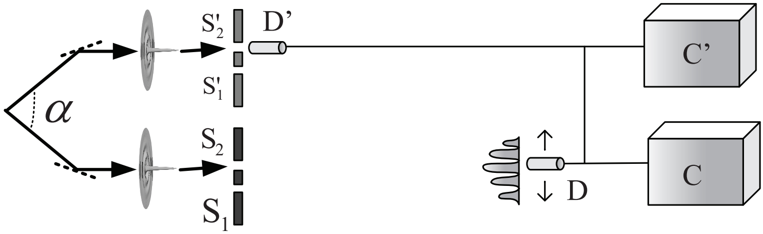

Figure 7-15: Predictions of nonlinear quantum physics.

So, the key question now is this: what were the results obtained with these experiments?

Argus, smiling, turned to Fabrus and said:

Thank you Fabrus, for your clear and succinct answer. In fact, you gave us a good overview of what can be expected from this interesting experience.
The answer to your question was given by the result of these sophisticated and interesting experiments done in 2012 in Germany by Heuer and colleagues. In these experiments, as expected, a clear interferential pattern was observed!
So, these experiments, together with others previously done in the 1990s by Mandel and his group, which have been extensively discussed in previous Dialogues, clearly show that the so-called quantum waves, empty waves, de Broglie waves, guiding waves, pilot waves, zero-point field waves, theta waves, subquantum waves … are, in fact, actual physical waves.
So, as I said earlier, the problem of knowing what the ontic nature of quantum waves is, i.e. if they are:
a) waves of probability, as intended by orthodox quantum mechanics or on the contrary,
b) waves endowed with objective physical reality
was satisfactorily resolved by the experience.

“So, I ask, why is it the opposite still taught in universities and written in books and scientific articles, that quantum waves are mere waves of probability and consequently devoid of any objective physical content?” exclaimed Lucius.

“Good question, Lucius! You’re absolutely right!” Argus continued:

> In fact, it’s verified that there is a great inertia in ideas. I will say even more: this inertia, this enormous reluctance to change opinions, to accept as something natural, the permanent becoming, is a human constant. Changing mindsets, changing the way we look at the world is very difficult. People are accustomed to a way of seeing things, a way of being in the world. Therefore, they develop an activity related to this way of thinking. In these circumstances, it’s perfectly natural that they don’t welcome a change, let alone a radical change. This is because, implicitly or even, in many cases, explicitly, they fear that their privileged statute, real or presumed, that they have acquired, may possibly be called into question.
>
> Let’s consider, for example, the situation of some very conservative university professors or researchers. On the university courses, they learn the orthodox quantum mechanics ‘by the book’. This is often taught in a perfectly uncritical way, as if it was a definite theory, a guaranteed truth, eternal and absolute. Imbued of this, or better said, formatted in this mental framework, they will painfully develop their entire scientific career. In these circumstances, they will, of course, resolutely defend those ideas that were instilled in them from their youth as if they were a religious dogma. These ideas, which in general and for their own convenience, never occurred to them to question. Ideas they accepted and more, defended, defend and will continue to defend as if they were irrevocable dogmas. In these circumstances, it’s not surprising to note that orthodox quantum mechanics, that is generally not well known, especially in its foundations, is assumed to be an absolute truth. Thus, it’s no wonder that when faced with situations that may possibly call into question these sacrosanct ideas, these researchers will react against them. Their way of proceeding is more or less as follows:
>
> At the first approach they try to ignore the new ideas.
>
> If such a tactic does not prove to be effective, at a second stage, as is the case with the experiments we’ve been discussing, they will try to show that the experimental results are perfectly compatible with the sacrosanct orthodox quantum mechanics, as has happened many

times throughout the history of science, and very similarly to what happened at the advent of modern science. The conservative researchers of the time, always on the side of the prevailing paradigm, always on the side of power, tried at all costs to save the Ptolemaic system against the nascent Copernican system. By adding epicycles to epicycles, it was then possible, as it is today, to adjust any astronomical data.
Indeed, by redefinition, adjustment and by an adequate manipulation of the basic assumptions of orthodox quantum mechanics, it's possible, by a very similar process to that used in the seventeenth century, to 'explain' a posteriori, post factum, all the new and unexpected experimental results. Of course, as in all circumstances, what really constitutes a difficult task to do is to anticipate a whole new experimental domain.
Unfortunately, this much-used process of pretending to explain divergent experimental observations by the subsequent addition of intricate physical and mathematical hypotheses in a perfectly ad hoc manner, and eventually other conceptual structures, piled up on each other, leads to final constructs more similar to 'pastichos' than to clear scientific explanations. This way of proceeding, as you'd imagine, goes against the scientific ideal of clarity and simplicity translated by the lex parsimoniae, i.e. Occam's razor.

After a pause, Iris said:

I think this unfortunate tactic of ignoring what doesn't suit us, to the detriment of scientific truth, in ignoring all that goes or can go against orthodox quantum mechanics, is presently being used a great deal specially in relation to the Heisenberg relations. Anyone who browses the Internet about recent imaging techniques and quantum lithography can see that in the concrete practice of our day-to-day lives we can go far beyond the limits imposed by the Heisenberg relations. It's incredible, then, that the absolute validity of the Heisenberg relations is still being affirmed!

"You're right, Iris!" Argus said.

Indeed, anyone who is aware of the modern techniques of quantum lithography and imaging knows that now it is perfectly possible to go well beyond the limits imposed by the Fourier diffraction transform translated by Heisenberg's relations.

In this burgeoning experimental domain of technological nature, something very interesting is occurring, at least in the field of sociology.
On the one hand, the experimenters and technicians don't care about the theoretical limits imposed by Heisenberg's relations. Therefore, as practical people as they are with their feet firmly on the ground, they'll progressively develop concrete physical systems, real devices, that would be impossible to manufacture if they took into account such limits, assumed as insurmountable.
On the other hand, we have the pure theorists who affirm, rightly so, that Heisenberg's sacrosanct relations form the core, the basis upon which the whole conceptual and formal structure of orthodox quantum mechanics rests. If they are called into question, the whole theory will collapse.
These theorists, using the well-known 'ostrich tactics', seek at all costs to ignore the experimental and technological reality which clearly shows that Heisenberg's relations are not adequate for describing all physical reality. This means there is a whole newly developed experimental domain that is beyond the reach of these relations.
I must add that this happens without any disrespect for the said relations. I want to emphasize once again, that Heisenberg's relations are, in fact, a great human achievement. However, they are ultimately mere human constructs, having been developed in a certain conceptual and experimental context. In this case, as we know, the conceptual context is closely related to the ontology of Fourier, introduced by that great physicist of the last century called Niels Bohr. Under these conditions, given the enormous technological development we have been witnessing, it's no surprise to see that it's possible in our day-to-day practice to go far beyond the limits imposed by Heisenberg's relations. Once again, nature revealed itself to be much richer and fruitful than previously thought. Again, we can conclude that any intention to limit the human capacity to predict and act is irrevocably doomed to failure.

After these words from Argus there was a silence, and as it was a little late we decided to end this discussion for today.

Eighth Journey

On a late September afternoon after the summer holidays we had our usual meeting around the new science at my house on the outskirts of Lisbon, north of the city. I was quite pleased with the arrangement because this would give me the opportunity to welcome and take good care of my dear friends. I was still busy with the typical bustle of these situations to ensure everything was in order, when Fabrus arrived accompanied by Argus to whom he had given a lift. Immediately I offered them refreshments and unsurprisingly we started talking about the holidays. We were happily drinking and snacking when Iris, Amadeus and Lucius arrived. After warm greetings, they immediately joined us for the drinks and snacks, talking about everything and nothing.

After this initial enthusiasm, we finally began to talk about science, mainly due to my efforts, with Argus starting it off:

> In our discussions about the new science, the nonlinear, relational and complex physics, which aims to propose another way of looking at natural phenomena, we begin by briefly referring to what our science was in essence until at the beginning of the twenty-first century. So, we emphasized its essentially atomistic and linear nature. We also discussed at length the essential difference between the traditional simplistic and linear process and the complex and nonlinear method. We said that this complex method is based on the genetic and organizational principle of eurhythmy, having mentioned some of its variants.
>
> On the other hand, we also had the opportunity to present, in its foundations, the new physics of the complex and nonlinear, referring to the fundamental concept of emergency. Likewise, we emphasized that the new nonlinear, relational and complex physics is closely related to the so-called non-exact sciences, such as the human and social sciences.
>
> We also discussed in some detail the starting points, the basic hypotheses, on which this new physics is based. From them it was shown how it was then possible to develop a whole complex and nonlinear theory of natural phenomena. This new physics, naturally,

promotes the unification of all branches of physics, from classical physics, to electromagnetism, relativity and quantum physics.

In order to highlight and illustrate the profound interrelationship of the new physics with the human sciences we used small examples, stories of metaphorical character whenever possible.

Following this presentation, we also highlighted this surprising effect, of an apparently strange nature, which emerged in the field of optics and was diffused mainly from quantum physics, known as the tunnelling effect. Recent experiments allow us to conclude that according to the theoretical predictions, the transition time between states in a situation of tunnelling is actually zero, or independent of the barrier length. If so, then the concepts of space and chronological time, considered as basic elements of our understanding until now, are not as fundamental as initially supposed after all.

Once developed in its general guidelines, the new physics of the complex and nonlinear, we turned to its applications. In these conditions, we began with the domain that gave rise to it, that is, nonlinear quantum physics.

Now, in today's journey we will talk about the application of this new physics to the gravitational and electrical phenomena, and to relativity. Of course, as we must understand, we will only address the essential aspects of these branches of new physics. Naturally and for historical reasons, we will begin with the gravitational phenomena.

We have already had the opportunity to talk about the conceptual bases on which the description of gravitational phenomena is based. Likewise, the concepts of force and mass have already been exhaustively debated. However, given its importance and subtlety it seems to us that it's never too much to emphasize the epistemic status of the classical concept of field, whether gravitational, electric or any other.

What we designate a gravitational field corresponds in general terms only to the description of the forces or accelerations that a gravitational particle experiences when placed in that field. That is, it corresponds to the description of the propensity of a complex gravitational particle to move in the real gravitational medium: the gravitational theta wave field.

"Argus, I don't quite see the difference between the classical gravitational field and the gravitational theta wave field", said Lucius.

"You're right! In fact, the question is somewhat intricate. Let's see if we can clarify it a bit further", said Argus.

> When we refer to a classical field, gravitational, electric or other, in last instance what we're talking about is about the distribution of forces, its direction and its absolute value, which a test element, that is a mass or a charge would experience if placed in that position. What gives rise to the appearance of these forces is completely ignored. In this context, what we are describing are the effects or the results of the interaction and not their causes.
>
> The example presented earlier of an illustrative metaphorical character, of the people at the Commerce Square in Lisbon, getting dressed or undressed was used to show that the concept of force was not fundamental but had only a pragmatic operational character, can now be used again with advantage to better clarify the problem. For that, let's just introduce a few minor modifications to this example.
>
> In this case, the observer, instead of varying the temperature uniformly across the square, will introduce changes. Let us then assume that the temperature hardly changes in the centre and decreases gradually until it reaches its minimum value on the periphery of the square. We will admit, for example, that at the beginning the temperature is constant throughout the area, having a value of twenty degrees Celsius. The temperature begins to vary so that its value continues to be twenty degrees in the centre of the square, while in the periphery it's minus ten degrees.
>
> In these conditions, the people located in the centre of the square practically don't experience temperature variations. For this reason, they don't have any need to put on their clothes since the ambient temperature remains practically constant in the area where they are.
>
> The situation is totally different if they are in the peripheral region of the square. There, as the temperature undergoes great variations, going from twenty above zero degrees to minus ten degrees, people will have to adapt and put their clothes on to ensure they don't get cold.
>
> This propensity, this tendency, in other words, this force, that attracts clothing to the people's bodies, will be all the greater the closer they are to the periphery of the square. At the centre of the square this tendency is almost null because in this region the temperature hardly changes. Under these conditions, it's possible to draw a graph of a vector field (Figure 8-1), which describes this propensity, i.e. these forces.

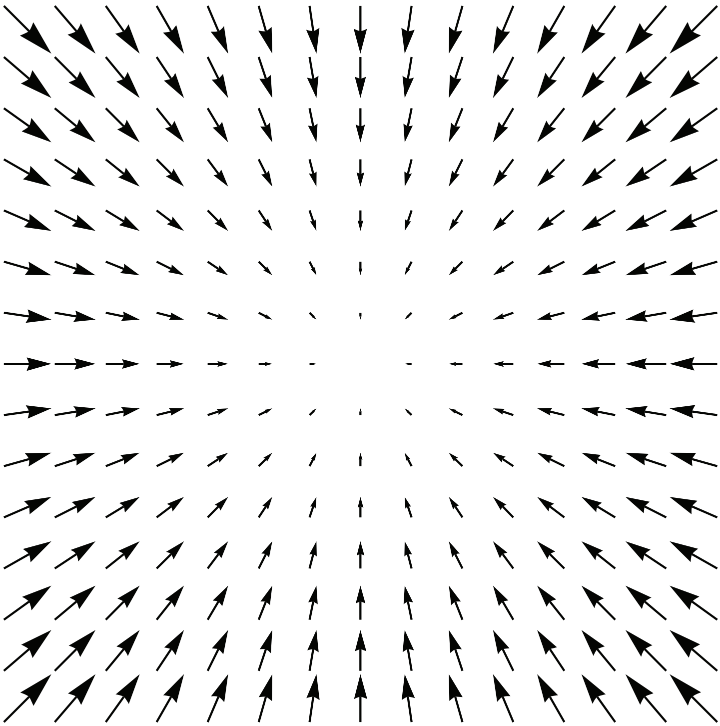

Figure 8.1: Graph of the force field.

In these conditions, as we have seen the force field – the gravitational field – translates only to an abstract pragmatic notion, quite useful but nonetheless devoid of any real physical content. Therefore, it corresponds only to the description of the propensity experienced by the complex particle to move when placed in the underlying real physical field: the real gravitational theta field. This field, endowed with physical reality, will then give rise to this propensity for the movement of the complex gravitational particle when reciprocally interacting.

So, it's very easy to understand why the gravitational, electromagnetic or any other field, doesn't constitute entities endowed with physical reality. This is because they don't correspond to the description of any real physical entity. In fact, the gravitational field, or any other, describes only a particular behaviour experienced by a complex particle. In the case in question, it translates only the propensity that the particle experiences to move when placed, under certain conditions, in a real physical medium, i.e. in a theta field. It's consequently related with the propensity for the gravitational acron to move, that is, with the average acceleration which it's subject to when immersed in the theta field endowed with real physical existence. However, if we opt for another possible property, another kind of interaction between the complex particle and the real physical medium, we must naturally expect a different kind of behaviour.

Once again, I stress that since the classical gravitational field corresponds only to a description of the forces or accelerations that a complex gravitational particle experiences when placed in a real physical medium – the theta wave field – the conclusion to be drawn is that classical fields, gravitational, electromagnetic or others, are devoid of any real physical ontological statute. In fact, they are merely abstract operational concepts and therefore devoid of any real physical content contrary to the theta wave field.

We know that the attractive force that a complex particle is subject to when placed in a classical gravitational field, is proportional to the inverse of the square of the distance

$$f \propto \frac{1}{r^2}$$

This expression is improperly designated the law of universal gravitation. In fact, this expression translates only the propensity for complex gravitational particles to move in a real theta field with an intensity roughly translated by the same expression. It should be noted that this expression, of the force being proportional to the inverse of the square of the distance, only appears to be adequate within certain limits. For very small or very large distances, as we saw in the Fifth Journey, such an expression is inadequate to describe the real physical situation.

In these conditions, the so-called *black holes*, the said black matter and black energy as we have previously mentioned must be understood as mere theoretical constructs devoid of any objective physical reality. This conclusion follows, of course, from the fact that these concepts were introduced assuming the absolute validity of the said law of universal gravitation, which was supposed to be valid regardless of the scale being used. Thus, this law assumed to be valid at very small distances, even at the limit when that distance would be zero. In this case, it would give rise to the said black holes. For very large or even quasi-infinite distances, in order to maintain the distribution of matter observed in space, this would imply the need to introduce dark matter and dark energy in order to maintain the universal validity of such law.

On the other hand, I must also remember that even for a real physical medium, a theta wave field with a density varying in the same way, the reciprocal interaction with the complex particle still depends on the relative value of the theta waves. Thus, the very same entity, the same complex particle, may interact with the real physical medium so that its propensity to move in it is roughly described by the said law of universal attraction or may, eventually, completely ignore the physical medium in which it's found to be. Under these conditions, the same particle can be assigned with the statute of having or not having mass. Everything depends, as we've seen previously, on the relative value of the respective theta wave intensities.

At this point Lucius asked, "I wonder if no one has already been concerned with what lies behind the law of universal gravitation since the beginning of the scientific revolution in the seventeenth-century?"

We must understand that the laws describing how gravitational forces act were known at least since Newton's works. However, I think the problem now is to know the 'why'. What is the reason, what is behind it, what gives rise to these gravitational forces.

To highlight this difference, between the 'how' it works and the 'why', the reason why it works, I think that, following the example used more than once by Argus, a metaphor will be useful to clarify the situation.

Suppose a person learns to drive a car. In these conditions the person learns that by inserting the key into the proper slot and turning it slightly clockwise, the engine starts working. Turning the key backwards causes the engine to stop working. They learn to use the gearbox, the brakes, etc. That is, they learn a whole set of recipes that properly used will allow them to drive the car well. If they are satisfied with this set of recipes, what will happen to the vast majority of people? Everything will be okay!

Suppose now that for whatever reason the car breaks down and stops working. Or, let's admit, a less probable hypothesis, that the person intends to enhance the behaviour of the car.

The set of recipes they have learned, ‘how’ to operate the car, are now not enough to face the new situation. To repair or even improve the car, the person needs to know the ‘why’ – what’s behind the recipes that have been learned to drive the car.
I think that this question, of knowing what lies behind, what gives rise to gravitational forces, to which the new physics of the complex and nonlinear, the eurhythmic physics, responds in a way that is comprehensible to anyone with an open mind and common sense, should have been placed before!

There was a pause, which was interrupted by Fabrus:

Indeed, you are quite right Lucius! The fundamental question you have formulated, of knowing the origin of the gravitational forces, was actually placed by Kepler at the very beginning of the scientific revolution. To explain the gravitational force Kepler will assume that the Sun emits some kind of radiation, somewhat analogous to the emission of light by a quasi-punctual source. In these conditions, knowing that the intensity of light decreases with the inverse of the square of the distance and by simple analogy, he was nearly able to derive an action, a gravitational force, whose variation also decreases with the inverse of the square of the distance.
This problem of the origin of gravitational forces was later taken up by Descartes, who represents the planets by vortices or swirls of a celestial fluid. However, it was Huygens the first to propose a kind of mechanism for gravitation supported in mathematical calculations. To this name we should add Nicolas Fatio, a friend of Newton, who in 1690, proposed a corpuscular theory of radiation to the Royal Society of London. However, it was Georges-Louis Le Sage (1724–1803) who proposed a much more developed theory to attempt to explain gravity.
Le Sage tried to explain the origin of gravitational forces in terms of their *ultramundane* corpuscles that would fill the entire space. Thus, these subtle corpuscles would strike the gravitational bodies giving rise to a repulsive force.

Under these conditions, an isolated body would not move due to the conjugate action of opposing and symmetrical forces which would neutralize each other as shown here (Figure 8-2)

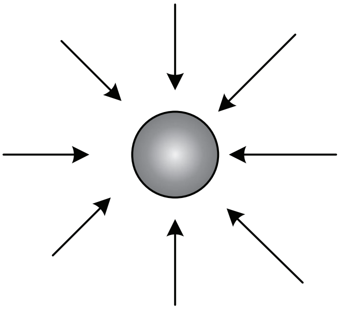

Figure 8-2: An isolated body does not move due to the equal and opposite action of the repulsive forces.

However, the case changes when we have two or more bodies. In this situation, each of the bodies acts as a barrier, a protective shield to each other, so that the overall effect causes the bodies to approach each other, as shown in this drawing (Figure 8-3):

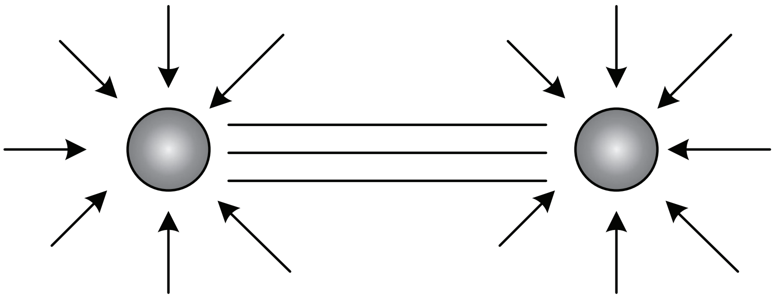

Figure 8-3: Two bodies approach due to the mutual shield action.

It's possible to show that this global force acts according to Newton's law of gravitation varying with the inverse of the square of the distance.

It must be said that this theory of Le Sage met a certain degree of success until the end of the nineteenth century. However, at that time it was shown that using statistical physics this theory had major problems related to the principle of conservation of energy. In the second half of the twentieth century several attempts were made to recover Le Sage's theory using either corpuscles or waves.

However, all these attempts had problems with the principle of conservation of energy, even though some authors have imagined truly ingenious processes to overcome this problem.

In fact, none of these gravitational theories, based on a crude linear force acting on the gravitational bodies, and consequently all of them based on the universal validity of the action–reaction principle, worked well. To make matters even worse, all these theories, mostly of an ad hoc nature, based on the traditional Cartesian linear method, suffered from the absence of a unitary conceptual framework for the explanation of natural phenomena.

In reality, in order to explain and make the nature of gravitational phenomena easy and intuitively perceptible, it becomes necessary to reject the simplistic linear Cartesian method and assume a physics of the complex processes, a eurhythmic physics, where nonlinearity, onto-interdependence between physical systems is assumed right from the beginning.

At this point there was a pause, and Argus took the opportunity to speak again. "After this beautiful introduction to the history of the theories of gravitation given by Fabrus, I think that although the subject has already been discussed in its foundations in the Fifth Journey, a few words must be said about the explanation of the origin of the gravitational forces given by eurhythmic physics."

In this case, a complex gravitational particle, assumed to be isolated in space due to the symmetry of the intensity of its theta wave, will not move because the average speed of the acron will be null. (Figure 8-4)

Figure 8-4: An isolated complex particle will not move due to the symmetry of the theta wave.

When we have two or more complex particles, the situation is quite different. Under these conditions, the symmetry of the intensity of the theta field is broken, and the particles, according to the principle of eurhythmy, will tend to get closer. The following drawing, (Figure 8-5) seeks to illustrate, in three dimensions, this situation for three successive moments of time.

Figure 8-5: Attraction in three successive moments.

As can be seen, as the theta waves approach each other, the acra will move to the regions of the global wave with higher intensity due to the eurhythmic propensity. This process proceeds until eventually the two waves coalesce into a single wave.

Taking a break for a drink, Argus paused before continuing:

I think we've talked enough about classical gravitational phenomena for now. Therefore, we will now talk about electromagnetic phenomena: The history of electricity and magnetism is a striking example of the development of a physical theory.
In fact, from meticulous data resulting from experiments on electricity and magnetism, obtained at the expense of hard and

delicate labour, it was progressively possible to elaborate a general theory which, within certain limits, describes quite well the collective electrical and magnetic phenomena.

The great majority of these electrical and magnetic phenomena, discovered at the cost of hard and persistent experiments, were integrated into a group of four equations, later published in a beautiful work by James Clerk Maxwell in 1873.

We must, however, recognize that Maxwell's electromagnetic theory, such as Newton's theory of gravitation, is, of course, a good theory for his scale of description of reality. However, now, nearly a century and a half later, the times are propitious for us to take a step forward and look at electromagnetic phenomena in the more general conceptual framework of eurhythmic physics. In order to carry out this task, it's necessary, from the first instant, to free ourselves from the basic hypotheses rooted in the simplistic linear Cartesian method. This new global process of looking at nature has the advantage of allowing us to have a better understanding of the actual physical processes behind the observed classical electromagnetic phenomena, but it will also help us to predict and develop a whole new universe of experimental possibilities and technological developments.

On the other hand, as I'm sure you understand, we are only interested in deriving the basic empirical formulas of electromagnetism from the fundamental principles of the new physics. Once the fundamental basic formulas of electromagnetism are established, it's possible to derive Maxwell's equations that open the doors to the whole theory, as you can see in any textbook on electromagnetism.

The first empirical formula of electromagnetism was discovered by Coulomb in 1784. For the static case, where the average speed of the electronic acron is null, Coulomb, inspired by Newton's work, managed to obtain the expected formula that describes, within a certain approximation, the interaction between electric charges. Of course, this formula, analogous to that of Newton, tells us that charges of the same sign repel each other and that of opposite signs attract each other according to the inverse of the square of the distance between them.

To explain the observed electric force, attractive or repulsive, we just have to remember that when two complex particles are in reciprocal interaction two extreme situations can occur:

1. The two waves, when overlapping due to a self-organizing process will enter into phase. In this case, due to the increase in the intensity

of the global theta wave, the particles – the electric charges – will attract, as can be seen in this drawing (Figure 8-6):

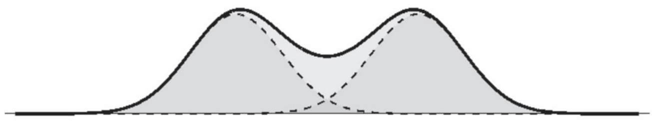

Figure 8-6: Attraction. Final intensity in bold. Intensity of each electronic theta wave in dotted lines.

2. Overlapping waves enter in phase opposition. Under these conditions, a gap of intensity will be created between the two waves (Figure 8-7)

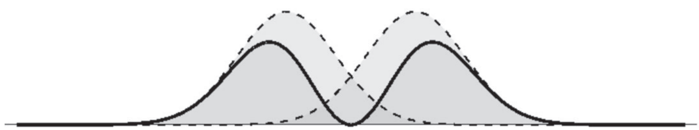

Figure 8.7: Repulsion. Final intensity in bold. Intensity of each electronic theta wave as dotted line.

So, the electronic acra will avoid this central region of lower relative intensity and will therefore have a propensity to move away, that is, to repel.

It's possible to show, within certain limits, that is to say, neither for very small distances nor very great distances, that this tendency for the complex electronic particles to approach can be described by Coulomb's formula varying with the inverse of the square of the distance. However, as in the case of gravitational particles, assuming the adequacy of the simplistic linear Cartesian approximation to this scale of description of reality, each electronic acron will only be, on average, sensitive to the theta field of the other particle. This conclusion results from the fact that fields at this level of approximation can be considered as independent. In these conditions, and as we have already mentioned, this field, for distances neither too small nor too large, has an approximate variation of $1/r^2$. Thus, the electric field can be expressed as proportional to the inverse of the square of the distance. Since the electric force is proportional to the field, it follows that the force will also vary in the same way.

Once again Argus paused, then continued:

We know from eurhythmic physics that every physical particle has a rather complex structure, formed by an extensive but finite wave, its theta wave and a complex structure very well located and highly energetic, the acron. The particle we are interested in now – the electronic particle, which we call the electron – will have similar generic attributes. However, we must be aware that each specific particle, in addition to the general attributes, has its own characteristics. These characteristics result from the particular way in which this particle interacts with the medium in which it's found. In order to be able to infer these properties resulting from the reciprocal interaction particle–medium, it may be useful to study some phenomena related to electricity and magnetism.
It's verified that in the empirical study of these phenomena the concrete nature of the physical medium plays an extremely important role. So much so that the observed average properties, ultimately resulting from a multiplicity of collective interactions, can be very complex, thus giving rise to very particular emergent behaviours. These behaviours, resulting from this multiplicity of extremely complex interactions, in practice can only be inferred from actual concrete experiences.
In electrical phenomenology, the notion of a conductor, a simple copper wire, for example, plays a highly relevant role. In a first approximation this conductor may be understood as a kind of cavity where the electronic acron can be displaced with an average speed other than zero.
This average speed is only different from zero when, what is commonly called a potential difference, is being applied to the conductor. This potential difference corresponds, or rather, results from the fact that the overall average theta field density is not constant. However, this average speed – generally quite small – is in the most common cases, relatively independent of the potential difference. This observed fact results, as we have previously seen in other journeys, from the interaction with the medium leading to the maximum possible speed compatible with the conditions of the particle–medium reciprocal interaction, called saturation speed.

As we have seen, in each physical medium and in each material, depending on the concrete physical conditions such as the organization of its constituent elements, temperature and others, there is a maximum possible speed – even in the case where the gradient of the global theta field intensity is very high.

Naturally, even free electrons in different media, namely in the said vacuum – a physical region characterized by a small matter density – may have different behaviours. In this case, its speed may increase until it will eventually stabilize, i.e. be saturated. However, in areas far from saturation, the average speed of the electron can continue to increase as a function of the operational concept of the potential difference.

Another observation taken from practice is that outside ordinary conductors, the probability of finding an electron is very small. From this empirical observation it will be reasonable to infer that the relative global theta field intensity must be very small outside the conductor.

Under these conditions, a schematic representation of the transverse distribution of the theta wave field density may be as follows (Figure 8-8).

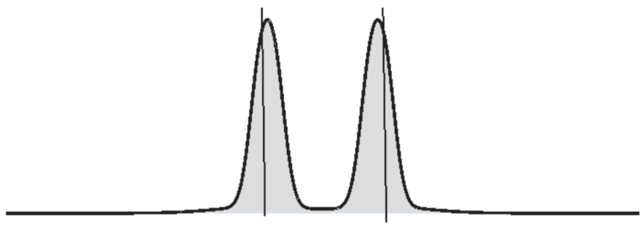

Figure 8.8: Schematic representation of the cross section of the theta field intensity in a conductor.

From this graph we can infer that the electronic acra tend to move preferably on the surface of the conductor where the field has a significative density.

On the other hand, we know that the intensity of the electric current, *I*, is proportional to the average speed of the electronic acra.

$$I \propto \overline{v}\,, ou\; I = \rho\overline{v}$$

In a conductor, under common circumstances and for a given potential difference, the speed of the electronic acra is constant. This fact is generally described by saying that the electric current I is constant. On the other hand, the so-called Ohm's law, which describes very reasonably the average of the empirical observations, tells us that the electric current is proportional to the potential, V

$$I \propto V, \text{ or } V = RI$$

This basic relationship of electronics was experimentally discovered by Ohm in 1826. The proportionality constant between the potential difference and the current, R, designated by resistance, depends on the nature of the conductor and other physical conditions such as temperature. We must also take into account that this so-called Ohm's law corresponds only to a simplistic description of the behaviour of real phenomena, and yet it's only suitable for certain conductors and for relatively low currents. For very high currents or for certain materials such as superconductors this law is no longer adequate to describe what happens. In other words, the said Ohm's law works well or it's relatively good to describe the observed phenomena when the simplistic and linear approximation is adequate.

From this relation, we can conclude that as the potential difference increases, the same will happen with the average speed of the electronic acra. This means that for each potential difference the material medium of the conductor will adjust itself until a maximum possible speed is established – i.e. the saturation speed – for the electronic acra, which is a linear function of the potential difference. We should not forget that electrical potential such as gravitational potential corresponds only to an operational abstract and physically non-existent concept, yet is quite useful to describe the behaviour of the electronic acron when plunged into a real theta wave field.

After these words from Argus there was a silence, which we all used to go for a snack and a drink. After this break, Argus restarted the discussion.

I think now is the time to talk about this strange phenomenon known from the remotest antiquity known as magnetism.

By the way, it should be remembered that the great Portuguese maritime discoveries were made with the aid of a compass, which was then called a navigation needle, used systematically in the caravels. However, the theory of the ‘natural magnet’ was later developed by William Gilbert who presented his ideas in his important work *De Magnete,* published in 1600.

Although the electrical and magnetic phenomena were initially regarded as independent, certain early investigators suspected that they should have something in common. So, after the discovery by Volta in 1800 of a device capable of producing electric current, Volta’s pile, numerous experiments were made all over Europe to try to experimentally show this electricity–magnetism interrelationship. It was in the winter of 1819–1820 when Hans Christian Ørsted was able to show that the electric current flowing along a conductor was capable of causing an observable action on a magnet.

Shortly afterwards, André-Marie Ampère, in 1820, experimentally verified that two conductors through which electric current flowed attracted if the current had the same direction and repelled if it had opposite directions.

From these empirically observed facts, Ampère concluded and rightly so, that after all magnetism was an effect resulting from the electric current.

“So how can you explain these phenomena in the eurhythmic physics conceptual framework?” asked Lucius.

“Well, that’s exactly what I was going to tell you.” Argus continued:

As we’ve already seen, the conductive wires, in our view, are assumed as cavities, regions where the electronic acra move. In turn, an electronic acra when moving will create an electric current jet, as can be seen, approximately, in this figure:

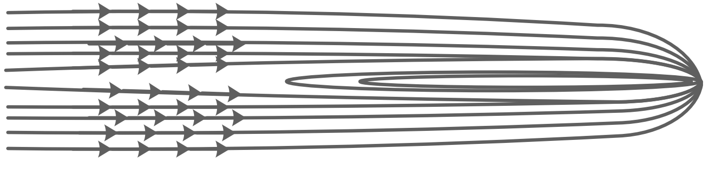

Figure 8-9: The movement of the electronic acron creates a current jet in the subquantum medium.

In a conductor, due to the collective motion of the electronic acra, we will have a current jet whose theta field intensity extends beyond the immediate vicinity of the conductor, thus creating a current fluid. When we have two isolated conductors, in a nearby neighbourhood, these two current fields will overlap, as shown in Figure 8-10.

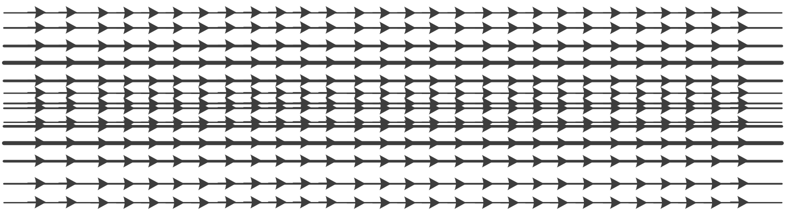

Figure 8-10: Two current jets with the same direction overlapping.

Amadeus, at this point, asked "Argus, I think I understand what you designate as an insulated conductor. However, I would like you, if possible, to clarify this concept a little better."

"Certainly! You're quite right, Amadeus" answered Argus.

Anyone less familiar with the electrical jargon may become confused when we talk about two insulated conductors that are together at the same time.
We say a conductor, for example a copper wire, is insulated when it has an insulating element around it. This insulation element was initially constituted by a coating of an insulating film. Currently, this insulating element is generally made of a special varnish.
If two non-insulated wires are brought into contact they become, for all practical purposes, not two individual conductors but one single conductor. For two or more conductors to keep their individuality it's required that they're coated with an insulating layer.

"Thank you, Argus! It's exactly as I thought", said Amadeus.

"Returning to our scheme", said Argus as he pointed at Figure 8-10, "if we consider the cross section of these two currents with the same direction, we will have the following distribution somewhat analogous to the one we have seen already in the case of the attraction between two particles, Figure 8-11."

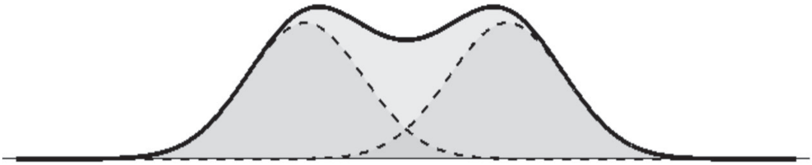

Figure 8-11: Cross section of two jets of current with the same direction.

As we can see, the intensity of the theta field is higher in the centre. As a result, the two current jets naturally tend to coalesce. In other words, the jets, the wires, will feel like an attractive force that brings them closer to each other. It's possible to show that within certain limits, i.e. neither for very small nor very large distances, can this force be described as varying with the inverse of the square of the distance separating the two conductors.

Let's now see the opposite case, when the current flowing in the conductors has opposite directions, as can be seen in Figure 8-12:

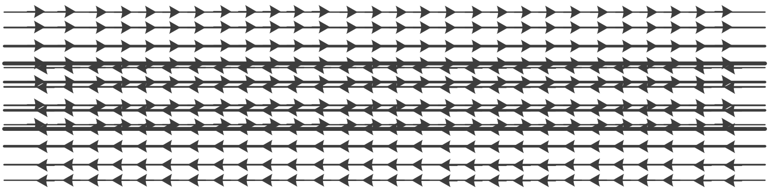

Figure 8-12: Two current jets with opposite directions.

In these conditions, as the direction of the currents is opposite, there will be an antagonistic action between the jets, forcing their average intensity to decrease in the overlapping region. This situation is indicated in Figure 8-13, that shows us its cross section.

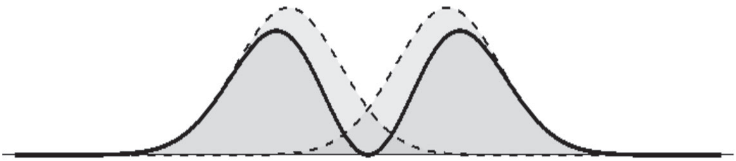

Figure 8-13: Cross section of two jets of current with opposite directions.

Once the average intensity of the theta field decreases in the central region, there will be a propensity for them to be further away from each other. This gap can be described by saying that there is a repulsive force that causes the conductors to move away from each other. Here again it's possible to show that within certain limits, this repulsive force varies with the inverse of the square of the distance between them.

From this we can conclude that magnets, whether natural, artificial or a winding of wires called a solenoid, all behave in a very similar manner, as indicated in Figure 8-14.

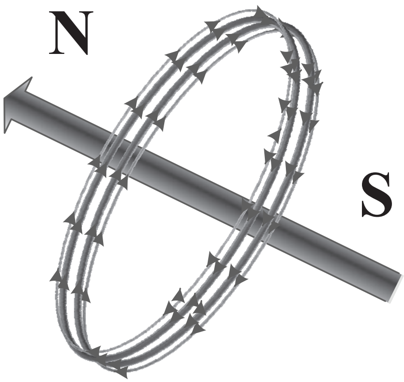

Figure 8-14: Magnet principle.

From this figure it can be seen that the poles of the magnet, north or south, result from this directionality imposed by the direction of movement of the electrons. When the two electron current jets are directed north–south there is attraction as shown in Figure 8-15.

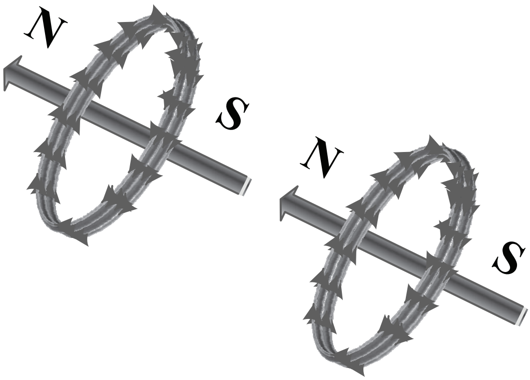

Figure 8-15: Magnetic attraction.

In this case the current jets of the theta field, that is, the electric currents have the same direction leading, naturally, to attraction. If they are oriented south–south or north–north the direction of the current jets will be opposite therefore leading to the destruction of the field leading in turn to repulsion, as seen in Figure 8-16.

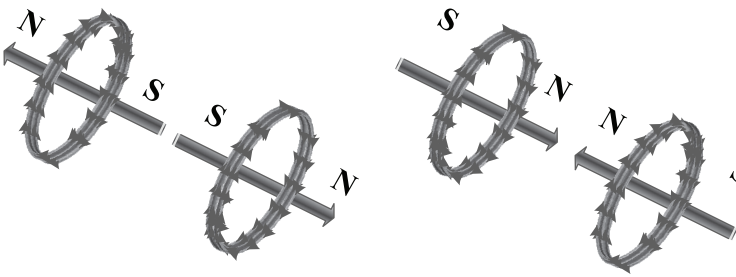

Figure 8-16: Magnetic repulsion.

"I think I've now realized the deep interconnection between the electrical and magnetic phenomena, hence the reason they're called electromagnetic phenomena, and more so the reason why there are poles in magnets! Ultimately, what we call magnetic force results from the combined effect of the collective motion of the electrons" said Amadeus, visibly satisfied.

Argus then said:

Now it's time to talk about a very important discovery made by Faraday in 1831. Without this discovery, naturally associated with earlier discoveries in the field of electromagnetism, all our modern technology would be unthinkable. It's the discovery of induction! Faraday connected an insulated conductor to a Volta's pile and placed another closed insulated conductor in its vicinity, as shown in Figure 8-17.

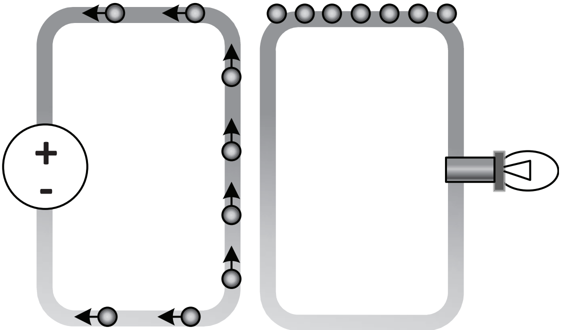

Figure 8-17: There's an electric current in the primary circuit.

So, in the conductor, in the primary circuit connected to the Volta battery, will flow a constant electric current.
Now, let's look at what happens in the secondary circuit, part of which is placed in the immediate vicinity of the primary circuit.
What can be observed, regardless of how many times the experience is repeated, is the absence of any phenomenon. This negative result can be observed if we connect a sensor to the secondary circuit, for example an electric lamp. This lamp will always stay off.
After many experiments, Faraday decided to reverse the direction of the electric current, that is, the direction of connection to the Volta pile, and more, he repeated this process of inversion systematically. To his surprise, he saw that the electric sensor, the lamp in our case, was manifesting itself, that is to say, it would go on and off

concomitantly, at the pace of the process of inverting the direction of the current (Figure 8-18).

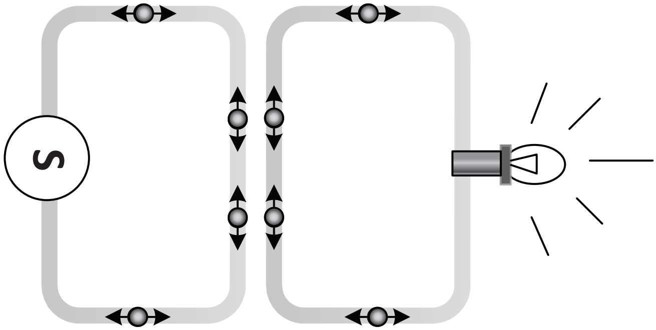

Figure 8-18: The primary circuit is turned on and off alternately.
A current is induced in the secondary circuit.

This induced action from the primary on the secondary circuit, was all the more the greater the speed of inversion of the current direction.

The conclusion to be drawn from these experiments is that a stationary current does not induce any observable effect in the secondary circuit. In order to observe any effect on the secondary circuit, the current in the primary circuit must be subject to a variation in time.

It's precisely this effect, referred to as electromagnetic induction, that all the electric current transformers that are so generalized today are based on.

I'm pleased to say that this phenomenon, which is so important and fundamental in electromagnetism, has an extremely simple explanation, even intuitive I'd say, when seen in the light of eurhythmic physics.

So, let's look at the significance of Faraday's fundamental experiences in the light of the new physics. These phenomena of induction are, as we shall see, the final result of a whole set of complex collective processes that can be simply described in the conceptual framework of eurhythmic physics. It must be borne in mind that the electronic acra move preferentially, and on average, to the regions where the density of the theta field is bigger, that is – in classical language – for regions of lower potential.

Still, we must be aware that in traditional electrical language there occurs a kind of linguistic semantic inversion. This linguist inversion happens because of the analogy with the waterfall, in which the water flows from the higher places to lower ones that is, from points of less gravitic field to higher gravitic regions, near the Earth's centre. The higher potential, the positive pole of an electric generator, corresponds to the regions where the real physical field is of lower intensity, while the negative pole corresponds to the higher field intensity.

Let's start by first talking about the primary circuit. This includes a direct current generator, the Volta pile. In order to have an average movement of electronic acra in the primary circuit connected to the generator, it becomes necessary to establish a potential difference in it, that is, a theta field of increasing intensity in the direction of this movement. On the other hand, the source, the Volta pile, is designed in such a way that it is permanently injecting electronic acra at the source, the zone of least relative field intensity. These electrons injected at the source, according to the principle of eurhythmy, will move to the region where the theta field is more intense. Once in this zone they are removed by the generator, so then the cycle, the movement of the electrons, repeats itself.

Now let's see what happens when the secondary circuit is placed in the immediate vicinity of the primary. In this case, the increasing intensity of the theta field of the primary circuit will overlap the field, which is on average, constant, of the secondary circuit. From the combination of these two fields, one of constant intensity and one of increasing intensity, a global theta field of increasing intensity will emerge. That is to say, in the secondary circuit a potential difference will then arise. Under these conditions, the electronic acra will, according to the principle of eurhythmy, move to this zone of field, of higher intensity of the theta field.

If no other action is performed there, the electronic acra will remain in this region of greater field intensity. Therefore, as time goes by in the secondary, except for the initial change everything will remain the same. In these conditions of interaction, the detector will not register any average movement, that is, any current of electrons (Figure 8-19).

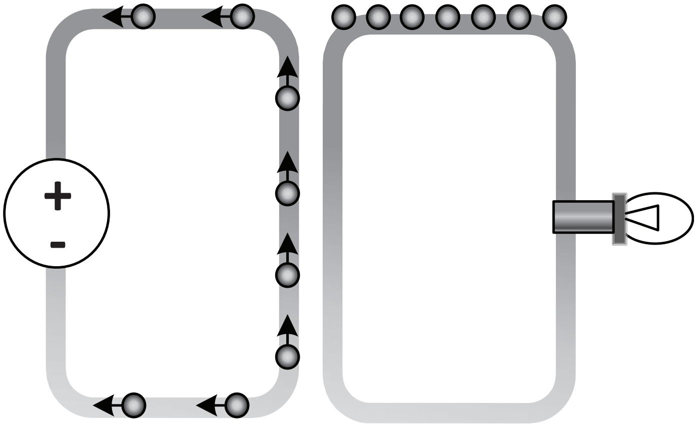

Figure 8-19: The primary circuit connected to the source. An induced potential difference arises in the secondary. The free electrons of the secondary conductor move to this region and remain there.

Now, if we reverse the connection at the source (Figure 8-20), the field reversal will naturally occur.

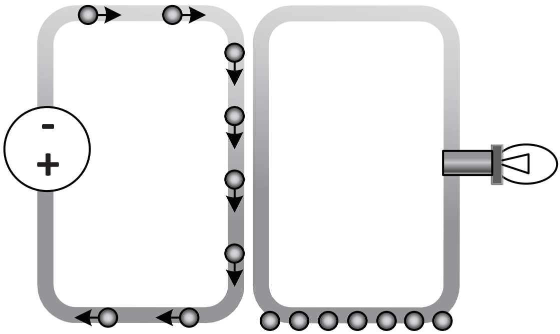

Figure 8-20: Reversing of the current direction in the primary. The potential difference induced in the secondary will be reversed and the free electrons of the secondary conductor will move to this region.

Under these conditions, the acra of the secondary will move in the opposite direction to the region of greater field intensity. During this time the detector, the lamp, will light up.
If we reverse the direction of the current in the primary again, a new inversion will occur in the secondary, and in this case the lamp, which serves as a detector, will light for a few moments. Continuing to reverse the current direction in the primary in a regular way, an alternating current will be induced in the secondary and so the electric lamp will turn on and off at this rate.

"By the way, I wanted to point out that there is another process of causing the movement of electrons in the secondary", added Fabrus:

We know that for there to be a movement of electrons, or rather an average movement of the electronic acra, it becomes necessary to have a potential difference, that is, a theta field whose intensity varies in time. Therefore, another way of inducing current in a circuit would be to approximate it or move it away from a theta field of variable intensity, as shown in Figure 8-21:

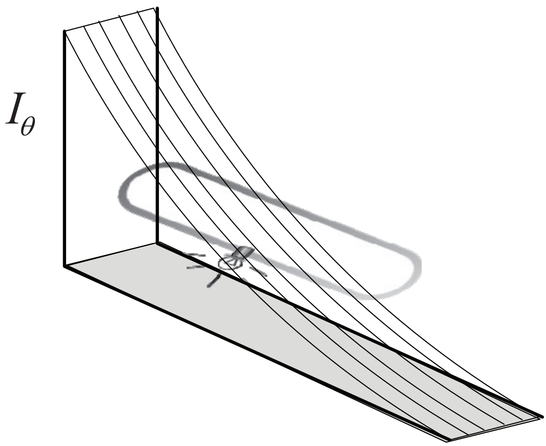

Figure 8-21: The secondary circuit approaches a theta field of variable intensity.

In this case, as the intensity of the theta field seen by the secondary will vary in time, likewise the propensity, the force that the electrons will be subject to, will also vary, thus giving rise to the appearance of an electric current.

After these words from Fabrus there was another break, which once again was enjoyed with a drink and some snacks. Argus eventually restarted the discussion:

We have been 207nalysing, very briefly, the classical electromagnetic phenomena seen in the light of eurhythmic physics. I think that now, to conclude, we can also say a few words about relativity and how it fits perfectly into the new physics.
At the end of the nineteenth century, as we know, we witnessed a prodigious experimental and technological development, especially when it comes to the determination of very small time intervals. This remarkable increase in accuracy in the measurement of time intervals will, in turn, allow to evaluate small possible variations in the speed of light. From the results of some of these experiments it was concluded that in the most common situations, the speed of light was independent of the speed of the emitting source.
In the conceptual framework of eurhythmic physics, this experimental result doesn't come as a surprise. In reality, what must be surprising is the realization that the simplistic linear Cartesian velocity-addition rule is adequate to describe so many experimental situations.
So, when we observe the photon, this basic ingredient of light, with the 'eyes' of the new physics, we find that it's an extremely complex entity in permanent reciprocal interaction with the medium. Under these conditions, the average speed of the photonic acron will depend, of course, on its reciprocal interaction with the physical medium. From this interaction it follows, of course, that the average speed of a photon in a given physical medium tends to its maximum possible value, which is, as we know, the saturation speed. This speed, in turn, is independent of the speed of the emitting source.
However, if we want to interpret these experimental results in the conceptual framework of the simplistic, linear Cartesian approach, we are in deep trouble. To accommodate these observable experimental facts, it becomes necessary to postulate, directly or indirectly, the invariance of the speed of light. That is to say, the facts observed over and over again showing that the traditional law of velocity addition is not adequate to describe the experimental results obtained in the interferometric experiments, instead of being

understood as a manifestation of the nonlinear, complex and relational relationship of the physical reality, will be concealed under the mysterious postulate of the invariance of the speed of light.
So, this natural physical entity we call light has a completely different statute from all the other entities, namely, that of having been assigned with the highest possible speed that any physical entity can achieve. It’s not only stated that the speed of light is the maximum possible, it’s even guaranteed that it’s always constant and independent of its reciprocal interaction source with the medium in which it’s found.
As in the case of classical gravitation and electromagnetism, in these Dialogues we shall limit ourselves only to the fundamental aspects of relativity.
Once we accept that in certain conditions of interaction of the photon with the surrounding physical medium, the average speed of the photon remains constant regardless of the speed of the emitting source or the measuring apparatus, we will be logically driven to the Lorentz transformation and then we will be in the domain of relativity.
Once the invariance of the velocity of light, i.e. the average speed of the photonic acron, is assumed explicitly or implicitly, and admitting the homogeneity of the real physical theta field, what in relativistic jargon is called space, we are then in possession of the basic ingredients upon which we can build relativity as we can see in any relativity manual.
Of course, as we have already mentioned, both in relativity and classical physics, the abstract and physically non-existent concept of referential, infinite in space and time, plays a fundamental role. On the other hand, we also know that the concept of referential, appropriate to a certain scale of description of reality, needs to be used with great cautiousness and therefore not subject to abusive extrapolations. This, for the obvious reason that infinite physical systems exist only in our imagination.

Argus paused, then continued:

A truer physics, more adequate and closer to reality must necessarily be finite!
In these conditions, if we want to go further in understanding natural processes, we will have to go beyond the concept of absolute and

infinite referential in space and time, devoid of any real physical content.

We cannot, from our local and finite measures upon which our science was built, extrapolate to the behaviour of the whole universe. If we do so, we are in danger of falling into great contradictions with the experimental evidence which will be discovered sooner or later. This position, as we have said many times already, is much more like a religious belief than a true scientific attitude. We must always bear in mind our natural limitations, translated in an extremely interesting way by the story we told earlier about the village of the blind people. Whenever we naively believe that we have access to the absolute, the ultimate, the definitive laws of nature, valid everywhere and forever, the future advances in science and technology will always show how naïve these pretensions were.

The speed of light, or rather, the average speed of the luminous acra, can be understood, as we have seen, in a very similar way to other complex physical entities. Although this subject has already been discussed, we will once again mention it briefly in this specific context, for the sake of a better understanding.

Let us assume, as in the vast majority of situations, that the photonic acron enters a relatively extensive theta field. This field, to a certain extent and within a crude approximation, can be described as a uniform and homogeneous referential. In this case, as we know, two extreme situations can occur:

8. The relative intensity of the mother theta wave of the photon entering the extensive but finite field, assumed homogeneous, is much smaller than that of the field (Figure 8-22).

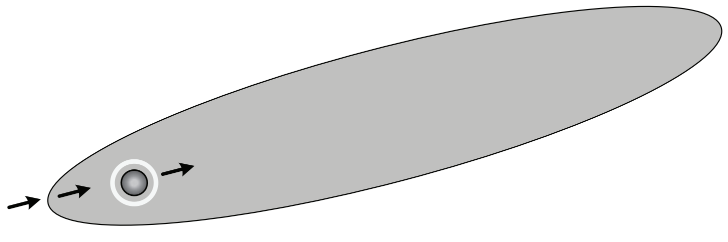

Figure 8-22: The photon enters a medium of much higher relative intensity.

In this case, the acron of the photon is for all practical purposes subject to the theta field of the physical medium in which it is immersed. Under these conditions, things happen as if the photon ignores its entry speed and starts travelling in the medium with the maximum possible speed, the saturation speed. This speed, for the same conditions of reciprocal interaction with the medium, will remain constant regardless of the relative speed of the source and the medium in which the measurement is made. In this particular case of interaction, in the laboratory at the place where we measure the speed of light, represented by C' in Figure 8.23, the measured speed will always be the same, whether it approaches the emitting source or distances itself from it.

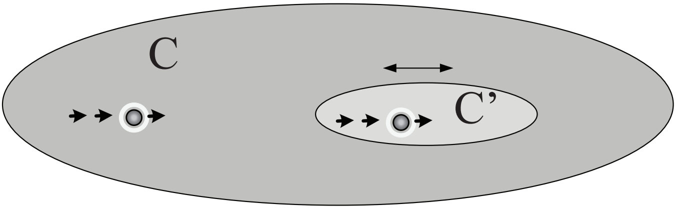

Figure 8.23: The speed measured at C' will always be the same, whether it approaches or distances the light emitting source.

This average speed with which the photonic acron moves, in the most common physical media is c = 300,000 km/s. In other physical media such as glass, this saturation speed decreases and we have, $v < c$.

Whenever these requirements, assumed implicitly or explicitly, are adequate for describing the observed physical phenomena then we can say that we are in the domain of application of relativity.

"If I understood correctly what you said, Argus", said Iris, "relativity theory is a good theory, that is, quite adequate to describe what is observed, and even for the prediction of new situations whenever we find ourselves in this extreme situation where its own theta wave, the mother-wave, has a negligible relative intensity in relation to the intensity of the theta wave of the physical medium in which the photon is moving. However, it seems to me that some conclusions and certain paradoxes that derive from the theory of relativity are ultimately a simple consequence of the naive pretension about the universal validity of this theory. If we restrict the theory to its field of application, or rather, to its domain of adequacy, then there would be no more problems."

"You're right, Iris! That's exactly it!" said Argus and continued:

In its domain of adequacy, the theory of relativity is a good human construction. As I said already, and I'll say it again, what is wrong is to assume implicitly and even explicitly its absolute universal validity.

Giving sequence to what I was saying earlier, let us now turn to the opposite situation:

2. The relative intensity of the mother theta wave is much larger than that of the field in which the photon will be injected (Figure 8-24).

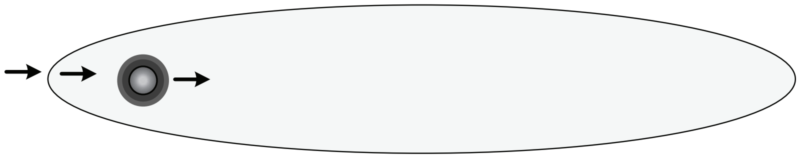

Figure 8-24: The photon enters a medium of much lower relative intensity.

In this case, the photonic acron completely ignores the medium where it was immersed. So, if we take measurements of the speed, assuming of course that the theta field of the measuring apparatus is also of low relative intensity, this will be dependent on the relative speed of the emitting source with the medium where the observation is being made. In these specific conditions of interaction, Galileo's simplistic law of velocity addition is therefore more than adequate to describe what we observe.

"This last situation is very interesting!" said Lucius. "Are there any experimental situations involving light where these conditions apply? That is to say, where Galileo's law of velocity addition is adequate in the description of the observed phenomena?"

Argus responded:

In fact, and against what is proclaimed in many books, and even in some manuals of physics, we know about some experimental situations involving light where the simplistic law of Galileo for the addition of speeds is more than adequate to describe the results of the observations.

Strange as it may seem, these experimental situations have been known for a long time. Early in the construction of relativity, in 1913, a French researcher named Sagnac made a rotating platform on which he placed an interferometer (Figure 8-25).

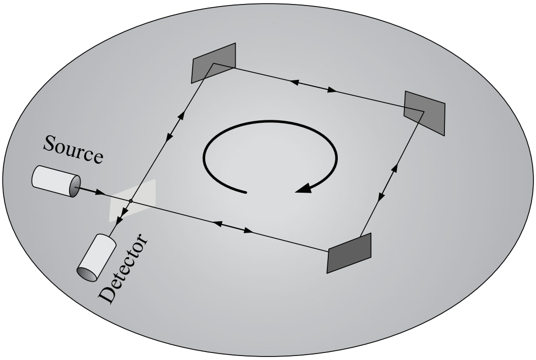

Figure 8-25: Sagnac interferometer.

In this device, a source emits a ray of light that reaches a half-silvered mirror, where it gives rise to a transmitted ray and a reflected one of equal intensity. These rays in turn will be directed to the mirrors where they will be reflected. From the conjugate effect of the mirrors, we will have two rays of light on the platform following a closed trajectory, one travelling in the direction of rotation, and the other in the opposite direction. These two rays, travelling in opposite directions, will be reunited and lead to superposition, in the region of observation where a detector is located, giving rise to an interferential pattern.

Now, in perfect contradiction with relativity, what Sagnac verified, when rotating the platform and in order to reproduce the experimental results, in this case the position of the observed interferences, was:

1. In the direction of rotation, light propagates with a velocity, $v_{\rightarrow}$, higher than its pretended limit, c = 300,000 km/s

$$v_{\rightarrow} = c + v > c,$$

where v is the linear speed with which the light ray moves, which in turn is a function of the speed of rotation of the platform.

2. While in the opposite direction of the rotation he had a speed,

$$v_{\leftarrow},$$

$$v_{\leftarrow} = c - v < c$$

i.e. a speed lower than the maximum limit, c.

So, to describe the results of this experiment, there was a need to deny the general validity of relativity and to use Galileo's speed-addition law, leading to speeds greater than c, $c > c = 300{,}000$ km/s. This experiment has been repeated numerous times with photons, electrons, neutrons, always with the same results.

At present, I'm glad to say this, there is a whole new, modern technology of gyroscopic laser compasses, used mainly in ships and aeroplanes for the permanent determination of their position, based precisely on the Sagnac effect. It's a technology somewhat analogous to GPS, but it has the advantage of being perfectly independent, as it doesn't need any emitter on Earth or on satellites.

"If this is so, why has relativity, which claims that the maximum speed is c = 300,000 km/s, not been questioned – or at least its general validity?" exclaimed Iris.

"You're quite right, Iris!" replied Argus, "I ask myself that question. As far as we know, Einstein never pronounced himself about Sagnac's experiment."

However, many researchers who vent to exhaustion the general and absolute validity of relativity have tried and continue to try to prove that the unquestionable experimental results from Sagnac's experience, go in no way against relativity. We are even faced with the rather strange attitude from certain authors – which would be hilarious if it wasn't an issue of such high importance – such as Paul Langevin, who, in one paper explains how the experimental results obtained by Sagnac, fit perfectly into relativity. Later, in other publications, he presents new different arguments, sometimes even contradictory with the previous ones, to explain the same results.

More recently, a new line of argument has emerged, supported by the fact that the Sagnac experiment is performed on a rotating platform. In that case, there may possibly be an acceleration effect, and in this situation the explanation of experience would fall into the domain of general relativity.

This controversy – whether Sagnac's experience is against or on the contrary fits into the conceptual framework of relativity – was recently solved in 2006 by Ruyong Wang and collaborators, using an extremely interesting experimental device, which they called a linear Sagnac interferometer. In this experimental device, the platform is still. What moves is an optical fiber ring. He begins by experimenting with a circular ring (Figure 8-26).

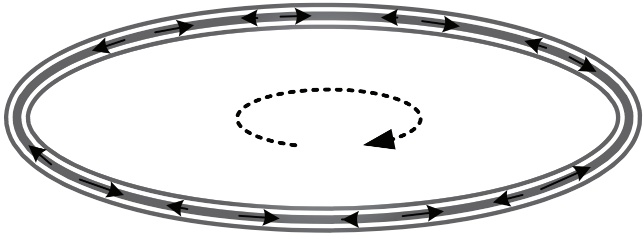

Figure 8-26: Ring optical fiber Sagnac interferometer.

The results, as expected, are precisely the same as those obtained with the classical interferometer. In this case, it can also be argued that is the gravitational effect due to the rotation of the fiber that causes the displacement of the interference fringes.

The next step consists of maintaining the same hypothetical gravitational effect. For this the same speed of rotation will be maintained while at the same time the optical fibers will be extended, as shown in the following figure (Figure 8-27).

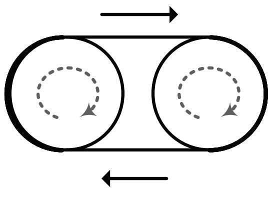

Figure 8:27: Elongated interferometer.

In these conditions, if the observed effect is due to the rotation, to the acceleration caused by the rotation, it's expected that the results will be the same, regardless of the elongation of the device.
Now, what is observed experimentally, is that the effect indeed depends on the elongation of the device. Thus, by increasing this distance further, (Figure 8-28), the effect increases.

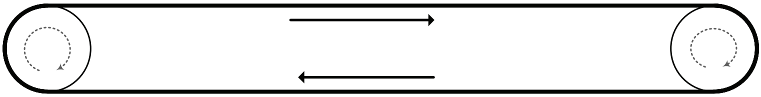

Figure 8-28: 50-metre linear interferometer.

These authors have experimented with several lengths, having reached a very significant value with the length of the linear interferometer reaching 50 metres and the wheels 30 cm in diameter. What they found was that the observed effect was fundamentally dependent on the length of the device, and not on its rotational speed. From these experimental results obtained with the linear Sagnac interferometer, we are led to conclude that in this particular case the law of linear addition of velocities is perfectly adequate to describe what is observed. Of course, these results lead to the conclusion that in practice we may have situations where the speed of light propagation is greater than 300,000 km/s. Thus, the conclusion to be drawn is that relativity is not adequate to describe this class of phenomena.
However, and to conclude, once again I'd like to point out that these conclusions don't deny the usefulness of relativity at all. In fact, relativity is a good approximation to describe reality at its scale of application and, within it, to the problems that are specific to it. However, what is profoundly wrong is the presumption, more of a religious nature rather than a scientific one, that relativity is adequate to describe any physical situation, already known or yet to be discovered, and therefore constitutes the last and ultimate theory ever produced by man.

After taking a small break, Argus said:

As an interim closing of our journeys of discussion on eurhythmic physics, I will mention here some possibilities that this new view of nature can, offer in principle:

1. Development of energy production processes at virtually no cost.
2. Control of gravitation.
3. Near-instantaneous transportation using the tunnelling effect.

On the other hand, I also wanted to add a note that I think is extremely important: Even if these potentialities, opened by the new physics, eventually come to fruition thus freeing man from energy dependence and making it possible to reach and inhabit new planets, there's still a lot to do, because although man may eventually come to radically alter his ability to act upon nature, this fact alone is not enough. For these possibilities to really contribute to a healthy evolution of mankind, it becomes especially necessary that this hard-won knowledge is seasoned with the salt of wisdom.

As I've said and now repeat, we should always bear in mind that science is essentially an adventure, a permanent demand for knowledge in the first stage, which desirably will lead to wisdom at a more advanced stage.

After these words from Argus, we all remained silent in the hope that anytime soon a new version of the Dialogues can be resumed.